GENERAL FIELD TRIP
GUIDEBOOK

Palermo, Italy, 12-22 September 2002
Cover - Rocca chi Parra quarry (Field Trip A). Very large neptunian dyke within the Inici Fm. Note the huge block of Inici limestone encased in a chaotic Rosso Ammonitico matrix; it bears on top some decimetres of Rosso Ammonitico sediments showing that the opening of this dyke took place after the beginning of pelagic sedimentation. This situation is no more visible because of the progress of the quarry front within the activity operated by S.E.L.P.A. srl.
(Photo by Luca Martire)

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M. Santantonio, Editor

F. Lozar, Volume Production Coordinator

C. Muraro, Draft Supervisor

September 2002
CONTRIBUTORS

Gloria Andreini
Marco Avanzini
Angela Baldanza
Annachiara Bartolini
Paola Beccaro
Adriana Bellanca
Carlo Bertok
Alessandro Bovero
Raffaella Bucefalo Palliani
Jesus E. Caracuel Martin
Daniela Cassioli
Raimondo Catalano
Fabrizio Cecca
Paolo Censi
Marco Chiari,
Pierangelo Clari
Miriam Cobianchi
Rodolfo Coccioni
John W Cope
Stefano Cresta
Carolina D'Arpa
Antonio Diligenti
Daniela Di Pietro
Piero Di Stefano
Fabio Duronio
Paolo Ferla
Andras Galacz
Francesca Gasparrini
Monica Ghirotti
Alessandro Grippo
Maria Gullo
Roberto Lanza
Giovanna Lo Cicero
Francesca Lozar

Gianni Mallarino
Agostino Marini
Maria Concetta Marino
Maurizio Marino
Domenico Marinucci
Nino Mariotti
Luca Martire
Daniele Masetti
Emanuela Mattioli
Guillermo Melendez
Carmelina Meli
Andrea Mindszenty
Daniela Montagnino
Cristina Muraro
Rodolfo Neri
Dario Nicchitta
Umberto Nicosia
Federico Oloriz,
T. Padovese
Giovanni Pallini
Guido Parisi
Giulio Pavia
Fabio Massimo Petti
Vincenzo Picotti
Renato Posenato
Massimo Santantonio
Carlo Sarti
Berengere Savary
Edoardo Semenza
Sergio Speziale.
Attilio Sulli
Soledad Ureta
Attila Voros
GEOLOGY OF SICILY: AN INTRODUCTION

RAIMONDO CATALANO, GIOVANNA LO CICERO & ATILIO SULLI

Department of Geology and Geodesy – University of Palermo – via Archirafi 26, 90123 Palermo, Italy

INTRODUCTION

This brief paper wants to introduce the fundamentals of the structure and stratigraphy of Sicily, mostly based on most recent studies, with the aim of better understanding the palaeogeographic and geodinamic setting in which the Jurassic sediments developed.

Sicily is part of the western central Mediterranean region and lies along the African-European plate boundary. It is a segment linking the African Maghrebides with southern Apennines, via the Calabrian accretionary wedge (Fig. 1). The chain and its submerged western and northern extensions are partly located between the Sardinia block and the Pelagian-Ionian sector, and partly beneath the central southern Tyrrenian sea (Fig. 2).

In this sector of the Mediterranean area the main compressional movements, after the Palaeogene Alpine orogeny, began with the latest Oligocene-Early Miocene counterclockwise rotation of Corsica-Sardinia, believed to represent a volcanic arc, and its collision with the African continental margin (BELLON et alii, 1977; DERCUORT et alii, 1986). The most accepted group of models postulates that thrusting was in connection with the westward subduction of the Adriatic and Ionian lithosphere beneath the Corsica-Sardinia block. Today, westward subduction is indicated by a north dipping Benioff zone west of Calabria and the Apennines, as deep as 400 km (GASPARRINI et alii, 1982), and the related calc-alkaline volcanism north of Sicily in the Eolian Islands (BARBERI et alii, 1974). Subduction and thrusting are contemporaneous with back arc-type extension in the Tyrrenian sea. Rifting processes started in the western Tyrrenian sea in the late Tortonian, migrating east-southeastwards and generating oceanic crust in two small districts (KASTENS et alii, 1988).

Three main elements characterize the “collisional” complex of Sicily and adjacent offshore areas (Figs. 3, 4).

a) The foreland outcropping in the southeastern corner (Hyblean plateau) and submerged in the Sicily Channel and in the adjacent Ionian sea. The sedimentary cover is underlain by thinned continental and oceanic crust, respectively. The present day foreland represents a remnant of a Late Jurassic-Early Cretaceous passive continental margin with its oceanic abyssal plain.

b) A Late Pliocene-Pleistocene northwest-dipping foredeep located along the northern side of the foreland.

c) A complex thin skinned chain of thrust imbricates, locally more than 15 Km thick consisting (from internal to external) of an “European” element (Peloritani Units) a “Tethyan” element (Sicilide Units) and an African element (Maghrebian Apenninic Units).

To illustrate the structure of the mainland of Sicily (excluding the Peloritani corner, Fig. 4) we present a number of deep geologic profiles crossing both western and eastern Sicily from north to south. The geological sections integrate the interpretations of several reflection seismic profiles (AGIP) with the available stratigraphic, palaeomagnetic and structural surface data, as well as those of the several, mostly reinterpreted, hydrocarbon exploration well logs. Most of the data were derived from the recently published papers of BELLON et alii (2000 a), CATALANO et alii (1998), CATALANO et alii (2000 a), CATALANO et alii (2000 b), CATALANO et alii (2001), CATALANO et alii (2002).

The described tectonic units were primarily produced by the deformation of basinal and platform carbonate successions. The resulting lithotectonic assemblages are here ordered by their geometric position.
in a N-S section across the present day chain. The stratigraphy and facies domains of western and eastern Sicily are summarized in a general scheme (Pl. 1 b). The distribution of the main tectonic assemblages and their tectonic relationships are illustrated in a general structural map of Sicily (Fig. 3). A more detailed tectono-stratigraphic map assembles the field geology of western Sicily (Pl. 1 a). It is based on the “Structural Model” of Italy (CATALANO et alii, 1991 b) and on more recently published geological maps and unpublished field data. Subsurface tectonic structures (faults, overthrust fronts and folds) were later drawn based on the interpretation of the seismic lines.

Western Sicily, a morphotectonic high which stretches from the Tyrrenian coast to offshore Sciacca (Fig. 4), is the key to understanding the geology of Sicily. Excellent exposures across this area make the study of the stratigraphic successions and the identification of the surface structures relatively easy. In eastern Sicily the main tectonic structures dip eastwards, and are buried below some kilometres of Miocene turbiditic siliciclastics and Plio-Pleistocene basin fills. Therefore western Sicily will firstly be described more in detail, then compared with eastern Sicily.

**PREVIOUS STUDIES IN SICILY**

Several authors have analysed the surface geology of westernmost Sicily. Among these BENEÔ et alii (1959) reached unsurpassed cartographic detail in their geological map of the Castelvetrano Quadrangle, and GIUNTA & LIGUORI (1973) provided innovative facies analysis of the Mesozoic carbonate and Neogene terrigenous deposits along the northern strip between the San Vito Peninsula and the Egadi Islands (Fig. 4). SESTINI & FLORES (1986) outlined a correlation between offshore and onshore sedimentary successions. CATALANO et alii (1989 b) and CATALANO et alii (1996) drew geological sections across westernmost Sicily, inferring the occurrence of a 7-8 km thick southeast vergent thrust pile formed in the Early Miocene - Early Pleistocene. MONACO et alii (1996) described western Sicily as simply representing a shallow ramp-flat system characterizing the thin skinned foreland-fold and thrust belt.

accompanied by the development of foreland basins and coeval piggyback basins within the chain (CATALANO & D'ARGENIO, 1982; CATALANO et alii, 1989b; VITALE, 1990). A structural investigation (OLDOW et alii, 1990) associated with palaeomagnetic studies (CATALANO et alii, 1977; CHANNEL et alii, 1990) confirmed that large-scale clockwise rotations of the thrust sheets (CHANNEL et alii, 1980) occurred during the Late Miocene-Pliocene and were accompanied by a progressive shifting in tectonic transport direction from east to south (OLDOW et alii, 1990). Recent papers by CATALANO et alii (2000 a) and by CATALANO et alii (2002) illustrated the structure of western Sicily, based on several seismic lines.

Field studies in eastern Sicily have described a tectonic wedge formed by the stacking of several thrust nappes over the Hyblean foreland (OGNIBEN, 1960; GHISETTI & VEZZANI, 1984; CATALANO & D'ARGENIO, 1982; BIANCHI et alii, 1989; LENTINI et alii, 1995; GRASSO et alii, 1991; LICKORISH et alii, 1999). The structure of the easternmost Sicily chain, first illustrated by LENTINI (1983), was later illustrated through a north to south deep cross section (BIANCHI et alii, 1989), running from the Nebrodi Mountains, northern Sicily (Fig. 4), to the Hyblean foreland. ROURE et alii (1990), using the same data of BIANCHI et alii (1989), constructed a differently structured geological section crossing eastern Sicily. Recently, BELLO et alii (2000 a), using several seismic sections, made a comprehensive structural reconstruction of eastern Sicily.

**STRATIGRAPHY AND FACIES DOMAINS**

Regional facies analysis indicates that the Palaeozoic-Mesozoic to Palaeogene rock assemblages represent the sedimentary cover of distinct palaeogeographic domains which belonged to the "Tethyan" ocean and the African continental margin prior to the onset of deformation. By contrast the Miocene-Pleistocene rocks were deposited during the deformation of these domains. The stratigraphy of surface units, as
derived from direct field investigations (Catalano & D'Argenio, 1978, 1982; Mascle, 1979; Di Stefano, 1988; Montanari, 1989; Bianchi et alii, 1989; Vitale, 1995; Di Stefano et alii, 1996; Di Stefano & Gullo, 1997), is briefly summarized to illustrate the synopsis in Pl. 1 b.

The "Tethyan" Units

These consist of rock bodies derived from the deformation of the so-called Sicilide Domain (Ogniben, 1960). The sedimentary successions, characterized by Upper Jurassic-Oligocene basinal carbonates and sandy mudstones (Monte Soro Unit and Variegated Clays Auct.) also include Upper Oligocene-Lower Miocene terrigenous turbiditic successions (internal Flyschs) detached from their substrate. The original substrate (oceanic crust ?) is not known.

The African Units

The sedimentary successions forming the main tectonic units are Mesozoic-Lower Miocene deep-water carbonates and cherts (locally named Imerese, Sicanian) and Meso-Cenozoic shelf carbonates (Pre-panormide, Panormide, Trapanese, Saccense and Hyblean-Pelagian). The rocks were deposited in different Mesozoic palaeogeographic domains of the African continental margin.

Meso-Cenozoic basinal carbonate successions

The Imerese succession consists of Triassic (Carnian) to Oligocene thin-bedded deep-water limestones and bedded cherts, with multiple Jurassic-Eocene carbonate platform-generated debris flows. The carbonate succession is locally unconformably overlain by uppermost Oligocene-Lower Miocene siliciclastic deposits (marly shales, turbiditic sandstones and quartzarenites). The Early Miocene rock-interval, locally known as Numidian Flysch appears often detached from the older substrate. Langhian-lower Tortonian marly shales with sandstone beds unconformably overlie the Numidian siliciclastics (Pl. 1 b).

The main bulk of the Sicanian rock assemblage consists of deep-water Carnian to Lower Miocene carbonates, followed by Middle Miocene clastic carbonates and marls. Lower Permian to Middle Triassic deep water clastic and carbonate deposits, with shallow water carbonate olistoliths, are believed to represent the substratum of the Sicanian succession (Mascle, 1979; Di Stefano & Gullo, 1997). Both the Imerese and Sicanian basinal successions have the same basal facies consisting of Middle-Upper Triassic marls and cherty limestones (Mufara and Scillato Fms.). The Sicanian succession clearly lacks the Jurassic-Eocene reworked shallow water carbonates and the Upper Oligocene-Lower Miocene Numidian-type strata that are typical lithologies of the Imerese sequence.

Meso-Cenozoic carbonate platform successions

The Pre-panormide succession, cropping out in westernmost Sicily, is made up of a) Triassic-Lower Liassic carbonate platform dolostones and limestones, grading upwards into Jurassic slope-to-basin or pelagic carbonate platform deposits; b) Lower Cretaceous to
Eocene cherty, turbiditic limestone and marls, unconformably followed by Oligocene-Lower Miocene marly limestone, interbedded with nummulitid-bearing glauconitic biocalcarenites, sandy pelites and Numidian (?) quartzarenites. Lower-Middle Miocene shallow water limestones and glauconitic arenites with marls follow upwards. A similar succession also characterizes the Egadi Islands and surrounding offshore areas, as confirmed by the westernmost offshore boreholes (CATALANO et alii, 2002).

The Panormide type-successions crop out in the Capo San Vito Peninsula as well as in the Palermo and Madonie Mountains (Fig. 4; Pl. 1 a). The Upper Triassic-Middle Liassic carbonate platform, mostly consisting of reef deposits, is followed by Jurassic pelagic platform rocks (Rosso Ammonitico) that are onlapped by Upper Jurassic-lowermost Oligocene reefoidal and slope limestones. Lower Miocene open shelf to reef limestones (locally known as “Mischio”) locally cover unconformably the eroded Meso-Cenozoic carbonates.

The Trapanese type-succession crops out along a west-east ridge between the Inici-Montagna Grande and the Kumeta-Busambra areas (Fig. 4; Pl. 1 a) and was penetrated by several wells. Upper Triassic-Middle Liassic carbonate platform dolomites and limestones are followed by Jurassic-Lower Oligocene pelagic platform deposits (Rosso Ammonitico with intensive neptunian dykes, Mn-crust condensed facies, Calpionellid and Scaglia-type limestone). Upper Oligocene-lowermost Miocene resedimented biocalcarenites and Burdigalian to Langhian, open shelf to coastal, glauconitic calcarenites and sandstones (Corleone Fm) unconformably overlie the Meso-Cenozoic carbonates.

The carbonate platform rock bodies, which crop out to the southwest in the Magagaggio-Sciaccia area and are buried in southwestern Sicily (boreholes in the Castelvetrano-Mazara area), have been described in the past as representing the Saccense domain (CATALANO & D’ARGENIO, 1978). The Saccense type-succession is similar to the Trapanese one, except for the Oligocene-Lower Miocene deposits displaying open shelf to reef facies.

**Meso-Cenozoic basin margin carbonates**

At Monte Genuardo (Figs. 3, 4), a unique succession crops out, where the Upper Triassic reef and back-reef lagoonal deposits are followed by the Liassic to Lower Miocene slope to basin carbonates (DI STEFANO & VITALE, 1993). The Upper Triassic strata could represent the margin of the Trapanese-Saccense shelf, while the Liassic-Lower Miocene interval has the same characteristics as the western Sicanian basinal succession (CATALANO & D’ARGENIO, 1978; MASCLE, 1979; DI STEFANO & GULLO, 1997).

**Upper Serravallian-Pleistocene deposits**

Both in western and eastern Sicily these strata overlie unconformably the Mesozoic-Lower Miocene carbonate and terrigenous successions. Serravallian to Tortonian terrigenous deposits, mostly clayey and marly, crop out all over Sicily, either overlying paraconformably the Lower Miocene glauconitic limestones and sandstones of the Trapanese-Saccense successions, or unconformably overlapping the already deformed Panormide and Prepanormide rock units and the Numidian-Sicilide nappe complex. This sandy marls unit is capped unconformably by reddish to yellow polygenic conglomerates, clayey sandstone and marls (Terravecchia Fm., late Tortonian-early Messinian). Large bodies of lower Messinian coral limestone and slope clastic carbonates (Baucina Fm.) lie over an eroded sandy substratum of the Terravecchia Fm. Messinian evaporites lap over an erosional surface cutting the underlying strata. The Messinian evaporitic succession is predominantly eroded in the northern areas but crops out extensively to the south and the east, in outcrops of southern Sicily.

The evaporitic strata are overlain disconformably by the well known Trubi Fm that is characterized by marl-limestone couplets. These Lower Pliocene rocks extend all over Sicily. A thick sedimentary wedge of mostly carbonate-clastic rocks, locally known as Marnoso-Arenacea del Belice Fm, overlies the Trubi limestone in western Sicily. From the base upwards, these rocks are composed of fine turbiditic sandstone and resedimented biocalcarenites, hemipelagic shales with interbedded siltstones and calcarenitic mudstones. Their age is bracketed between 3.8 and 2.5 Ma (VITALE, 1995). Uppermost Pliocene-Lower Pleistocene sandy shales, calcarenites and shallow water carbonates mostly cover the westernmost and eastern areas. Sequence stratigraphy, ages and the tectonic role of the Pliocene-Pleistocene basin fill have been described by VITALE (1995).

**THE CHAIN**

**WESTERN SICILY**

The western and central Sicily fold and thrust belt connects Sicily to the Late Cenozoic Maghrebian chain submerged between Sardinia and Sicily itself (CATALANO et alii, 1989 a; CATALANO et alii, 1996). Although the surface geology is well known, the subsurface structure was largely unknown.

Recently, the area has been investigated using a grid of multichannel seismic reflection profiles, shot by AGIP in the early eighties and more recently. An interpretation of the seismic reflection profiles, published preliminarily by BORNATI et alii (1997), CATALANO et alii (2000 a), CATALANO et alii (2002), is the main support for the basic knowledge presented here. This bulk
of data provided a more advanced definition of the shape of the geologic bodies, at depth, as well as their mutual relationships, offering interesting insights on the kinematics of deformation.

**Westernmost Sicily**

Geoseismic and geologic cross sections calibrated by both borehole stratigraphy and related field geology were used to interpret the main structure at depth in westernmost Sicily. The structural edifice shows, from the bottom:

- a 7-8 km thick wedge of Meso-Cenozoic carbonate platform imbricates (Panormide, Trapanese-Saccense units);
- a 1 to 3 km thick tectonic stack of Upper Mesozoic—Middle Miocene thin basin carbonates and

![Figure 5](image)

*Figure 5 - Section A (trace in Pl. 1 a) crosses the westernmost Sicily c: Detail of the seismic grain in the carbonate flexure (area outlined on B). TP: Trapanese unit (TP is the top). PN: Pre-panormide unit (PN is the top). ST: Serravallian-Tortonian sequences. TV: Terravecchia Fm. deposits. M: Messinian horizon. PP: Plio-Quaternary succession."

![Figure 6](image)

*Fig. 6 - Seismic profile showing the subsurface extension of the Montagna Grande structure. Notice the overriding of the Trapanese carbonates (TP) on the Pre-panormide Nappe (PN) previously emplaced on the platform carbonates. For acronyms see Fig. 5.*
clastics (Pre-panormide Nappes) overriding the carbonate platform Units;
- a sedimentary wedge of upper Tortonian-Middle Pleistocene strata that fill syntectonic basins.

The carbonate platform thrust wedge (Trapanese-Saccense units) displays two main tectonic levels. The upper level consists of northward dipping ramp-like imbricates arranged in large antiforms (Pl. 1 c; Fig. 5). NW-verging back-thrust faults splay out from the main structure and are seen also in outcrop at the northern side of Montagna Grande. The whole body extends beneath the Pre-panormide nappes and dips northwards, below the Panormide derived thrust wedge of the San Vito Peninsula (Pl. 1 a).

The lower carbonate platform body is internally dissected by south-verging thrusts (Fig. 5; Pl. 1 c). It extends from south-western Sicily northwards beneath the upper carbonate structural level, which culminates in the Montagna Grande outcrop (Pl. 1 a). There, the two superimposed carbonate bodies are more than 8 km thick (Pl. 1 c; Fig. 6).

The Pre-panormide nappes consist of a stack of thin, flat lying, bodies overriding the Trapanese units (Fig. 5; Pl. 1 a, c). Most of the outcropping Pre-panormide rocks are highly contorted, displaying a chaotic setting at the surface. When observed on seismic lines (Fig. 5; Pl. 1 c), the allochthons appear to have maintained their structural coherence and lateral continuity. These allochthons were emplaced above the Serravallian-lower Tortonian cover of the Trapanese shallow water carbonates. Locally the original thrust bodies are passively refolded and transported by later deformation over the uppermost Miocene-Pliocene strata. The geoseismic sections crossing the southern sector of the study area shed light on the structural setting of the thick terrigenous body formed by the Late Miocene clastics and their Messinian evaporitic cover (Pl. 1 c). They are involved in a post-Miocene deformation which originated NE-SW trending and minor NW-striking fold and fault structures (Pl. 1 a).

Central western Sicily

In central western Sicily only the foothills structures are exposed, since the foredeep and foreland are located southeastward in the Sicily Channel some kilometres away from the Sciacca coast (Fig. 4).

The geological sections crossing both the western and the eastern side of the area show that the overall tectonic edifice is formed, from the bottom, of the following structural levels bounded by large scale subplanar discontinuities (Pl. 1 d, e).
- The lowermost level is a 8 to 9 km thick thrust wedge formed of over 3 km-thick imbricates, clearly detached from their basement. Seismic data, constrained by boreholes (e.g. Marineo well, Fig. 7) and surface data, image carbonate platform units belonging to the Panormide, Trapanese and Saccense domains. The carbonate platform thrust system is characterized by two southward-vergent stacked imbricate fan systems (Pl. 1 d, e, f). The upper carbonate wedge develops from the Tyrrhenian coast to the latitude of Pizzo Telegrafo-Monte Magaggiaro (Pl. 1 a, d, e) where the main leading edge of the imbricate fan occurs as a major thrust front involving Lower Pliocene strata (Pl. 1 e). The lower platform carbonate imbricate fan lies at a depth of 4 to 8 kilometres, in central and southern Sicily and reaches the surface in the Sciacca area as a large ramp anticline involving Lower Pleistocene clastics. Faults form at shallow depth and sole out in a slightly north-dipping detachment surface, in a progressive migration towards the foreland. The S-vergent imbricate fan system overthrusts the submerged Pelagian carbonate platform foreland, close to the southern Sicily coast (Fig. 3; Pl. 1 a, f) and has minor shortening with respect to the overlying carbonate platform structural level.
- The intermediate structural level consists of a stack of about 2000-3000 m thick thrust ramps overriding, along a slightly north-dipping detachment level, the carbonate platform imbricates. From north to south they consist of the Imerese and Sicanian basinal carbonate thrust sheets (Pl. 1 f). These are overridden by the thin Numidian Nappes, which is, in places, overlain by remnants of the Sicilide Nappe. The NE-dipping Imerese basin thrust sheets, with associated south-verging asymmetric folds, crop out in the eastern Palermo Mts. region, where they overthrust the Panormide Units (CATALANO & DI MAGGIO, 1996) as well as the Trapanese carbonate platform imbricates, which is seen both in the subsurface and in outcrop along the Kumeta Ridge (Pl. 1 a). Later back-thrusting in the underlying carbonate platform units brought the latter to override the Imerese units, inverting the original stacking order (Pl. 1 f). The Sicanian imbricate stack is found southwards of the Rocca Busambra-Maranzusa alignment, up to the southern slope of the Sicani Mts. In the Ribera region (Pl. 1 a). The thrust system is buried in Central Sicily beneath the Neogene-Pleistocene Gela accretionary wedge (Gela Nappe, OGNiben, 1969; Fig. 8; Pl. 1 f) and continues eastward in southeastern Sicily. In detail, the Sicanian edifice is a pile of some major tectonic bodies which overlie the Middle Miocene top of the Trapanese-Saccense or Hyblean carbonate platform imbricates along a gentle north-dipping regional surface. Locally, the carbonate platform units overthrust in turn the previously emplaced Sicanian thrust sheets along high-angle fault planes that are seen at the Rocca Busambra ridge and in the Sicani Mountains subsurface (Pl. 1 f). The units show duplex accretion, roughly southwards vergence and later (Pliocene) internal imbrication. The Mount Genuardo imbricate overthrusts (Pl. 1 d, e) the higher carbonate platform units in the southwestern study sector (Pl. 1 a);
Fig. 7 - A Triassic-Liassic intraplatform basin type: the Marineo basin in western Sicily. It extends westwards and northwards beneath the Neogene clastics of the Belice Basin.

- The uppermost level is represented by i) Miocene molasse deposits, Messinian evaporites and Lower Pliocene Trubi limestones that are folded, faulted and detached from their substrate; ii) Middle Pliocene-Lower Pleistocene elastic carbonate deposits, filling large syn-tectonic depressions; iii) the Gela accretionary wedge which overlies the Saccense carbonate platform in the southern part of the study area (Pl. 1 f).

EASTERN SICILY

A grid of seismic profiles linking the Hyblean plateau to the Nebrodi Mts. (Figs. 3, 4) provided new insight on the deep geometry of the accretionary wedge (BELLO et alii, 2000 a; BELLO et alii, 2000 b). The results obtained, compared with the structural setting of western Sicily, have confirmed the hypothesized continuation of the buried eastern Sicily carbonate structures into western Sicily (CATALANO & D'ARGENIO, 1978, 1982), as well as the occurrence of a thick carbonate platform thrust wedge reaching the Tyrrenian coast (CATALANO et alii, 1993).

A geological section (slightly modified from BELLO et alii, 2000 a) based on field and borehole data and calibrated by gravimetry and magnetometry illustrates the general structural setting of eastern Sicily (Pl. 1 g). Excluding the Calabrian element, three main structural levels can be distinguished in the chain which lies above an unaffected northward-dipping crystalline basement, located at a depth spanning from about 15 km beneath the Tyrrhenian margin to 7 km beneath the Hyblean foreland (Pl. 1 g).

a) The lowest level of the chain results from the Meso-Cenozoic, mostly carbonate platform, S-vergent 3-4 km thick ramps (Panormide-Trapanese to Hyblean p.p. rock bodies) that overthrust the carbonate foreland located in the Southeastern Sicily and its offshore.

b) The intermediate level consists of a wedge of thin flat-lying Meso-Cenozoic basinal carbonate thrust sheets (Imerese to the north and Sicanian to the south: Fig. 8) resting on the deformed Hyblean carbonate platform (Pl. 1 g). In eastern Sicily the carbonate basinal units, buried below a wedge of Sicilide and Numidian units, 4000 m thick (Pl. 1 g), rise to the surface in the Mt. Judica-Scalpello ridge, where Sicanian embraces thrust over the deformed Hyblean foreland (Fig. 3).

c) The upper structural level is a thrust wedge made of the Sicilide units, the Lower Miocene Numidian and time-equivalent internal Flyschs and the Gela Nappe (Fig. 3).

The Sicilide Units are believed to have been emplaced, during the Early Miocene, on top of the more external nappes. The Sicilide complex reaches its greatest thickness in eastern Sicily (Fig. 3; Pl. 1 g) where it has been preserved in a wide depression of the chain (BIANCHI et alii, 1989). In the northeastern sector the Sicilide nappes underlie the Peloritani Crystalline Units (Fig. 3). The Gela Nappe is a thin skinned accretionary wedge which overthrusts its Upper Pliocene foreland marine sediments (Fig. 2, Pl. 1 g). The wedge is
Fig. 9 - The seismic profile (A) illustrates the thrust front of Gela TS. The relationships between the Gela foredeep basin and the nappe emplacement are shown. The basin developed during Late Pliocene and was filled by Pleistocene sediments. In (B) a geological section restored from seismics and wells shows that the Gela TS overlies duplexes of the Outer Carbonate TS, resting above a N-dipping thrust plane. Key: PP- Plio-Pleistocene deposits; M- Messinian reflector; Tp- top of carbonates. 0.8- age of sequence boundary in million years.

composed of Cretaceous-Eocene Variegated Clays, Lower Miocene Numidian Flysch and Lower Miocene to Lower Pleistocene folded and faulted clastics, evaporites and older carbonates of foreland basin origin. The structure thins towards the submerged thrust front in the southern Sicilian offshore (Fig. 9). The accretion of the Gela Nappe began in the Middle Pliocene (CATALANO et alii, 1993) and was active up to the Middle Pleistocene as proved by the deposits as young as 0.8 Ma involved in the deformation (Fig. 9).

d) The syntectonic basins. Syntectonic Upper Miocene-Lower Pliocene clastic, evaporitic and carbonatic successions unconformably seal the previously shortened structures (Pl. 1 f). The rock units are variably folded and faulted previous to and during the setting of Pliocene-Pleistocene satellite basins. Re-imbrication, hinterland-verging structures, back-thrusting and frontal accretion accompany the tectonic wedge, as evidenced from north to south (BELLO et alii, 2000 a).

THE FOREDEEP

The WNW-ESE trending foredeep (Figs. 2, 3) is a narrow, weakly deformed depression (Gela Basin), partially buried by the frontal termination of the Sicilian Mountain belt. It extends from the Hyblean Platform onland to the southern Sicily offshore. The basin developed from the Late Pliocene onwards, as evidenced by biostratigraphy, and is probably related to the inflection of the carbonate substrate due to the frontal nappe loading (CATALANO et alii, 1993). The basin fill consists of Plio-Pleistocene pelagic marly limestones, silty mudstones and sandy clays unconformably overlying the Messinian evaporites.

THE FORELAND

The foreland region is exposed in southeastern Sicily (Hyblean Plateau) and continues offshore southwards in the Sicily Channel and eastwards in the Ionian sea (Figs. 2, 3). The autochthonous sedimentary cover (about 7 km thick) overlies an "African" continental crust and consists of thick Triassic-Liassic platform and slope to basin carbonates (e.g. Streppenosia, Modica Fms etc.), overlain by Jurassic-Eocene pelagic carbonates and Cenozoic open shelf clastic deposits (PI. 1b; see also PATACCA et alii, 1979; CATALANO & D'ARGENIO, 1982; LENTINI, 1983; BIANCHI et alii, 1989; MONTANARI, 1989; ANTONELLI et alii, 1991).

Seismic and well data indicate lateral facies transition from the Hyblean domain into the Saccense-Trapanese domains located in western Sicily (CATALANO, 1987; ANTONELLI et alii, 1991). The Hyblean carbonate platform extends northward in the subsurface.

Towards the Ionian sector, the described foreland preserves the features of an NNW-SSE ancient passive continental margin-oceanic abyssal plain system (CATALANO et alii, 2000 b; CATALANO et alii, 2001).

THE PASSIVE CONTINENTAL MARGIN

The passive continental margin extends from the Hyblean-Malta shelf, through the Malta Escarpment, to the western Ionian sea.

The continental margin crust becomes progressively thinner eastwards (Pl. 1 h, i) as revealed by the rising of the Moho depth from 30 km in the Hyblean shelf to about 19 km in the western Ionian. In addition to Early Mesozoic block-faulting of both the basement and sedimentary cover (Pl 1 i), the large igneous intrusions generating strong magnetic anomalies (FINETTI & MORELLI, 1973; MORELLI, 1985) support the "transitional" nature of the crust flooring the Malta slope and the western Ionian sector.

The sedimentary cover, lying above the thinned
"transitional" crust, is made up of Lower Mesozoic carbonate platform rocks followed upwards by Upper Mesozoic-Lower Cenozoic pelagic limestones (Pl. 1 h, i). The lateral continuity across the Malta Escarpment of these sedimentary facies and the depositional relationships between the carbonate platform and the basinal deposits enable to locate the original edge of the Mesozoic continental margin in the western Ionian (Pl. 1 i). The Malta Escarpment owes its morphogenesis to the reactivation caused by more recent NNW-SSE vertical and/or transtensional tectonics (CASERO et alii, 1984). It is worth noting that the Malta Escarpment does not separate continental from oceanic crust, as the original Continent/Ocean boundary is located well easterly beyond the Escarpment.

THE IONIAN OCEAN

The Ionian abyssal plain is floored by a crust whose seismic characteristics strongly differ from the adjacent western sectors (Fig. 10).

The most impressive signature of the Ionian crust is a couplet in the form of a highly reflective layered body and a transparent and unstratified band with overlapping hyperbolae (CATALANO et alii, 2000 b). The inferred oceanic crust is overlain by 5 to 7 km of seismically interpreted pelagic facies; the oldest strata onlap the oceanic crust immediately to the east of the C/O boundary. Despite the fact that tectonic subsidence analysis, deep sea floor (> 4000 m in the abyssal plain), low heat flow values (DELLA VEDOVA & PELLIS, 1992) support a Late Jurassic-Early Cretaceous age, the absence of borehole stratigraphy impedes the possibility of defining the true age of the ocean formation.

TECTONIC EVOLUTION

The tectonic history of the Sicily FTB is one of an essentially continuous forward migration with a combination of duplexing and clockwise nappe rotations. Following the Early Miocene “collision” (subduction?) of the Sardinia Block with the African margin, the evolution of the thrust belt-foredeep system started in the Late Oligocene with the internal imbrication of the crystalline Calabrian (Peloritani) units and their emplacement above the Sicilide domain. Reflecting the transport direction, the foreland basins characterised by Upper Oligocene-Lower Miocene Flyschs, migrated progressively eastward. Deformation first reached the oceanic (?) and/or thinned continental crust basinal domain with the detachment of the Sicilide terrains and the Lower Miocene Flyschs that were emplaced southeastward over more external domains forming the structurally highest units in the chain. Their transport is bracketed between

![Fig. 10 - Oceanic crust in the Ionian abyssal plain (from CATALANO et alii, 2000 b).](image-url)
Fig. 11 - Palaeogeographic reconstructions of the Sicilian continental margin during the Permian and Triassic:
a) Middle Permian (from CATALANO et alii, 1991a): TU) Shallow-water deposits of Tunisia, partly with pelagic influx; SI) Permian deep-water siliciclastic and clastic-carbonate deposits in western Sicily (Sicanian domain); LA) shallow-water Middle and Upper Permian of the Lagonegro domain in southern Apennines and its possible prolongation into the Imerese domain of Sicily (IM).
b) Late Triassic (from CATALANO et alii, 1993). Dashed lines are the traces of the sections in Fig. 12.

the Langhian and early Tortonian, as demonstrated by the occurrence of the Middle Miocene sandy clays that seal the already deformed Numidian/Sicilide nappe complex.

This early phase of thrusting involved, during the Early-Middle Miocene, the basinal derived rock bodies (Imerese-Sicanian) with duplex geometries and major tectonic transport. The preferred detachment levels were Permian clastics and carbonates, Middle Triassic marls with dolomites, Lower Cenozoic pelagic carbonates and turbiditic siliciclastics.

Deep seated thrusting detached and deformed the buried carbonate platform rock body, determining axial culmination and antiformal stacks. The wedging at depth of the carbonate platform substrate implied re-imbrication and shortening into the overlying basinal carbonate nappe pile, as well as in the highest structural levels, accommodating their progressive stacking. Most of the thrusting involving the carbonate platform body occurred during Late Miocene-Early Pleistocene. This deformation timing is supported by the syntectonic deposits filling the thrust-top basins on the growing chain and by the tectonic involvement of the overlapping Pliocene-Lower Pleistocene clastics during the late imbrication.

High-angle fault planes mapped in the field, with mesoscopic strike-slip structures (GHISSETTI & VEZZANI, 1984; MONACO et alii, 1998; ABATE et alii, 1998) appear on deep seismic profiles to sole out along detachment planes. The detachment is located at various depths in the seismic sections but never crosses the crystalline
basement. The faults indicate that the thrust was accompanied by lateral movements. It is related to right oblique transpression resulting from latest Miocene-Early Pleistocene clockwise rotations. Northwards in the belt ("hinterland zones"), the already imbricated substrate was eroded and block-faulted after the Messinian along listric and normal growth faults (AGATE et alii, 1993). The extensional event opened half grabens that were progressively filled by clastic wedges. Later, structural inversion of the half graben deposits took place between 2.5 and 1.4 Ma. Between 1.4 to 0.8 Ma extensional structures dissected the basins, which again experienced compressive deformation between 0.8 and 0.5 Ma. The last 0.5 Ma involved strong vertical tectonics. The two main extensional events are linked to the opening of the Tyrrhenian sea.

MESOZOIC PALAEOGEOGRAPHY

The palinspastic restoration of the present-day structural edifice defines two main palaeogeographic domains at the end of the Triassic: (1) an internal deep water domain (Imerese and Sicanian) which rimmed (2) an irregularly outlined shallow-water embayment (Panormide, Trapanese-Saccense and Hyblean) on continental crust that was probably attached to Africa, but separated from Apulia (CATALANO et alii, 1991 a and references therein).

At the end of the 1980s, important constraints for the palaeogeographic reconstruction of Sicily were provided by new studies on the strongly debated Palaeozoic of central Sicily apparently pertaining to the Sicanian thrust sheets. Permian to Lower Triassic deep-water siliciclastic and carbonate deposits characterized by well preserved conodont and radiolarian faunas indicate the presence of a deep-water basin in Sicily since Early Permian times (CATALANO et alii, 1988, 1989a). The occurrence of circumpacific radiolarians in the Permian deposits of Sicily documents that the deep-water basin was connected eastward to the main Tethyan domains in the Permian. The connection must have passed across the present Ionian sea separating Apulia from Gondwanian Africa at that time and later in the Early Triassic (Fig. 1 a). The Permo-Triassic stratigraphy of Sicily implies that rifting along the North African margin started at least in Early Permian times.

Sicily could therefore belong either to the passive margin of the Permian ocean or to a Permian rift with thinned continental crust which was the westward continuation of the Permian Tethys (CATALANO et alii, 1989a; BERNOULLI et alii, 1990; CATALANO et alii, 1991a; STAMPFLI et alii, 1991). This opens new perspectives on the Late Palaeozoic-Early Mesozoic palaeogeographic setting and on the inherited crustal characteristics of the central Mediterranean area.

Stratigraphic and structural data are consistent with a Sicilian Triassic crustal palaeogeography characterized by a wide carbonate platform developing onto the African continental crust, flanked to the (present-day) north by a large basinal area (Fig 11 b). In this stretched continental crust area, slope to basin facies characterized the Imerese basin, growing beside the Panormide carbonate platform (Fig. 12). Pelagic facies were widespread in the nearby areas (Sicanian basin) which extended to the east, bordering the shallow water domain (Trapanese-Saccense-Hyblean carbonate platform). Rifting locally affected the huge shallow water domain, probably starting in Late Triassic time. Major extensional
features appear to dissect the top of the Triassic-Liassic carbonate platform with the formation of margins and troughs (Fig. 13). The intraplatform basins of BERNOULLI & JENKYNs (1974) may have formed around the Rhetian-Hettangian boundary.

During the Jurassic, the Sicilian area was affected by profound modifications of the palaeogeography and lateral facies shifts in response to N-directed extension tectonics linked to the sinistral transcurrent motions between Africa and Europe (DEWEY et alii, 1989). CATALANO & D'ARGENIO (1982) described the collapse of carbonate platform margins producing large slope megabrecia bodies, formation of pull-apart like basins (e.g. Marineo and Streppenosa basin); JENKINS (1970) illustrated foundering of sectors of the carbonate platforms due to accelerated subsidence, uplift and erosion, all developing contemporaneously. Intrabasinal highs with Rosso Ammonitico-type condensed pelagic sedimentation (pelagic carbonate platforms) were a typical feature of the Trapanese and Saccense domains through most of the Jurassic.

Recent data from the adjacent Pelagian-Ionian region (CATALANO et alii, 2000 b; CATALANO et alii, 2001) are particularly important for understanding the Early Mesozoic history of this area. Two conjugated passive continental margins are preserved at both sides of the Ionian sea: the Pelagian-Malta to the southwest and the Apulian swell to the northeast (Fig. 14). The Ionian sea confined between these margins could be a remnant of the Mesozoic Tethys. The reconstructions of Tethys (ZIEGLER, 1988 and references therein) suggest that the Ionian is part of the Western Tethys branch. Notwithstanding the uncertainty on the age of the basin opening, the Ionian oceanic spreading could have developed in the Sicilian sector during the Late Jurassic-Early Cretaceous, evolving from a Permian continental rifting. The present day SE-NW trending orientation of the Ionian ocean and the Sicilian and southern Apennines Mesozoic palaeogeography suggest that the oceanic crust could continue to the west-northwest as already depicted by CATALANO et alii (2001). Such a region could have hosted the more internal deposits (Sicilide), the first to be thrust over the African continental margin (Fig. 15).

Finally, field data, such as folding and faulting of the pre-Middle Eocene multilayer, occurrence of large carbonate megabreccias bodies, deep truncations and regional gaps at the Cretaceous-Eocene boundary (CATALANO & D'ARGENIO, 1982; GULLO & VITALE, 1987; CATALANO et alii, 1991 b) correlated to some offshore structures imaged by reflection seismics (ANTONELLI et alii, 1991; CASERO & ROURE, 1994) suggest that the Early Mesozoic half-graben and basinal structures have often been inverted as positive structures. These events could be framed into the dextral relative motion of Africa respect to Europe during the Cretaceous-Palaeocene (DEWEY et alii, 1989).
Fig. 15 - Late Oligocene to Early Miocene palaeogeography of the central Mediterranean. The 330 km wide Ionian Mesozoic Ocean had to be transferred to the west-northwest, since the restoration of the southern Apennines thrust sheets implies thinned but still continental crust to the north of the Ionian sea (modified from Catalano et alii, 2001).

CONCLUSIONS

The structure of Sicily essentially consists of a carbonate accretionary wedge, mainly made up of basinal Meso-Cenozoic carbonate basinal units, overriding a 8 km-thick platform carbonate thrust wedge which is, in turn, detached from an undeformed crystalline basement. Both imbrication geometry and internal deformation of the original units suggest a tectonic evolution due to a combination of underplating and rotation of the thrust units towards the Pelagian foreland. The timing of this deformation is bracketed between the Early Miocene and Early-Middle Pleistocene. The progressive detachment of the more internal Meso-Cenozoic carbonate basinal units and their transport above the external units occurred during the Early-Late Miocene. The uncoupling of the carbonate platform from its basement and its duplexing, as well as the re-imbrication and shortening of the overlying basinal thrust sheets, took place during the latest Miocene-Early Middle Pleistocene. These events are believed to be linked to transpression associated with clockwise thrust rotations.

The palinspatic restoration of the tectonic wedge suggests that the Imerese and Sicanian domains were originally located in a more internal palaeogeographic setting with respect to the carbonate platform during Triassic-Jurassic time. This restoration is in agreement with the model of a rifted Triassic carbonate platform, attached to the African craton, and irregularly bordered by a widespread basinal domain.

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AN OUTLINE OF THE JURASSIC STRATIGRAPHY AND PALEOGEOGRAPHY OF WESTERN SICILY

PIETRO DI STEFANO

Department of Geology and Geodesy – University of Palermo – via Archirafi 22, 90123 Palermo, Italy

INTRODUCTION

In the last three decades the Jurassic paleogeography of Sicily and of the central Mediterranean area has been the subject of several reconstructions in the frame of the evolution of the Tethyan domains (see ZIEGLER, 1988; DERCOURT ET AL, 1993 and references therein; STAMPFLI & MARCHANT, 1997, among others). Several attempts of restoration on a more local scale have been also proposed (GIUNTA & LIGUORI, 1973; PATACCA et alii, 1979; CATALANO & D'ARGENIO 1982; MONTANARI, 1987; ANTONELLI et alii, 1991; NIGRO & RENDA, 1999; DI STEFANO & MINDSZENTY, 2000) partly based on detailed stratigraphic and sedimentological data collected during the '70's (WENDT, 1964, 1969; CAFLISH, 1966; JENKYNs, 1970; GIUNTA & LIGUORI, 1972; SCANDONE et alii, 1972; MASCLE, 1974).

The Jurassic sedimentary basins of western and southern Sicily were located along a sector of the African margin. They developed on a wide Late Triassic carbonate platform-basin system that was transitional to the evaporitic areas of Tunisia to the south. Owing to Jurassic rifting, these basins reached their maximum differentiation during the Middle Jurassic. Tectonic motions in this area were influenced by the eastern termination of a Maghrebine transfer zone (BASSOULLET et alii, 1993) connecting the Central Atlantic to the Ligurian rifting zones. The Jurassic successions overlying the crystalline units of the Peloritani Mountains in

Fig. 1 - Structural sketch map of Sicily (mod. after AA.VV. (1991) – Structural Model of Italy, sheet n° 6) with the main localities quoted in the text.
northeastern Sicily were probably located north of this transfer zone (BOUILLIN et alii, 1992).

At present the sedimentary fills of the Jurassic basins are dispersed in the structural mosaic of the Maghrebian–Sicilian chain (Fig. 1). Their detailed paleogeographic restoration is hampered by the complex tectonic relationships caused by the interplay of Tertiary collisional processes and clockwise rotations (CATALANO et alii, this vol. and references therein). Moreover the amount of lateral displacement experienced by individual paleogeographic sectors of this area during Mesozoic and Cenozoic times is poorly constrained. The mutual position of local paleogeographic zones is therefore still a debated issue.

Outlining the main steps of the evolution of the Jurassic basins across western and southern Sicily requires that the paleogeography of the wider Late Triassic platform-basin system along the African margin (CATALANO et alii, 1996 and this vol.) be briefly treated first.

LATE TRIASSIC

At present a part of the Triassic carbonate platform is well known in the subsurface of the foreland areas of southeastern Sicily (Hyblean plateau), where it reaches a thickness of more than 3000 m (Sciacca Formation, Fig. 1). To the west it extends to the deformed foreland areas in southwestern Sicily. In addition, this platform characterises the structural units of the chain from Corleone to Trapani and the Egadi Islands. In this latter area the Triassic platform is locally evaporitic (sabhka). Different sectors of this wide carbonate platform are differentiable by their Middle-Upper Mesozoic and Cenozoic sedimentary successions, and are locally known as the Hyblean, Saccense and Trapanese domains (Fig. 2-3), (CATALANO & D’ARGENIO, 1978, 1982a).

A further Late Triassic to Eocene carbonate platform domain is well known as the Panormide Domain (OGNIBEN, 1960) in northwestern Sicily. It is fragmented into several structural units outcropping from the San Vito Lo Capo Peninsula, to the Palermo and Madonie

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**Fig. 2** - Late Triassic - Jurassic chronostratigraphy of the main sedimentary domains of western and southern Sicily. Ages for the stage boundaries after GRADSTEIN et alii, 1995.
Mountains. Based on stratigraphic relations (e.g. the presence in some Trapanese successions of Panormide-derived reworked calcarenites, calcirudites and megabreccias of Late Jurassic and Cretaceous ages), the Panormide domain is considered as a northern prolongation of the wide carbonate shelf, partly adjacent to, and continuous with, the Trapanese domain (Fig. 3), (CATALANO et alii, 1996).

DI STEFANO et alii (1996) have named the Triassic carbonate shelf comprising the Hyblean, Saccense, Trapanese and Panormide domains as Siculo-Tunisian platform. Facies distribution indicates this platform was characterized by a huge peritidal-lagoonal area that was transitional to extensive sponge reefs edging the platform. Northward the Siculo-Tunisian platform was transitional to the Sicanian domain, a deep water basin since the Permian (CATALANO et alii, 1988, 1991). The slope and peribasinal areas lying between the Panormide sector and the Sicanian Basin characterized a paleogeographic zone, strongly influenced by the adjacent Mesocenozoic platform, that is known as the Imerese Domain (CATALANO et alii, 1996).

During Rhaetian and Early Liassic times the Siculo-Tunisian platform was progressively dissected by NW-SE and SW-NE striking faults, which are also well seen in the foreland zones of the Hyblean plateau and offshore in the Sicily Channel (ANTONELLI et alii, 1991). As a consequence several intraplatform basins were created (CATALANO & D'ARGENIO, 1982 b) totally or partly surrounded by wide and still productive carbonate shelves. Timing of the opening of these basins is bracketed between the Rhaetian-Hettangian (Streppenosa basin in the Hyblean area) and the Pliensbachian. Extensional/transtensional tectonics were also active along the transitional zones of the former Triassic platform/basin system, inducing tectonic retreat of the platform margins, margin collapses and, in some cases, uplift and erosion.

EARLY LIASSIC

In Early Liassic times, carbonate platform

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**Fig. 3** – Paleogeographic sketch (a) of the main sedimentary domains of western and southern Sicily during Middle Jurassic times (mod. after Di Stefano & Mindszenty, 2000): Bs Roeca Busambra, Er Erice, Ga Mt. Gallo, Ge Mt. Genuardo basin, Ku Mt. Kumeta, In Mt. Inici, Mr Marineo Basin, Mg Montagna Grande, Mm Mt. Magaggiaro, Sb Streppenosa basin. In b) Mid Liassic reconstruction of the central Mediterranean area according to STAMPFLI & MARCHANT (1997).
sedimentation continued across large faulted blocks of the Siculo-Tunisian Platform, resulting in a several hundred metres thick unit of perilidal and lagoonal limestones (Inici Formation). The platform margins were dominated by oolitic/bioclastic sand wedges, often prograding onto the adjacent peribasinal areas. In distal sectors of the Sicanian basin radiolarian cherty limestones and marls were deposited. Contemporaneously, black shales and calcareous turbidites were sedimented in the Streppenosa basin (Streppenosa Formation).

In the Panormide domain the Upper Triassic carbonate platform was uplifted and eroded during the Late Rhaetian or earliest Hettangian as suggested by a deep erosional truncation overprinted by paleokarste (see Fieldtrip A). Clastic carbonates were accumulated in the adjacent Imerese basin as a result (SCANDONE et alii, 1972), giving rise to dolomitic aprons up to 500 m thick (Fanusi Formation).

Early drowning of sectors of the Late Triassic platform margin are recorded also by the Monte Genuardo succession (central-western Sicily), where Lower Liassic aprons made of oolitic-skeletal limestones overlie tilted blocks of shallow water dolostones (see Fieldtrip A).

During the Late Hettangian or Early Sinemurian a sector of the Trapanese domain, located between the Monte Kumeta and Rocca Busambra zones, sunk and became the site of deposition of radiolarian cherty limestones and black shales. While the existence of this basin (Marineo Basin, CATALANO & D'ARGENIO, 1982b) is documented by subsurface data (Marineo well), its areal extension is still unknown.

MIDDLE LIASSIC

During this time interval the termination of the still productive carbonate platforms is recorded (JENKYN, 1970). The age of the topmost deposits of the Inici formation is generally dated as latest Sinemurian (GUGEBERGER, 1936; ARKELL, 1956; GIACOMETTI & RONCHI, 2000). A Pliensbachian age for the Inici top is reported from Monte Erice and Rocca che Parla (WENDT, 1969). In some structural highs (e.g. Monte Kumeta) an anomalous benthic production occurred during early Pliensbachian (DI STEFANO et alii, 2002a). The termination of the carbonate platforms caused the cessation of oolitic-bioclastic shedding and a drop of sedimentation rates in the peribasinal areas.

Tectonic motions are documented by a first generation of neptunian dykes filled by crinoidal limestones (WENDT, 1971) and huge volumes of in situ breccias along major faults. Uplift and erosion of Inici strata are well documented in the Sciacca area, where listric faults predating pelagic sedimentation produced block rotations associated with deep erosional truncations (e.g. Monzealese quarry, DI STEFANO et alii, 2002b; see Fieldtrip B2). In the Trapanese domain a subaerial truncation of the Inici top is documented at Rocca Busambra (see Fieldtrip B1). In some structural highs the productivity change during the Pliensbachian is marked by the presence of crinoidal and brachiopod limestones (e.g. Monte Kumeta; see Fieldtrips A and B2). Part of these deposits was emplaced as calciturbidites into the adjacent basins. Although tectonic activity was intense in this time interval, the drastic drop in carbonate productivity was perhaps related to eutrophic conditions that have recently been documented in other Tethyan regions like the Apennines (MORETTINI et alii, in press; GALLUZZO & SANTANTONIO, in press; see Fieldtrip B4).

Thick wedges of megabreccias were emplaced along fault-controlled escarpments. One example from peribasinal areas of the Sicanian domain can be observed at Prizzi, near Corleone, where a thick prism of Middle Liassic breccias consisting of Upper Triassic reef-derived limestones (Prizzi Megabreccia, DI STEFANO et alii, 1996) overlies a deep erosional truncation on Norian deep-water cherty limestones. Tectonic instability in the Sicanian basin is also evidenced by giant slump phenomena resulting in intraformational conglomerates (pebbly mudstones), as observable at Cozzo Ledera near Cammarata.

Also the Panormide platform and the adjacent Imerese basin experienced major changes during the Middle Liassic. After a long-lasting subaerial exposure, a partial flooding of the platform across small and isolated tilted blocks took place, giving rise to an open shelf benthic carbonate production. Carbonate grains were largely exported into the Imerese basin, as indicated by skeletal calciturbidites alternating to radiolarian marls and cherty calcilutites in the Crisanti Formation.

LATE LIASSIC

By these times the former Triassic Siculo-Tunisian platform had turned into a complex mosaic of basins and swells connected by escarpments, on which the deposition of normal, condensed and composite-pelagic facies associations (sensu SANTANTONIO, 1993) took place. These pelagics are informally indicated as Rosso Ammonitico (CATALANO et alii, 1981) and are equivalent to the Buccheri Formation of the Hyblean domain (PATACCA et alii, 1979).

Over most of the structural highs, thick ferromanganese crusts formed and Toarcian to lower Bajocian ammonitic limestones were only preserved in sparse metre- or centimetre-scale depressions and neptunian dykes.

In the Monte Erice area, near Trapani, an up to 100 m thick succession of ammonitic cherty limestones of
Late Liassic-Tithonian age (Erice Formation) overlies unconformably the Inici Formation (WENDT, 1971). These pelagics were considered as the filling of a subsident furrow (GIUNTA & LIGUORI, 1973; CATALANO & D’ARGENIO 1982b) and have recently been reinterpreted as ramp deposits (MARTIRE 2001; SEE FIELDTRIP B1).

In the Sicanian basin mostly radiolarian marls and cherty limestones were deposited. The Imerese and Sicanian basins recorded the progressive switching from carbonate to siliceous sedimentation. Locally an imprinting of the Early Toarcian anoxic event (JENKINS & CLAYTON, 1986) was recorded, as described by PARISI et alii (2001) in the Piana degli Albanesi succession (see Fieldtrips A and B2).

**DOGGER**

The Middle Jurassic pelagics in the structural high of the former Siculo-Tunisian platform are mostly condensed Bositra and Protoglobigerina massive limestones. They commonly overlie through paraconformities or low-angle unconformities the ferromanegean crusts or directly the Inici top, with stratigraphic hiatuses spanning the Aalenian (or Pliensbachian) and the early Bajocian.

In the Sicanian and Imerese basins siliceous sediments are widespread. Extension was active at the time, as indicated by synsedimentary faults, giant polyphase neptunian dykes and an intense magmatic activity. Basaltic pillow lavas and hyaloclastites were in fact emplaced throughout different paleogeographic zones (see Fieldtrip A).

In the Panormide domain bauxites formed in small, isolated areas (e.g. Monte Gallo, FERLA & BOMMARITO, 1988; see Fieldtrip A).

**MALM**

During Oxfordian and Kimmeridgian times the deposition of Rosso Ammonitico facies, mostly consisting of nodular reddish calcilutites, continued. The Tethyan acme of siliceous sedimentation (BAUMGARTNER, 1987, 1990) is also recorded on and around pelagic paleohighs (e.g. Monte Inici, Guidaloca, Monte Kumeta). As suggested at Monte Inici, near Castellammare del Golfo by CECCA et alii (2001), the lateral transition, over a fairly short distance, observed between the Rosso Ammonitico and radiolarian cherts could be the evidence for a strong paleotopographic control on the accumulation and in situ preservation of radiolarians. This is well documented in the Apennines (BAUMGARTNER, 1987; SANTANTONIO, 1993; see Fieldtrips B3 and B4) as well as in the Southern Alps (see Fieldtrip B5), where sea-bottom topography is seen to control the distribution of radiolarian-rich deposits at various scales.

During late Kimmeridgian and Tithonian a wide spectrum of pelagic carbonate facies such as stromatolitic-ammonitic limestones, Saccocoma limestones, Pygope limestones, and radiolarian marls were deposited in relation of the articulate paleotopography of the former Siculo-Tunisian platform. In the Sicanian basin deep water limestones and marls replaced siliceous sedimentation.

During the latest Tithonian to earliest Cretaceous, the deposition of calpionellid limestones, locally known as Lattimusa Formation, progressively blanketed almost all the sedimentary domains.

A different evolution is recorded in sectors of the Panormide domain that were sites of bauxite accumulation. These areas were progressively flooded during the Kimmeridgian, and the benthic carbonate production recovered, reestablishing healthy carbonate platform conditions. A fast progradation of this platform onto the adjacent slope areas then occurred. The platform was bordered by coral-Ellipsactinia reefs and/or by oolitic-skeletal sands. These carbonates were largely exported both as individual grains or as lithoclasts into the adjacent Imerese basin, producing an up to 100 m thick prism of Calcaire ad Ellipsactinia interbedded with siliceous sediments, still dominating in this deep-water domain (see Fieldtrips A, B2).

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Pre-Symposium Field Trip A  
(12-15 September 2002)

AN INTRODUCTION TO THE JURASSIC GEOLOGY OF WESTERN SICILY

SCIENTIFIC COORDINATOR

PIETRO DI STEFANO

CONTRIBUTORS

FOREWORD

The aim of this excursion guidebook is to offer an up-to-date outline of the Jurassic geology of western Sicily. Localities well known since the end of the XIX century have been selected, along with new areas of scientific interest, in order to demonstrate the Jurassic sedimentary evolution of different palaeogeographic domains that were later fragmented and incorporated into the Maghrebian-Sicilian chain as a product of Tertiary collisional processes.

The description of the localities that will be visited is based on a multidisciplinary approach resulting from the co-operation and convergence of several groups of specialists dealing with such diverse fields as regional geology, stratigraphy, paleontology, sedimentology, petrography and geochemistry.

The main topics are: the peritidal "Panormide Platform", with a Liassic-Kimmeridgian angular unconformity marked by bauxites; Liassic platform drowning, synsedimentary tectonics and pelagic sedimentation; pelagic carbonate platforms and their condensed successions in the Trapanese and Sciacca zones; facies and geometries of pelagic units and their integrated biostratigraphy and isotope stratigraphy; unconformities, platform-flank clastic wedges, neptunian dykes, paleoescarpments; the outer ramp succession at Monte Erice, with storm-related calcarenites, and breccia megabeds; the slope to basin evolution of the pillow-lava-bearing Monte Genuardo succession; deep-water sediments of the Imerese Domain; the evolution of a structural high to a pelagic escarpment at Monte Kumeta.

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Pietro Di Stefano

STOP 1 – MONTE GALLO: A JURASSIC ANGULAR UNCONFORMITY MARKED BY BAXITES IN THE PANORMIDE CARBONATE PLATFORM

P. DI STEFANO, G. MALLARINO, A. MINDSZENTY & D. NICCHITTA

Monte Gallo, near Mondello, is an isolated massif, bordered by Plio-Pleistocene faults rising from the Palermo plain along the Tyrrhenian coast. It exposes mostly Mesozoic to Eocene shallow-water dolostones and limestones, that are onlapped by Pleistocene calcarenites. The Monte Gallo succession belongs to a major thrust sheet extending across the northern sector of the Palermo Mountains. The Mesocenozoic facies succession of this structural unit is considered as typical of the Panormide Domain. It consists of Upper Triassic peritidal dolostones and dolomitized limestones, followed by Upper Jurassic-Lower Cretaceous peritidal and bioclastic-oolitic limestones and by Albian-Cenomanian rudist limestones. Eocene nummulitic limestones unconformably overlie the Mesozoic strata (Fig. 1).

The lower part of the exposed section along the quarry cut (Fig. 2) consists of thick bedded whitish dolomitic limestones and limestones of Norian-Rhaetian age (Fig. 3). The most common lithofacies in these deposits are megalodont/algal grain-packstones and loforitic/peloidal wackestones, generally organised into shallowing-upward cycles. Large megalodonts are abundant either in growth position or reworked, associated with porostromate cyanophyceans, rare dasycladales (Griphoporella curvata) and benthic foraminifers (Aulotortus sp.).

An irregular erosional truncation marks the top of these limestones with an angle of about 10 degrees. Bauxitic material is preserved in pockets and karren along the erosional surface and fills up a dense network of sedimentary dykes both bed-parallel and subvertical. Dark-gray speleothems up to several cm thick can be found in some cavities, predating the bauxite accumulation. The results of petrographic and isotope geochemical studies of the bauxitic filling (FERLA & BOMMARITO, 1988; CENSI & FERLA, 1989) are discussed below.

A thick succession of Upper Jurassic-Cretaceous grey limestones follows above the erosional truncation. This discontinuity surface is displaced by Tertiary low-angle normal faults. One of these faults, with a
displacement of about 1.5 m, is well seen on the right side of the quarry cut (Fig. 2).

The Jurassic facies organisation and biostratigraphy in the lower part of this succession have been the subject of detailed studies (Nicchitta, 1998) and demonstrate the onset of a new carbonate platform and its transgressive trend, from restricted lagoons to tidal flats and higher energy open lagoons under high-frequency eustatic oscillations.

A few beds (each about 20 cm thick) of a gastropod packstone (Fig. 4a), alternating with mm thick red to green marls, onlap the erosional surface at a very low angle. These beds suggest deposition in restricted ponds or lagoons during slow marine flooding of the bauxitic substrate. The reddish colour of the micritic matrix around gastropods indicates bauxitic material was incorporated into the ambient sediment during the transgression. Grey pack/wackestone with small gastropods also fills metre-scale cavities in the underlying Triassic limestones. Dark-gray speleothems are interposed between the filling material and the host rock. The origin of these fillings is most probably related to the removal of bauxites from dissolution cavities, during transgression, to be replaced by gastropod-bearing carbonate mud.

A thicker bed (about 40 cm) follows upward. It consists of a gastropod coquina grading into algal wacke/packstone dominated by a monospecific dasycladalean assemblage (*Salpingoporella grudii*) and small gastropods (Fig. 4b). This bed is capped by stromatolites that are overlain in turn by a thin layer of greenish marls.

Up-section about 20 m of tidal/supratidal cycles occur, with grey stromatolites and loferitic limestones alternating with thin marly levels. Higher energy lagoonal deposits such as bioclastic grainstone to packstone (Fig. 4c) and oolitic grainstones gradually appear in the upper levels. These deposits alternate with loferites and lower energy bioclastic mud/wackestones (Fig. 4d), producing decimetric to metric scale shallowing upward cycles. Upwards the frequency of the high-energy deposits gradually increases, confirming the general transgressive trend from the Kimmeridgian up to the Tithonian (Nicchitta, 1998).

The occurrence of *Kilianina lata* Oberhauser and *Paragurongina caelensis* Cuillier, Foury and Pignatti-Morano associated with a rich fossil assemblage typical of the *Kurnubia palastiniensis* Zone (Chiocchini & Mancinelli, 1977; De Castro, 1991) indicates a Kimmeridgian age for the lowermost 70 m of grey limestones above the unconformity. Upwards the association of *Clypeina jurassica* Favre & Richard and *Campbeliella striata* (Carozzi) suggests the transition to the Tithonian *Clypeina jurassica* Zone.
Fig. 4 – Microfacies from the Kimmeridgian limestones above the unconformity at Contrada Spinassanta: a) Gastropod coquina with geopetal infills of reddish silt; b) Algal-gastropod packstone with Salpingoporella grudii (RADOICIC). c) Skeletal grainstone with benthic foraminifers (Kurnubia palastiniensis HENSON and Pseudocyclammina sp.) d) Algal wackestone with Salpingoporella grudii (RADOICIC) and rare foraminifers.

The Monte Gallo unconformity thus marks a Liassic to Oxfordian hiatus; however, we cannot exclude the erosion of younger marine Lower Jurassic strata during the prolonged subaerial exposure affecting the platform. Notwithstanding the long apparent gap, the actual hiatus may have been relatively shorter (perhaps less than 10 to 15 My). This is also supposed by the textural and geochemical characteristics of the “bauxite”. In fact, even though according to the analyses of FERLA & BOMMARITO (1988) and FERLA et alii (this volume) the red palaeosoil of Monte Gallo does contain “free” alumina minerals, its alumina to silica ratio would qualify it as a “bauxitic clay” rather than commercial-grade bauxite, and its oolitic-intraclastic texture (with round grains predominant over weakly segregated true ooids) also implies a relatively low textural maturity.

The occurrence of bauxites within the shallow water carbonate sequence means on the other hand that the subaerial exposure must definitely have lasted longer than any of the ephemeral exposures related to the high-frequency cyclicity of these carbonates. As pointed out by BARDOSSY & DERCOURT (1990), D’ARGENIO & MINDSZENTY (1991, 1992, 1995), and COMBES & BARDOSSY (1990), such a long lasting exposure requires the tectonically controlled uplift of sectors of the depositional environment, resulting in a relative sea-level fall at either local or regional scale. As to the tectonic settings where long lasting subaerial exposures may occur, D’ARGENIO & MINDSZENTY (1994) suggest the following three major cases: (i) collisional settings either on the exposed/eroded top of nappe-stacks or on flexural forebulges (ii) passive plate interior settings, in sectors affected by intraplate stress-related lithospheric arching and (iii) tensional settings at the crests of rotating fault-blocks or - in strike-slip zones - in areas locally uplifted by transpression. Whenever uplift by any of these mechanisms results in exposure of the shallow marine sediment under humid tropical conditions, ferrallitic soils would form, and the soil-forming event would be recorded as bauxites or bauxitic red clays in the
stratigraphic succession.

This unique Sicilian example must have occurred on the “attached” shelf of the African craton and was therefore rather close to the future site of opening of the southwestern arm of the Tethys. Subaerial exposure was most probably produced by (trans?) tension-related block faulting rather than simply by lithospheric arching. Catalano & D’Argenio (1982b), Di Stefano & Gullo (1987) and others infer a general strike-slip regime for the whole region during the Jurassic. They tentatively correlated a belt of platform-margin clastics with one of the supposed major strike-slip fault zones separating the - partially exposed - Panormide carbonate platform from the adjoining Imerese basin. The idea that the (Middle Jurassic) Monte Gallo was probably the exposed crest of one of the rotating blocks of the zone is supported by the restricted areal extent of the bauxite and by the angular nature of the unconformity.

It is suggested that the Monte Gallo bauxites - although occurring during more or less the same time interval as other bauxite deposits of the Adriatic-African side of the opening Western Tethys (e.g. South Alpine-Dinarid sector and Hellenids) is geodynamically different, because of its isolated position and because of the likely tectonic mechanism which produced them.

PETROGRAPHY AND GEOCHEMISTRY OF THE MONTE GALLO BAUXITES

P. Ferla, P. Censi & C. Meli

At Monte Gallo emergence and a subtropical climate contributed to the formation of continental deposits, whose remnants are found either as the filling of karstic hollows in underlying strata, or in the form of specific material contributed to deposition in adjacent basins.

Observations in sparse pockets, where the continental sediment escaped erosion occurs, reveal two parts, brick red or yellowish in colour, one massive with ooids, and the other fine-grained.

Fragments occurring in the former have diverse textures and composition: pisoids, ooids, irregular clasts and a fine-grained matrix: X-Ray identification confirms the presence of boehmite, hematite, anatase and minor kaolinite. The fine-grained portion is instead composed by kaolinite, illite and hematite, or of goethite if it is altered and yellowish in colour (Fig. 5). Geochemical analysis on this material (Rb, Sr, Nb, Y, Zr, Ti, Cr, Ni) also point to an abundant basalt-like volcanic component, as well as to an independent clay fraction rich in illite. It might be a mixture of two materials, the dominant one being the result of erosion of a bauxite-laterite section, and the rest being limestone-derived “terra rossa”.

Fig. 5 - Different ooid textures in the karst bauxite of Monte Gallo: boehmite (grey) and hematite (black); ooids have 1-3 mm diameter.

Fig. 6 - $\delta^{13}$C vs $\delta^{18}$O diagram of the isotopic analyses on calcite in the various rocks of the Monte Gallo section.
Upon X-ray and geochemical analysis all the carbonates throughout the Spinasanta section are solely composed by calcite. Distinct generations of calcite have been observed in the laterite-bauxite cropping out in the Monte Gallo area. Here the laterite-bauxite material accumulated in palaeokarst hollows occurring between the megalodon limestone of the Panormide shelf and the overlying Malm limestones. The isotopic composition of both the Triassic and Malm limestones fit in well with these rocks having originated in a marine setting ($^{13}$C=0.0±2‰). Carbonate from fractures in speleothems consists of mm thick, alternating layers of clastic carbonate silt and authigenic “length-fast” calcite that grades inwards to “palisade” calcite (alabaster).

Samples of alabastrine calcite show variable $^{13}$C values from +0.91‰ to -11.76‰ (PDB1): these latter are typical for carbonate precipitated at equilibrium with soil carbon dioxide-rich fluids, such as could have originated from C3 type, vegetal matter, in the presence of reef limestones and a very high water/rock ratio (Fig. 6).

The isotopic composition of calcite is intermediate between that of measured host rock and of the speleothems.

The laterite-bauxite material, of clastic “vadose” origin, is cemented by equigranular sparry calcite growing beneath the low-groundwater table level; the isotopic composition of these calcite crystals appears to have been affected by low water/rock ratio, their $^{13}$C values being near the values of the host rocks (Fig. 7).

The marine transgression that followed in the Late Jurassic produced a new marine infilling for the existing karst hollows, made of fossiliferous lime mudstone.

The isotopic results show that the laterite-bauxite material cropping out at Monte Gallo formed under conditions with high humidity, high temperature, and decaying vegetal matter, and are thus consistent with a rain forest environment.

### STOPS 2 AND 3 - MONTAGNA GRANDE NEAR SEGESTA: AGE, FACIES AND DEPOSITIONAL GEOMETRIES IN A JURASSIC PELAGIC PLATFORM OF THE TRAPANESE DOMAIN

**L. Martire**

The Montagna Grande sector (Fig. 8), like many other portions of Jurassic successions that will be visited in the next stops, is completely bordered by thrust faults and surrounded by Miocene deposits. The Mesozoic carbonate rocks have been upthrwn along post-

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**Fig. 7** - Structures, microscopic textures and isotopic composition of different parts of the schematic section of the Monte Gallo bauxite outcrops.

**Fig. 8** - Location of sections described in Stops 2 and 3. 1, Poggio Rocchione. 2, Rocca chi Parra. 3, Le Rocche. 4, Montagna Grande.
Messinian faults that postdate the emplacement of the main embricated thrust sheet complex.

The object of these stops is the stratigraphic succession of the Trapanese Domain, which starts with a thick pile of peritidal platform limestones (Inići Formation: Upper Triassic-Lower Jurassic), followed by typically condensed and often nodular pelagic limestones (Rosso Ammonitico: Middle Jurassic to lowermost Cretaceous). These, in turn, change into thicker successions of pelagic sediments belonging to the Lattimusa and Scaglia formations, spanning the Early Cretaceous-Paleogene interval.

The Jurassic rocks cropping out in the area of Montagna Grande have been studied for more than a century. Some authors were mainly concerned with the rich Middle and Upper Jurassic ammonite assemblages (e.g. GEMMELLARO, 1882; CHRIST, 1960); other authors provided detailed lithological descriptions of the diverse stratigraphic successions (e.g. WENDT, 1964; JENKYNs, 1970; GIUNTA & LIGUORI, 1972; MASCLE, 1973). Recently, a review of some sections has been made in the light of the advances made in carbonate facies analysis, physical stratigraphy and biostratigraphy (MARTIRE et alii, 2000; SAVARY, 2000).

The attention will be particularly focused on two sections of the Middle-Upper Jurassic pelagic limestones, exposed along quarry cuts, in order to describe their sharp and abrupt facies and thickness changes, an evidence of the paleostructural control on the Jurassic sea-bottom physiography and sedimentation.

THE ROSSO AMMONITICO

Rosso Ammonitico is the name given to carbonate rocks that are widespread in the Mediterranean Jurassic and very well known also for ornamental use. After many years of research and at the end of a Symposium completely devoted to it (FARINACCI & ELMI, 1981), it became clear that there is not a single “Rosso Ammonitico” facies. Rather this name was given to many different rocks, sharing of course certain common features but differing in various significant respects.

What, in general, is meant for Rosso Ammonitico?

The basic, ubiquitous, characteristics are the occurrence of ammonite moulds and of a nodular structure. The typical colour is red but grey or green colours also occur, often a result of late diagenesis. The nodular structure may be defined as the juxtaposition of cm-sized, rounded portions of lighter coloured, nearly pure limestone (i.e. the nodules), and of the so called matrix, consisting of dark red marls or marly limestone. The lack of carbonate grains typical of a shallow-water platform environment, and the scarcity of terrigenous sediments are common features of the tipically pelagic Rosso Ammonitico. Most of the sediment is biogenic, being represented by the skeleta of both planktonic and benthic, though not necessarily light-dependant, organisms (e.g. calcareous nannofossils, calcispheres, foraminifera, radiolarians, thin shelled bivalves, gastropods, echinoderms), and this explains the very low sedimentation rates, in the order of mm/ky, and the frequent occurrence of stratigraphic discontinuities.

Which is the origin of the nodular structure?

The relative proportion of nodules and matrix allows for at least a first-level distinction. AUBOUIN (1964) was one of the first to realize this; he separated a basinal, marly Rosso Ammonitico from a more calcareous facies, typical of swell areas. The latter was furthermore distinguished into a “flaserkalke”, related to continuous albeit slow sedimentation and deeply modified by late diagenetic processes, and a “knollenkalke”, characterized by discontinuous sedimentation documented by the occurrence of hard-grounds.

Focussing here the attention on the calcareous Rosso Ammonitico, a more detailed analysis reveals that several different objects, having a different nature and origin, may all be called nodules. Correspondingly, the nodular structure can derive from the combination of a wide spectrum of processes including bioturbation, winnowing, early cementation, and pressure dissolution. In a milestone paper, JENKYNs (1974) criticized the model based on the theory of subsolution (HOLLMANN, 1962), and proposed that nodules be generated by precipitation of carbonate supplied in a very shallow burial phase by dissolution of the less stable carbonate grains. OGG (1981), instead, suggested that later diagenetic processes (pressure dissolution) sourced the carbonate for nodule lithification. A totally different hypothesis was proposed by MASSARI (1981), who stressed the importance of biomats in binding and cementing sediments and giving rise to spheroidal nodules (oncoids) or to dome-shaped structures (stromatolites). An important contribution was given by CLARI et alii (1984) who, in agreement with conclusions by KENNEDY & GARRISON (1975) on the britsh Chalk, identified two main categories of nodules: the predepositional nodules, represented by portions of sediment with a rocky coherence at the moment of deposition
What is the paleoenvironmental and paleobathymetric meaning?

No present-day analogue exists for the Rosso Ammonitico. As CECCA et alii (1992) have remarked, an important paleogeographic reorganization in the Early Cretaceous modified climate, ocean circulation and ocean chemistry in such a way that no ocean has since had the same features of the Western Tethys, resulting in the disappearance of the Rosso Ammonitico. Consequently, the interpretation of this peculiar facies in terms of paleoenvironment cannot rely on actualism. In spite of this, on the basis of univocal geological evidence, all authors agree on aspects such as: 1) the Rosso Ammonitico, in its more calcareous facies, is the typical product of sedimentation on top of fault blocks resulting from the rifting and drowning of carbonate platforms; 2) being detached from the continent and surrounded by deeper basins, the only source of sediments is the slow, pelagic rain plus a benthic component, resulting in typically condensed facies; 3) currents were intermittently active, as documented by intraclasts, taphonomically reworked ammonites also of considerable size, frequent erosional discontinuity surfaces, and traction laminae mainly preserved within neptunian dykes; 4) bottom conditions were highly oxygenated as indicated by the red colour of the rock.

Much debated, on the contrary, is the depth at which Rosso Ammonitico sediments were deposited. In a classical paper on the tectono-sedimentary evolution of Southern Alps, WINTERER & BOSELLINI (1981) estimated a depth of about 1000 m for the Rosso Ammonitico Veronese. In the last decade, however, studies in Central Apennines and Southern Alps have reported paleontological and sedimentological evidence suggesting much shallower depths: CECCA et alii (1990) MONACO (1992), SANTANTONIO (1993) and ZEMPOLICH (1993) described hummocky cross stratified beds, interbedded within various facies of Rosso Ammonitico of different ages. One occurrence is especially intriguing, since the Tithonian upper slope/basin margin beds of Rosso Ammonitico sandwiching the hummocky cross-bedded level (hummocks 1.5-2 m across) also bear pennular corals interpreted as deep-photic zooxanthellate forms (SANTANTONIO et alii, 1996, and bibliography therein). At least two independent lines of evidence therefore suggest relatively shallow local paleodepths for the Rosso Ammonitico.

To conclude, the old notion of the Rosso Ammonitico as a deep ocean sediment has proved to be largely uncorrect whereas new lithoand biofacies associations have paved the way for stimulating new keys of sedimentary, biological, and diagenetic interpretation. It can conservatively be stated that the Rosso Ammonitico, like other typical Tethyan Jurassic pelagic lithofacies, could be sedimented across a broad range of depths, including photic environments above the storm base level. Being lithofacies alone relatively uninformative, any speculation on paleodepth must rely - besides biofacies analysis - on the geometrical constraints provided by geological mapping and general basin analysis.

Regarding the nodular structure itself, only a detailed petrographic analysis enables to unravel the wide spectrum of processes involved in the genesis of red nodular limestones, and hence to interpret correctly the sedimentological significance of this charming facies that marks important phases in the evolution of sedimentary basins related to Mesozoic extensional regimes.
STOP 2 - POGGIO ROCCIONE QUARRY, A COMPLETE SECTION OF THE ROSSO AMMONITICO: BIOSTRATIGRAPHY, FACIES AND SYNSEDIMENTARY TECTONICS

L. MARTIRE & G. PAVIA

In this section (Fig. 9) the Inici Formation is poorly exposed, yet the boundary with the overlying Rosso Ammonitico is well observable. It is represented by a complex surface, characterized by a very irregular topography with pillars up to 30 cm high, capped by a thick crust of Frutexites-like Fe-Mn oxides. This jagged morphology is identical to the one occurring at the top of crinoidal limestones at Monte Kumeta and described by Di Stefano & Mindszenty (2000). It will be visited, and duly described and commented, on the fourth day of this field trip (Stop 14).

Above this inherited rock ground (CLARI et alii, 1995) the Rosso Ammonitico begins. Though the total thickness is only about 12 m, it is possible to subdivide the succession into a discrete number of levels, owing to their sedimentological and textural characteristics and the presence of stratigraphic discontinuities.

Level 1 (50 cm): bioclastic-peloidal grainstones; the bioclasts are mainly represented by thin-shelled bivalves (Bositra). The top part of the level shows truncated ammonite internal moulds which testify the presence of an erosional discontinuity surface. The presence of Homeoplanulites (Parachoffatia) arispinctoides, H. (P.) gr. subbackeriae, Hecticoceras (Prohecticoceras) retrocostatum, Oxycerites gr. aspidoides allow to refer this level to the lower part of the upper Bathonian.

Level 2 (100 cm): the level begins with a nodular facies and changes upward into a massive facies. The latter is made up of peloidal wackestones to packstones and bears a complex discontinuity surface; burrows with a diameter of about 2 cm and with mineralized walls are in fact cut by a planar, non-mineralized surface. The development of this discontinuity is the result of a phase of firm ground bioturbation followed by mineralization (hardground phase: Fig. 10) and, finally, by submarine erosion. Scattered ammonites, such as Eohecticoceras costatum and Procerites quercinus, collected from the top of this level, indicate an early late Bathonian age.

Level 3 (80 cm): massive peloidal and bioclastic packstones with Bositra shells. A specimen of Lissoceras ventrplanum indicates a late Bathonian age for the very base of Level 3. At the top of the level a thin bed (10-15 cm), purple in colour, is characterized by the presence of glauconite grains and taphonomically reworked (reelaborated sensu FERNANDEZ-LOPEZ, 1984) ammonites, the internal moulds being clearly
recognizable because of their orange colour and, microscopically, their different texture (Protoglobigerina-rich packstones and wackestones). The identified taxa, which include Macrocephalites sp., indicate the lower Callovian. The base and the top of this thin level consist of irregular erosional surfaces more or less intensely coated by Fe-Mn oxides.

Level 4 (90 cm): texturally similar to the underlying rocks, this level is made of interbedded stromatolitic and bioturbated nodular strata.

Level 5 (170 cm): in this level, limestones with a well-developed nodular structure are interbedded with massive beds with beautiful dome-shaped stromatolitic laminae (Fig. 11). All the nodules, generally less than 5 cm across, are represented by predepositional nodules (CLARI et alii, 1984) such as intraclasts, oncoids and ammonite moulds, often with erosionally truncated upper sides capped by stromatolitic domes. These nodules are made up of Bosira-bearing wackestones embedded in a packstone matrix crossed by dissolution seams. Stromatolitic beds, on the contrary, mostly consist of wacke- to packstones rich in Protoglobigerina and peloids. The top of this level corresponds to a discontinuity surface having an unusual morphology. It is a sharp, flat surface characterized by the presence of pillars up to 10-15 cm high and few centimetres across with a rather regular, decimetric, spacing; they are all invariably coated by laminated crusts of Fe-Mn oxides, several mm- thick, referable to Frutexites (Fig. 12). The truncation of ammonite moulds demonstrates the erosional nature of this discontinuity surface. Observations made on orthogonal vertical quarry fronts reveal that these pinnacles are not a bidimensional view of narrow ridges, but are actually pillars with an equidimensional base.

Interpretation of the mechanisms responsible for the sculpture of such a jagged surface within pelagic sediments is by no means straightforward. The most likely hypothesis at present is to call upon an erosional phase of a burrowed, inhomogeneously lithified sea bottom. The pillars could correspond to exhumed vertical burrows more intensely cemented than the surrounding sediments. Encrustation by Fe-Mn oxides, then, could have protected these high-standing structures from any further erosion.

Level 6 (300 cm): this level starts with a 30-40 cm thick stromatolitic massive bed with abundant ammonites, including rather large-size specimens (up to 25 cm in diameter). Texturally it consists of wackestones/packstones with peloids, protoglobigerinids and calcareous dinocysts. Upsection, this interval can be divided into two parts, both showing a gradual variation from nodular and marly facies at the base to more calcareous and massive facies towards the top.

The ammonite assemblage of the very base of Level 6 is typically early middle Oxfordian and belongs to the P. (Dichotomosphinctes) antecedens Subzone (top of the Perispinctes plicatilis Zone). Besides most frequent phylloceratids (e.g. Holcophylloceras zignodianum, Sowerbyceras tortisulcatum), characteristic forms include Lissoceratoides erato, Tornquistes cf.

Fig. 10 - Poggio Roccione quarry. Discontinuity at the top of Level 2 represented by a sharp, flat, erosional, not mineralized surface. Fe-Mn laminated crusts are preserved only in the depressions of the original, irregular, mineralized hardground that has been eroded before deposition of bed 3. Note also Fe-stained walls of firm ground burrows.

Fig. 11 - Poggio Roccione quarry. Stromatolitic layers within Level 5 showing a LLH morphology.
Fig. 12 - Poggio Roccione quarry. Hardground at the top of Level 5. This surface is characterized by a very peculiar morphology with pinnacles often capped by Fe-Mn oxide, Frutexites-like crusts.

kobyi (M + m), Gregoryceras tenuisculptum, Passendorferia tenuis, P. (Dichotomosphinctes) gr. Antecedens (C. D'ARPA & G. MELENDEZ, pers. comm.).

The finding of a Pygope sp. provides a Tithonian age for the top of this interval.

Level 7 (200 cm): dark red coloured nodular limestones. The nodules are smaller, usually less than 3 cm across, have a flatter overall shape and are made up of Saccocoma wackestone. The contrast with the matrix, a Saccocoma packstone, is more marked than in the other levels. The abundance of clay along dissolution seams testifies the intensive pressure dissolution experienced by the matrix, whereas nodules, which were cemented early, preserved their original texture.

Level 8 (250 cm): the level begins with a sharp contact, underlined by a stromatolitic horizon. The strata above the contact are alternatively pink and massive, or nodular, dark marly limestones. The nodules mainly consist of intraclasts, with a subsphaerical shape and usually less than 1 cm across. Upward, the texture becomes more and more micritic, and radiolarians appear. The topmost strata pass gradually to the white mudstones of the Lattimusa Formation.

On a recently reactivated quarry front, very interesting post-depositional structures are observable within levels 4 to 6 (Fig. 9). The limestone underlying the jagged discontinuity surface (top of Level 5) in fact shows a set of bedding-parallel neptunian dykes that may be either discontinuous and centimetre-sized or laterally continuous and ranging in thickness from few millimetres to more than 20 cm. The infilling of these cavities is variable and depends on their size and on the distance from the jagged discontinuity surface. The smallest and deepest (within Level 4) ones are solely filled with sparry calcite cement (Fig. 13). Up-section, red mudstones fill the lower part, producing geopetal structures. In the last 50 cm of Level 5 these cavities are laterally enlarged up to more than 20 cm, and are completely filled with coarser sediments such as wackestones or packstones, often cross-bedded internally, with echinoderm debris, belemnites and aptchi. One of these dykes develops at the discontinuity surface, where it cuts through the pinnacles (Fig. 14), and extends also upwards within the base of Level 6 (bed 6a of Fig. 9).

In the overlying beds, on the contrary, a chaotic structure occurs (Fig. 15). The massive stromatolitic beds of the middle part of Level 6 (bed 6b) are locally disrupted into dm-sized slabs which float in a matrix of darker red, marly, nodular limestone of the overlying bed 6c. Wherever the stromatolitic bed 6b is lacking, a sort of funnel is formed in correspondence of which the nodular limestone of the bed 6c is markedly bent downward. At about 80 cm above the base of Level 6, a nodular but more calcareous bed (6d) shows no thickness variations, thus representing the seal to the underlying chaotic structure.

These features can be explained as the result of an
Fig. 15 - Poggio Roccione quarry. Collapse structure in beds 6b and c. Owing to the breakage and sliding of bed 6b, the overlying plastic sediments collapsed into the funnel-like depression.

An instantaneous event of fracturation (seismic shock?) affecting a depositional slope, postdating deposition of the nodular marly limestone of bed 6c but likely predating sedimentation of bed 6d. Partially to almost completely lithified limestones (levels 3 to 5) were fractured and gravitationally displaced along irregular bedding-parallel surfaces giving rise to open fissures increasingly larger upward, allowing for an improved communication with the sea floor. On the contrary, the overlying, nearly unlithified plastic sediments collapsed within the “trench” generated by slabbing of the brittle base of Level 6.

Last, a vertical dyke, 20 cm wide, crosscuts at least beds 4 to 6c and all the horizontal dykes, demonstrating a later phase of fracturing.

Calcareous nannofossils in the micritic sediments infilling the bedding parallel fissures, despite overall poor preservation, include the following taxa: Watznaueria britannica, W. manivitae, W. barnesae, Cyclagelosphaera deflandrei, C. margerelii, C. wiedmannii, Conusphaera mexicana mexicana, C. mexicana minor, Microstaurus chiastus, Polycostella beckmannii (F. LOZAR, pers. comm.). This assemblage is referable to the Microstaurus chiastus Zone (BRALOWER et alii, 1989), spanning the upper Tithonian-lower Berriasian interval. However, the absence of Cretaceous forms like Rotelapillus laffittei and Nannococcus steinmannii strongly suggests a late Tithonian age for the fracturing event.

Even though we will not visit them, other two sections of Rosso Ammonitico have been measured and studied, with a variable degree of detail: the section of Le Rocche (SAVARY, 2000), which is just on the other side of Poggio Roccione, and the Montagna Grande section, a natural outcrop to the West of the Poggio Roccione quarry. In spite of the short distance (less than 3 kms), these sections are significantly different in several respects (Fig. 16). Most important is the appearance of cherty beds in the Montagna Grande section: these thinly bedded and easily weathered cherty limestones correspond to the largely grass-covered, 10 m-thick interval observable in the natural profile, and sandwiched between two cliffs of massive limestone. No biostratigraphic data are available for this part of the section, except for the upper Bathonian indicated by a specimen of Cadomites bremeri at the base of the Rosso Ammonitico. However, if we assume for this siliceous interval an age comparable to that documented in the (not very far) Inici sections, we can infer a middle Oxfordian-early Kimmeridgian age corresponding to the lower part of Level 6 of the Poggio Roccione section. Another, albeit less striking, variation is the thickness change of the lower part of the Rosso Ammonitico from Le Rocche to Poggio Roccione. These variations are an evidence for role played by sea bottom paleotopography on facies distribution and sedimentation rates. A possible paleotectonic interpretation for the whole Montagna Grande sector will be given in the next stop.
The Jurassic deposits, spectacularly exposed along the active quarry front of Rocca chi Parra, have been recently described by Martire et alii (2000). In the last two years, however, the ongoing activity, while destroying certain structures, has indeed revealed new useful details.

The Inici Formation is exposed for a thickness of about 30 metres. The boundary with the Rosso Ammonitico is a planar surface, that only very locally shows the pillars encrusted by Fe-Mn oxides described in the previous stop.

The most striking feature of this outcrop is the presence of a well developed network of neptunian dykes crossing the white limestone of the Inici Fm., easily distinguished through the dark grey colour of their infill. Dykes range from horizontal to vertical, and from few centimetres to several metres in width. Different generations of neptunian dykes have been identified. Some of them are sealed by the first beds of Rosso Ammonitico, whereas others cut through them. This is confirmed by a direct dating of the dyke fillings, which is possible in a few cases. A subhorizontal fissure yielded a middle-upper Bathonian ammonite association with: Eohecticoceras cf. biflexuosum, Hecticoceras (Prohecticoceras) crassum, Paroecotraustes cf. rhodanicum and P. thrax. Subvertical dykes contain no ammonites but, being filled by wackestones to grainstones with Bositra, crinoid ossicles, Saccocoma or Pygope, indicate several different phases of infilling up to the latest Jurassic. In the grainstones, early calcite cements are abundant, both syntaxial and isopachous, documenting an active water circulation also in the deeper parts of the dykes, i.e. tens of metres below the sea floor.

Subvertical dykes have a dominantly NW-SE strike, but NE-SW trends also occur. Whenever cross-cutting relationships can be directly observed, the latter result to be older. Another set of thinner and less accessible fractures, that approximately dip 30°-40° W, show unclear relationships with the other dykes. In the largest dykes, up to 10 m wide megablocks of the Inici Formation (Fig. 17) collapsed into the fracture, still bearing on their top beds of Rosso Ammonitico, several decimetres thick. These blocks float in a grey matrix with a chaotic structure, again referable to the Rosso Ammonitico Formation. The characteristic shape and limited areal extent of some of the dykes, that change abruptly in width along strike, are strongly suggestive of small pull-aparts related to local transtension.

In the Rocca chi Parra quarry, the Rosso Ammonitico is quite different from the Poggio Roccone section: the colour is grey and, importantly, the thickness is greatly reduced, ranging from few decimetres to a maximum of 3.5 m. In any case the thickness of the Rosso Ammonitico is only indicative because significant changes may take place over a short distance. Three sections, about 200 m apart, will be described in order to highlight these differences: one is located in the central part of the quarry, while the others are found in its western side.

Because of dangerous access to the quarry front, we will not have a close view to the described sections. Moreover they do not show any more exactly the same features reported below because of the ongoing quarrying activity. The different stratigraphic subdivisions, however, may be seen also in the distance, and blocks
scattered on the quarry floor may be hammered.

SECTION A: CENTRAL PART OF THE QUARRY (Fig. 18)

Level 1 (30-40 cm): dark grey glauconitic to pyritic, bioclastic packstones with Bositra, crinoid ossicles and benthic foraminifers (Vidalina). Abundant centimetre-sized lithoclasts of pelagic limestone, often encrusted by Fe-Mn oxides, occur together with abundant moulds of taphonomically reworked ammonites, including Adabofoloceras subobtusum, Phylloceras plicatum and Macrocephalites sp., indicative of a late Bathonian to middle Callovian age. This level can be interpreted as a transgressive lag.

As to ammonites, WENDT (1964, p. 72) gave a long list of taxa indicating a mixed assemblage spanning the upper Bathonian (e.g. Oxycerites aspidoides), lower Callovian (e.g. Macrocephalites compressus), and middle Callovian (e.g. Rehmannia (Loczyceras) segesta). This bed has to be assumed as the type-level from which GEMMELLARO (1882) derived all the specimens and the syntypes of his new species described in the "zona con Stephanoceras macrocephalum" monography. Fossils are very common and can be easily collected also from loose blocks scattered on the quarry floor. Mediterranean phylloceratids such as Phylloceras isomorphum and Holcophylloceras zignodianum are especially abundant.

Locally lower Callovian taxa are locally frequent, sometimes wonderfully preserved like one specimen of Reineckeia turgida typical of the Macrocephalites gracilis Chron, Indosphinctes patina Subchron of the latest early Callovian.

Level 2 (10 cm): bioclastic packstones to grainstones. The top of the level is a discontinuity surface, thoroughly burrowed with glauconite and Mn oxide encrustations.

Level 3 (40-100 cm): protoglobigerinid-rich wackestones with millimetre-scale stromatolitic lamination. Several discontinuities are present in this level and are characterized by the erosional truncation of ammonite moulds or by Frutexites-like crusts of Mn oxides. The finding of Aspidoceras binodum and Orthosphinctes (Lithacosphinctes) gidoni suggests a late Oxfordian age.

Level 4 (60 cm): the boundary with the underlying level is a discontinuity surface encrusted by Mn oxides, overlain by a stromatolitic horizon and, locally, by a fossiliferous lag. Above this surface, massive wackestones follow, which are characterized by abundant crinoid ossicles up to 1 cm in size.

Level 5 (140 cm): massive wackestones, still rich in crinoids at the base and characterized by a nodular structure, due to the presence of bored and mineralized millimetre-sized intraclasts. Although no ammonites were found, the occurrence of Saccocoma at the base and of Calpionella alpina at the top indicate that this level spans the Kimmeridgian-early Berriasian interval.

A sharp discontinuity surface, underlined by firm ground burrows and glauconite mineralizations (Fig. 19), occurs at the boundary between levels 5 and 6 (i.e. between the Rosso Ammonitico and Lattimusa Formations).

Level 6 (170 cm): evenly bedded white mudstones referable to the upper Berriasian based on the association of Calpionellopsis oblonga and Calpionella elliptica. At the top of the level, the occurrence of Olcostephanus asterianus sensu COMPANY (1987) indicates the upper

![Image](image-url)

Fig. 18 - Lithostratigraphic logs of two sections at the Rocca chi Parra quarry: A: central part; B: western side. (modified after Martire et al., 2000).

Fig. 19 - Rocca chi Parra quarry, Section C. Rosso Ammonitico-Lattimusa boundary: every bed is bounded by discontinuities that are more or less intensely coated by glauconite. Firm-ground burrows are particularly well developed at the top of the first bed of the Lattimusa Fm.
Valanginian (Saynoceras verrucosum Zone).

Level 7: well-bedded and light-coloured micritic limestones, with slumped intervals, referable to the Hybla and Scaglia formations. This interval, exposed for some tens of metres on the quarry front, has not been studied in detail.

SECTION B: WESTERN SIDE OF THE QUARRY (Fig. 18)

Level 1 (10 cm): packstones to grainstones with bivalves (Bositra), crinoid ossicles and benthic foraminifers (Vidalina). This bed overlies the Inici Formation through a sharp, non-mineralized surface that cuts also through some subvertical neptunian dykes. The top of the level is an erosional discontinuity surface, that truncates ammonite internal moulds, and is encrusted by Fe-Mn oxides. Among the ammonites, uppermost Oxfordian perisphinctids occur.

Levels 2 (20-40 cm) and 3 (30 cm): wackestones with protoglobigerinids and small gastropods, showing a well developed, undulose, millimetric lamination due to stromatolitic domes. All the strata are bounded by erosional discontinuity surfaces coated by Fe-Mn oxides. Biostratigraphically, levels 2 and 3 are clearly distinguishable. Level 2 contains typical late Oxfordian ammonite taxa, such as Passendorferia aff. ziegleri. Level 3 yielded a rich ammonite assemblage referable to the early to late Kimmeridgian transition: Taramelliceras compsum, Idoceras gr. dedalum, Nebrodites peltoideus, N. favaraensis, Presimoceras herbichi, Aspidoceras acanthicum. The last bed of Level 3 is a Saccocoma-rich wackestone that at the top may have either a hardground rich in glauconite, with firm ground burrows and bivalve borings, or a breccia with glauconite and Fe oxides, containing taphonomically reworked ammonites among which Hybonoticeras cf. knopi, referable to the uppermost late Kimeridgian. Above this discontinuity surface, the white mudstones of the Lattimusa Fm. begin.

SECTION C: WESTERN SIDE OF THE QUARRY (Fig. 20)

Mid way between sections 1 and 2, a newly exposed section shows a very interesting and peculiar situation which helps clarify both the nature and age of the Inici-Rosso Ammonitico boundary. The top of the Inici Fm., in fact, in correspondence of a subvertical neptunian dyke 2 m wide, is deeply incised and characterized by a concave-up surface that, over a distance of a few metres, merges with a normal bedding plane (Fig. 21). The resulting depression, more than 3 m deep, is at least some tens of metres across until the westernmost side of the quarry. A symmetrical situation is visible to the east, even though complicated by a possible Cenozoic fault zone. Few metres-across highstanding portion of the Inici white limestone occurs separating areas where the Fe and Mn-encrusted inherited rock ground with the typical pinnacled morphology is visible. Rosso Ammonitico sediments show complex geometries within the depression. Two mini-sequences may be measured on the opposite sides of the subvertical dyke, that is on the steep and on the flat parts of the depression bottom. Most of the beds in this lower part of the Rosso Ammonitico are separated by discontinuity surfaces marked by black Fe and Mn coatings or by mineralised stromatolitic beds (Frutexites). These surfaces are highly irregular and result in a pinch and swell geometry of beds. A lag rich in mineralised lithoclasts and taphonomically reworked fossils (ammonite moulds, brachiopods, crinoids) may also occur at the base. This set of beds, which reaches a maximum thickness of about 1 m, is characterized by a dark grey colour and can be correlated with levels 1-4 of Section A in Fig. 18. Most of the beds are fossiliferous and have markedly different ages. More in particular, the palaeontological-biostratigraphical features of beds A to E are as follows:

Bed A: It contains Choffatia caroli, C. leptonata, and C. (Subgrossouvria) recuperoi, which indicate the lower Callovian and in particular the middle part of the Macrocephalites gracilis Zone.

Bed B: A specimen of Passendorferia [M] [P. (Enaytes) n. sp. (C. D’ARPA, pers. comm.)] refers the bed to the Gregoryceras transversarium Zone, P. (Dichotomosphinctes) Subzone, of the middle Oxfordian, as in the Erice succession.

Bed C: The presence of Taramelliceras cf. obumbrans associated with Holcophylloceras zignodianum and Euaspidoceras sp. allows to assign,
Fig. 21 - Sketch of a complex stratigraphic situation in the western part of the Rocca chi Parra quarry.

Fig. 22 - Cross-section showing the stratigraphical and geometrical relationships among Inici, Rosso Ammonitico and Lattimusa formations and neptunian dykes of different generations at the Rocca chi Parra quarry.

again, this bed to the *Gregoryceras transversarium* Zone.

Bed E: This bed is early Tithonian in age due to the presence of *Haploceras cf. cassiferum* and *H. staszycii*; the first taxon should indicate the *Virgatosimoceras albertinum* Zone. This bed seals a vertical neptunian dyke, 25 cm across, filled with a coarse packstone containing abundant crinoidal debris and *Pygope janitor*, which is a common form starting from the lower Tithonian.

The main part of the depression, however, is filled with light grey limestones which onlap both the Inici Fm. and the lenses of dark grey limestones paving the
concave-up surface carved into the Inici Fm. This filling sequence, about 250 cm thick, consists of Saccocoma-bearing wacke- to mudstones, locally showing stromatolitic laminations and often crossed by a network of cm-wide burrows filled with crinoidal packstones. The last bed is a mudstone with intraclasts made of radiolarian- and calpionellid-bearing wackestones. The micropaleontological assemblage (Calpionella elliptica, C. alpina, Remaniella cadischiana) indicates the calpionellid Biozone C (lower Berriasian) of REMANE (1974). This bed is bounded both at the base and at the top by glauconite-coated discontinuity surfaces (Fig. 19). The overlying beds are the white mudstones of the Lattimusa Fm., bearing Tintinnopsella carpathica, T. longa, Remaniella cadischiana, Calpionellopsis oblonga, typical of calpionellid Biozone D2 (upper Berriasian).

On the highstanding portion, where the top of the Inici Fm. displays the Fe-Mn encrusted pinnacles, in Autumn 1999, but only for a couple of months, the exploiting works revealed an ammonite-rich lens of glauconitic packstone at the very base of the Rosso Ammonitico Fm. The assemblage, referable to the latest Bajocian-earliest Bathonian, is described later on. These discontinuous fossiliferous deposits are directly overlain by white limestone beds that, when traced laterally, correspond to beds occurring about 2 m above the base of the Lattimusa in the depression-filling succession. The peculiar geometric and stratigraphic situation described in Section C may be interpreted as the result of a submarine slide possibly triggered by the fracturation phase which generated the oldest vertical dyke, affecting both the top layers of the Inici Fm. and the scattered Middle Jurassic deposits directly resting on them. As suggested by WINTERER et alii (1991), these detachment surfaces had a stepwise geometry and followed preexisting physical discontinuities such as bedding planes.

The correlation among the three sections is easy because, thanks to colour differences, it is possible to follow the beds laterally. Levels 1 to 4 in section A, levels 1 to 3 in section B, and interval DG in section C, in fact, are characterized by a dark grey colour that contrasts with the light grey colour of Level 5 in section A and interval LG in section C (Fig. 22), which in turn is well distinguishable from the white mudstones of the Lattimusa Fm. All this clearly indicates that the Rosso Ammonitico at Rocca chi Parra is characterized by great variations in lithosome geometry, a direct result of the morphological top of the underlying Inici Fm. In particular, on the western side of the quarry front (Sections 2 and 3), a marked thickness reduction of the Rosso Ammonitico (from 350 cm to 60 cm) takes place through the gradual thinning of dark grey beds along with the pinch out of light grey beds, which are in fact missing in Section B (Fig. 23). Furthermore, also the lowest beds of the Lattimusa display the same geometry, and they directly overlie the dark grey part of the Rosso Ammonitico in Section B. All this gives rise to a pattern of multiple onlaps between unconformity-bounded sedimentary bodies, namely of the lower part of the Rosso Ammonitico over the Inici Fm., of the upper part (Tithonian-lower Berriasian) of the Rosso Ammonitico over the lower part, and of the Lattimusa over the whole Rosso Ammonitico.

A more general comparison with the other sections of the Montagna Grande sector reveals how peculiar is the case of Rocca chi Parra, which is characterized by sedimentation over an irregular sea floor of a thin, condensed and discontinuous Rosso Ammonitico. A general scheme of the evolution of this sector may be envisaged as follows (Fig. 24). After the drowning of the Inici platform, whose top was characterized by the pinnacled and Fe-Mn encrusted surface, pelagic sediments rich in ammonites began to be patchily preserved in the Bajocian, and were affected by intense reworking. In Bathonian times, an extensional tectonic phase, possibly associated with strike-slip movements, caused an important re-structuration of this part of the Trapanese Domain. Block faulting, and possibly tilting, resulted in the generation of an irregular sea bottom paleotopography that controlled the sedimentation patterns. The Le Rocche-Poggio Roccione-Montagna Grande transect possibly corresponded to a gentle slope where the thickness of Bathonian to Oxfordian beds increased downslope, i.e. towards Montagna Grande. Rocca chi Parra, instead, possibly because of the intersection with transverse structures (transfer faults?), became an isolated highstanding block. The fracturation associated with Bathonian tectonics resulted, on one hand, in the opening of several large, vertically extensive and differently oriented fissures, and, on the other, in the
triggering of large slides which left wide concave-up scars. Bathonian to Kimmeridgian Rosso Ammonitico sedimentation thus took place over an irregular rocky bottom, the original pinnacled, drowned top of the platform being only locally preserved. Another tectonic pulse, occurring in the latest Jurassic, could have been responsible for the opening of new dykes and for a slight overall tilting of the Rocca chi Parra sector, resulting in the marked pinch out of the light grey, Tithonian beds. The same event likely caused a steepening of the Le Rocche-Poggio Roccione-Montagna Grande slope, producing bedding-parallel dykes due to creeping of semolithified sediments and to loose sediment collapse structures (Poggio Roccione). The sedimentation of the uppermost part of the Rosso Ammonitico did not completely level the Bathonian paleotopography, which still influenced the lower part of the Lattimusa, as is documented by pinch out of beds and onlap relationships at the top of Rosso Ammonitico.

**LATE BAJOCIAN AMMONITES FROM THE ROCCA CHI PARRA QUARRY**

The lenticular bed (see above), about 10 m across and about 30 cm thick, directly resting on the mineralized crust of the Inici top, contains a great quantity of brachiopod and mollusc shells, among which late Bajocian and early Bathonian ammonites are the most significant component for their abundance and taxonomic diversity. Stratigraphic and textural information indicates that the fossiliferous lens was the result of a single depositional event which chaotically concentrated the material reworked from partially lithified limestones; possibly these "pebbles" were transported by high-energy agents, e.g. storm currents sweeping the pelagic platform.

In fact, the state of preservation of fossils (Fernandez-Lopez, 1991; Pavia & Martire, 1997) indicates that they are taphonomically reworked in a typically condensed fossil assemblage. Evidence of reclamation are common and consist of phosphatization of internal moulds, glauconite coating on both the neomorphic shell and the internal mould, lithological discontinuities between mould and matrix, abrasion surfaces cutting shell and mould, reverse geopetal structures (Fig. 25). The ammonite assemblage therefore resulted from the mixing of subsequent paleo faunas spanning the Bajocian-Bathonian boundary. Late Bajocian taxa are represented, among others, by common specimens of the *Dimorphinites dimorphus* group, parkinsoniids like *Parkinsonia subplanulata*, and perisphinctiids such as *Lobosphinctes costulatosus* and *Planisphinctes tenerissimus*, all significant forms of the late *Parkinsonia parkinsoni* Chron, and by scattered *Pseudogarantiana* sp. and *Spiroceras cf. annulatum* of the early *P. parkinsoni* Chron. Furthermore the dimorphic couple *Morphoceras-Ebrayiceras*, and scattered parkinsoniids comparable to *P. (Gonolkites) convergens* and *Lobosphinctes subprocerus* are earliest Bathonian taxa, indicative of the basal *Zigzagiceras zigzag* Chron.

In the mixed assemblage, phylloceratids are the prevailing taxonomic group with an abundance of more than 40 % of the whole ammonite sample, in which the frequent *Calliphyllococeras disputabile*, *Holocophylloceras zignodianum*, *Psychochylloceras haloricum* and *Adabofoloceras* pl. ssp. state a clear Mediterranean affinity of these ammonite paleocommunities. Moreover, the common *Nannolytoceras tripartitiforme* seems to be an endemic form whose architecture falls within the phyletic lineage *N. polyhelictum* to *N. tripartitum*, which
is well documented in the uppermost Bajocian of the Western Tethys (PAVIA, 1973). Among Ammonitina, morphoceratids are the best represented group with an unusual number of taxa of the genus *Dimorphinites*, including some new species, and of its microconch counterpart *Vigoriceras* (Fig. 26). Their taxonomic study is still in progress, but it is clear that the presence of undescribed new species and the comparison with other Tethyan morphoceratids will (1) add significant detail to document the evolutive lineages which, starting from the ancestral late Bajocian stock, led to the more diversified Bathonian faunas, and will (2) help trace paleobiogeographic links and migration routes from Western Sicily (i.e. from the North-African margin) to the Submediterranean and central Mediterranean sectors during the Middle Jurassic.

Some early Bathonian ammonites had already been recorded from the Rocca chi Parra quarry by WENDT (1964, p. 71), including *Morphoceras* sp. ind., but no latest Bajocian forms had so far been found. Our new findings therefore add significant new data on the upper Bajocian to lower Bathonian of western Sicily; furthermore, for the first time, they allow to make comparisons with other Western Tethyan ammonite faunas and, more in general, to elucidate paleobiogeographic patterns during the Middle Jurassic. A similar fossil assemblage is only known from the famous locality of Contrada Burgilamuni, near Agrigento, studied by GEMMELLARO in 1877; nevertheless this locality cannot be presently located in the field because both the fossiliferous calcareous olistoliths, embedded within the tectonized Neogene marls of the area of Favara (MOTTA, 1957), were completely destroyed by Gemmellaro's own samplings, and also because the outcrops have been covered by urban expansion. In common with the Favara ammonites are *Nannolytoceras tripatitiforme*, *Oppelia plicatella*, *Cadomites daubenyi*, *Parkinsonia* (*Oraniceras?*) *ditomoplocum*, *Prorsisphinctes hoffmanni*: they still await for a more precise biochronologic attribution, which will probably become possible through correlation and taphonomic analysis of Rocca chi Parra fossil assemblage.
STOP 4 - BAIA DI GUIDALOCA (SCOPELLO): INTEGRATED BIOSTRATIGRAPHY IN THE ROSSO AMMONITICO FACIES OF THE GUIDALOCA SECTION (UPPER JURASSIC-JURASSIC/CRETACEOUS BOUNDARY)

J.E. Caracuel, G. Parisi, A. Bartolini & E. Mattioli

INTRODUCTION AND GEOLOGICAL SETTING

The Guidaloca section crops out on the Guidaloca Beach, 3 km west of Castellamare del Golfo (Fig. 27). This area paleogeographically belongs to the Trapanese Domain (CATALANO & D'ARGENIO, 1982a).

From bottom to top, the Jurassic succession is made up as follows: Inici Formation, Crinoidal Limestone, Rosso Ammonitico and Calcare a Calpionelle (Lattimusa Formation). In the Trapanese domain the Rosso Ammonitico Unit is subdivided into two members, generally separated by a siliceous, radiolaritic interval (MAUZ & RENDA, 1996; DI STEFANO & MINDSZENTY, 2000). This stop will be focused on the radiolaritic interval (Marne e Calcareniti con selce), the upper member of Rosso Ammonitico and the lowermost part of the Calcare a Calpionelle.

Integrated biostratigraphy will be used here to interpret the sedimentary evolution of the succession.

LITHOSTRATIGRAPHY AND MICROFACIES

The Upper Jurassic succession at the Guidaloca beach is built up of 12.5 m of alternating marly/calcarenitic levels, with chert in nodules and ribbons, overlain by 20 m of Rosso Ammonitico in a marl/limestone lithofacies (upper member) (Fig. 28). The succession lies unconformably over the Inici Formation, and is overlain by the Calcare a Calpionelle Unit of latest Tithonian age (CARACUEL ET ALII, 2001).

MARN E CALCARENITI CON SELCE UN I T
Due to later faulting, two partial sections will be described separately (GD-A and GD-B; 2.5 and 10 m thick, respectively), composed of alternating siliceous limestones and marls, siliceous siltstones in thin irregular beds, with chert in nodules and ribbons, and incipient nodular intervals, especially near the base (Fig. 28, Stop 4a and 4b). The upper part includes probable slumps just below the boundary with the overlying Rosso Ammonitico Unit, but recent tectonics make any interpretation difficult (Fig. 28, Stop 4b). Based on radiolaria and calcareous nannofossils, the age ranges from latest Bathonian to early Kimmeridgian. Also, the last occurrence of protoglobigerinids recorded in the middle part of the GD-B section suggests the upper part of this interval is already Kimmeridgian.

Macroinvertebrates are scarce and poorly preserved as randomly oriented ammonite internal moulds (mostly small-sized phragmocones), belemnites, along with aptychi and fragmented echinoderm thecae. Many ammonites bear evidence of intense reworking, like internal mould fractures and truncation planes incompatible with master bedding. Nevertheless, no differences between the microfacies in the internal molds and in the surrounding matrix are noted.

Textures are commonly wackestones with occasional packstones rich in radiolaria. The main microfossil components are radiolaria, Globochaeta, protoglobigerinids, sponge spicules, thin-shelled bivalves ("filaments"), Saccocoma and calcareous hyaline foraminifers, mainly Lenticulina. Planar orientation of elongate bioclasts as "filaments" evidences the generalized lack of burrowing, even at the top of individual depositional event levels.
Calcari a Calpionelle (Lattimusa Fm.)
white rhythmic limestones with chert
calpionellid wackestones (poor packstones)
with radiolarians, Globochaete, Cadosina, "filaments" and foraminifers

Rosso Ammonitico Unit
marly/calcareous nodular limestones with chert, mainly as nodules
Saccocoma packstones (wackestones), with Cadosina, radiolarians, Globochaete, "filaments" and foraminifers

"Marne e Calcareniti con Selce" Unit
siliceous limestones and marls, siliceous siltstones finely and irregularly bedded with incipient nodular intervals
radiolarian wackestone (occasionally packstone) with Globochaete, prtogobiogids, sponge spicule, "filaments", Saccocoma and foraminifers

Fig. 28 - Lithostratigraphy and main lithofacies of the Guidaloca section.
Rosso Ammonitico Unit

Two partial sections (GD-C and GD-D; 12 and 8 m respectively) of nodular condensed Rosso Ammonitico facies with chert in nodules and ribbons were studied. The base is mainly composed of marly Rosso Ammonitico with abundant chert in ribbons, while the upper part is built of cherty/calcareous Rosso Ammonitico (Fig. 28, Stop 4d). Toward the top of this unit nodules become less and less evident and sedimentation evolves gradually to the white cherty limestones of the Calcari a Calpionelle Unit (Fig. 28, Stop 4d).

This section, especially in the lower part, bears abundant macroinvertebrates (mainly ammonites and subordinate belemnites, brachiopods, crinoids and echinoids), which permit a zone-level ammonite biostratigraphy for the uppermost lower Kimmeridgian-lower Tithonian p.p. The upper part of the unit, that is comparatively ammonite-poor, was dated by calpionellids and radiolarians as lower Tithonian p.p.-uppermost upper Tithonian (Fig. 29, 31 and 32).

As typical for the Rosso Ammonitico facies, ammonites are preserved as internal moulds, lying parallel to the stratification and with their upper side variably corroded, with no size-distribution. Some inner moulds lying vertically, especially small specimens, are interpreted as due to intensive bioturbation caused by large Thalassinoides (preserved only as horizontal frames) and small Chondrites and Planolites, occurring at the top of the calcareous nodular intervals.

Textures are packstones and wackestones for both the marly and the calcareous Rosso Ammonitico lithofacies. Microfossils include Saccocoma, Cadosina (mid-section), radiolarians (mostly in the lower part), Globochaeta, calpionellids (in the upper part), thin-shelled bivalves ("filaments"), and benthic foraminifers (mainly Lenticulina).

Calcari a Calpionelle Unit (Lattimusa Fm.)

At the Guidaloca beach the Calcari a Calpionelle Unit overlies the Rosso Ammonitico through a transitional boundary. It crops out as more than 90 m of monotonous white cherty limestones in thin irregular beds (Fig. 28, Stop 4d). Upwards, the Hybla Fm. (Barremian-Albian in age) overlies the Calcari a Calpionelle Unit through a faulted contact. No trace fossils have been recorded. Macroinvertebrates are scarce and only represented by ammonites, aptychi, brachiopods and echinoderm fragments.

Textures range from calpionellids-bearing wackestones to packstones with radiolarians, globochaetes, cadosinas, "filaments" and foraminifers. Based on calpionellid biostratigraphy, the Calcari a Calpionelle Unit encompasses the uppermost upper Tithonian to the Valanginian p.p.

Biostratigraphy

Biostratigraphic data for the Upper Jurassic succession at Guidaloca were derived from ammonites radiolarians, calcareous nannoplankton, calpionellids, and other additional microfossils such as Protoglobigerina. An extensive biostratigraphic and systematic treatment for these fossil groups will be given in the appendix below.

Marne e Calcareniti con Selce Unit (Callovian-Early Kimmeridgian)

This unit is extremely poor in ammonites, with only small, fragmented and poorly preserved specimens of Sowerbyceras, Phylloceras and Calliphylloceras. A base of this interval, calcareous nannoplankton biostratigraphy indicates the Callovian to early Kimmeridgian, based on different species of the genera Watznaueria and Lotharingius. The middle and upper parts were dated by radiolarians as UAZ 8-10 (Bathonian to early Kimmeridgian). The last occurrence of protoglobigerinids at GD-B 3 m further supports the interpretation of the upper part as being already Kimmeridgian.

Rosso Ammonitico Unit (Upper Member-Uppermost Lower Kimmeridgian-Uppermost Tithonian)

The lower part of the Rosso Ammonitico facies bears rich ammonite assemblages that permit a zone-level biostratigraphy for the uppermost lower Kimmeridgian through the lower Tithonian p.p. More than 150 ammonites were collected in situ. The Kimmeridgian (Divisum to Beckeri Zones) was recognized based on the genera Presimoceras, Nebrodites, Mesosimoceras Taramelllicer, and Hybonoticcer. The lower Tithonian (Hybonotatum to Verruciferum Zones) is characterized by several species of Hybonoticcer, Schaireria, Haploceras and Ptychophylloceras, among others. Fözy (1995) also collected in this interval Semiformiceras cf. darwini Aulasmoceras cf. linaresi, Discosphinctoides rhodaniforme and Subdichotomoceras sp.

The remainder of the succession is comparatively ammonite-poor. Near the top a specimen of Durangites was collected, which dates the uppermost Tithonian, in agreement with the record of calpionellids. The upper 5 m of Rosso Ammonitico provided calpionellid assemblages with Chitinoidea, overlain by the Crassicollaria Zone. The Praetintinnopsella Zone (sensu POP, 1974; equal to the Chitinoidella Zone, Andrussov Subzone, sensu GRUN & BLAU, 1997) seems to be either missing, or unrecognizable due to poor preservation that usually characterizes condensed nodular limestones.
**CALCARI A CALPIONELLE (UPPERMOST TITHONIAN-VALANGINIAN P.P.)**

The base of the rhythmic limestones with chert of the Calcari a Calpionelle Unit was dated as the Crassicollaria Zone (Intermedia/Catalanoi Subzones). The record of the Calpionella Zone starts at metre 1 of the Calcari a Calpionelle Unit. The studied 90 m of the Calcari a Calpionelle Unit yielded calpionellid assemblages of the Calpionella, Calpionellopsis, Calpionellites and Tintinnopsella Zones (Andreini et alii, 2001).

**SEQUENTIAL AND PALEOENVIRONMENTAL DYNAMICS**

During the Middle Liassic-Tithonian, deposition of relatively thin brachiopod/crinoidal limestones and Rosso Ammonitico facies with local intercalations of bedded cherts and siliceous marls was dominant across the Trapanese domain according to MAUZ & RENDA (1996) and Di Stefano & Mindzenty (2000). This suggests deposition over an irregular morphostructural high. The area was subjected to tectonic instability which affected sedimentation (hiatuses and redeposited lithotypes). At Guidaloca the condensed Rosso Ammonitico (upper member) starts in the Divisum Zone and can be related to a major change of the sedimentary input analogous to that recorded in the Apennines by Cecca et alii (1990). In the latest Tithonian, deposition of the Calcari a Calpionelle started, suggesting a deepening of the depositional palaeoenvironment.

The Marne e Calcareniti con selce Unit includes laminated siliceous limestones and siltstones, suggesting redeposition from surrounding areas. The scarcity of planar microbioclasts of Saccocoma and Bositra buchi ("filaments") probably suggests relatively strong hydrodynamics, so these potentially "floating" microbioclasts (MARTIRE, 1992; CARACUEL et alii, 1997) were swept off the platform.

The Rosso Ammonitico Unit is composed of variably marly/calcareous intervals with little evidence of resedimentation (pebbly-mudstones are remarkably missing). Nevertheless, a variable degree of winnowing of microbioclasts is noted, which caused repeated microfacies turnover from imbricated planar microfossils (Saccocoma+"filaments") to rounded microbioclasts (Globochaete+Cadosina+Radiolaria). During the Kimmeridgian these alternations are interpreted as variable wind-driven current hydrodynamics that affected the sea-bottom. Nevertheless, "blooms" of Cadosina (mainly during the Tithonian) and Calpionellids (in the upper Tithonian) were also affective in counterbalancing radiolaria.

According to the global eustatic curve in HAQ et alii (1987, 1988), the Upper Jurassic encompassed the 2nd Order Supercycles LZA-4 (transgressive period; lower Oxfordian-lowermost Tithonian) and LZB-1 (regressive period; lowermost Tithonian-Lower Berriasian). Thus, the Kimmeridgian/Tithonian boundary represents the maximum flooding at the 2nd Order Supercycles, which records a generalized faunal condensation, with dominant ammonites. During the transgressive period (Supercycle LZA-4) overall hydrodynamic energy decreased, as evidenced by less frequent levels with imbricated planar Saccocoma+"filaments". During the subsequent regressive period (Supercycle LZB-1), microfacies are enriched in resedimented microbioclasts, derived from surrounding areas.

**Appendix I - Remarks on Kimmeridgian-lower Tithonian Ammonite faunas**

J.E. CARACUEL


The most favorable interval for ammonite biostratigraphic zonation in the Guidaloca section is the lower part of the GD-C interval, which records the uppermost lower Kimererdigian-lower Tithonian p.p. (Fig. 29). Similarly to the underlying GD-A and GD-B intervals, the base of GD-C is ammonite-poor, and only non-diagnostic phylloceratids and a single specimen of Presimoceras gr. herbichi (Hauer) where recorded. This latter species characterizes the upper part of the lower Kimererdigian (Olóriz, 1978; Caracuel, 1996; Sarti, 1993). The fauna is consistently small-sized and badly preserved as inner cast phragmicoones.

The middle Kimererdigian is comparatively richer in ammonites, and their preservation is better, also as inner casts. The faunal assemblage is still dominated by phylloceratids (mainly Sowerbyceras, loryi and silenum groups). Significant ammonites recorded in this interval are Nebrodites (N.) cf. cafisi (Gemmellaro), Pseudowaagenia cf. acanthomphala (Zittel), Glochiceras (Lingulaticeras) sp. gr. procurnum Ziegler and Taramelliceras (T.) gr. Compsum (Oppe) trans.
Franciscanum (Fontannes), which belong to the upper part of the Compsum Zone. The Cavouri Zone is thin, and bears abundant S. loryi (Munier Chalmis in Pillet & De Framentel). Here, a specimen of N. (M.) cavouri was collected just above the last record of Taramelliceras (T.) gr. compsum (Oppe) trans. franciscanum (Fontannes).

The upper Kimmeridgian is the most ammonitiferous interval. Faunas are also well-preserved as inner casts, with abundant large-sized ammonites with no significant taphonomic biases. Along with dominant phylloceratids (mainly Sowerbyceras loryi and tortisulcatum trans. silenum, and Calliphyloceras) and lytoceratids (Lytoceras orsinii, liebigi and polycyclum), we sampled abundant Hybonoticeras of the group bekeri (Neumayr), pressulum verestoicum (Herbich) and pressulum pressulum (Neumayr), Aspidoceras cf. sesquimodosum (Fontannes in Dumortier & Fontannes), Glochiceras (Lingulaticeras) gr. procaruum Ziegler, while perisphinctids include Biplisphinctes and Pachysphinctes. The pre-Verruciferum lower Tithonian is also well-characterized with ammonites. Phylloceratids are comparatively scarce with respect to the Kimmeridgian [mainly Ptychophylloceras ptychoicum Quenstedt, recorded from the base and Calliphyloceras kochi (Oppe)]. The Hybonotum Zone is characterized by Hybonoticeras of the groups: pressulum pressulum (Neumayr) and hybonotum hybonotum (Oppe), and aspidoceratids like Aspidoceras rogoznicense (Zuschinner) and Schaireria neumayr. Checa. In the Albertinum/Darwini Zone the ammonite record becomes scanty. We were only able to collect a single specimen of Pachysphinctes aff. bathyplocus (Waagen) similar to Pachysphinctes sp. A, in the LAD of the underlying horizons is also significant in this respect. Moreover, Fozy (1995) records in the Guidaloca section Semiformiceras cf. darwini and Aulasimoceras cf. linaresi from an horizon just above the record of H. (H.) pressulum. Finally, the Verruciferum Zone is clearly marked by the occurrence of Haploceras (Haploceras) elimatum (Oppe), H.
(Hypolissoceras) carachtheis (ZEUSCHNER) and H. (H.) verruciferum (MENEGHINI). FÖZY (1995) collected also Discosphinctoides rhodoniforme and Subdichotomoceras sp. from this unit.

Appendix II - Calcareous nannofossils

E. MATTIOLI

DATA

In order to analyse the calcareous nannofossil assemblage, twelve samples were studied in the GD-A portion of the Guidaloca section and nine in the GD-D portion (Fig. 30). The sampled intervals were purposely those where ammonite stratigraphy was unavailable. Sampling was carried out in less siliceous and less nodular intervals, in order to avoid those levels where the nannoflora is commonly poorly preserved. Samples were prepared by simple mechanical fragmentation of a small volume of rock, dilution with water, spreading onto a cover glass and drying in a stove. Cover glasses were attached to slides with Canada balsam. Smear slides were prepared as homogeneously as possible, so that nannofossil abundance in different slides be comparable. Observations were done under a light polarizing microscope, at 1000X magnification. Nannofossils, both coccoliths and the incertae sedis Schizosphaerella spp., were counted in each slide in a variable number (200 to 400) of views. The surface of one field of view is 3.14 x 10-2 mm2. Total and relative abundances recorded in each sample were then divided by the number of views examined; the abundance per field of view is reported in the tables in Fig. 4. As a result of this semiquantitative analysis, 4 classes of abundance were established (Fig. 30).

All the studied samples contain calcareous nannofossils, although in the GD-A portion the assemblages are very poor in 4 samples. Preservation of nannofossils was evaluated on the basis of the overgrowth/dissolution effects, according to ROTH (1984). Despite the variable degree of preservation, nannofossils were identifiable in all the studied samples, and three classes of preservation were established:

- good - no or only light overgrowth and/or dissolution;
- moderate - light dissolution of delicate forms and/or loss of the delicate central area structures;
- poor - some coccoliths are severely affected by dissolution, some other coccoliths and Schizosphaerella spp. are overgrown, but specific determination is still possible.

The average preservation of the studied samples varies from poor to very poor, with the dominance of overgrowth effects mainly on specimens belonging to the genus Watznaueria. Only the sample at 3.10 m of the GD-D interval revealed moderate to well preserved assemblages.

Total and species abundance values are in general low, with the exception of a few samples in discrete levels (Fig. 30).

INTERPRETATION – DISCUSSION

ROTH (in RIEDEL & SANFILIPPO, 1974) described the nannofossil assemblage in the Sant’Anna section, which is located in the Sicani Mts., SW Sicily, some 90 km to the south of the Guidaloca section. The authors gave a Tithonian-early Berriasian age for the Sant’Anna section, based on nannofossil assemblage. MANIVIT, in DE WEVER et alii (1986), and MANIVIT et alii (1986) studied the calcareous nannofossils in the same section as RIEDEL & SANFILIPPO (1974). In DE WEVER et alii (1986) the Sant’Anna section was divided into three intervals, namely a green radiolarite interval, a nodular limestone interval with abundant ammonites, and a third interval with white marly limestones. According to DE WEVER et alii (1986), the Sant’Anna section spans the late Oxfordian to early Valanginian.

The first two intervals of the Sant’Anna section correspond in all probability to a part of the Guidaloca section, namely the GD-B to GD-D interval. The nannofossil assemblage in the GD-A interval is dominated by different species of the genus Watznaueria. Watznaueria britannica (STRADNER, 1963) REINHARDT, 1964, and Watznaueria manivitae BUKRY, 1973, the most abundant species in the assemblage, are characterized by different morphotypes displaying different sizes (GIRAUD et alii, 1998; MATTIOLI & ERBA, 1999; AUDOIN et alii, 2001). Because of the thorough presence of Cyclagelosphaera wiedmannii (whose first occurrence is found in the Tethyan domain at the Bathonian/Callovian boundary; MATTIOLI & ERBA, 1999), of Schizosphaerella spp., Lotharingius crucicentralis (MEDD, 1971) GRÜN & ZWEILI, 1980, and Lotharingius hauffii GRÜN & ZWEILI in GRÜN et alii (1974) (that are still present in the lower Kimmeridgian assemblages of southern Germany; PITTET & MATTIOLI, 2001), a Callovian-early Kimmeridgian age can be inferred for the GD-A interval. However, according to radiolaria data, the base of the overlying interval (GD-B) can be dated as early Oxfordian. The GD-A interval is therefore Bathonian/Callovian to early Oxfordian in age. It is difficult to further refine the chronostratigraphy of this interval, due to the presence of dominantly long-range taxa. Furthermore, due to the absence of the marker species, it is impossible to refer this interval to the nannofossil zones recently proposed by BOWN & COOPER (1998). The nannofossil record of the GD-A interval seems to be therefore older than the assemblages described in RIEDEL & SANFILIPPO (1974) as Tithonian and by DE WEVER et alii (1986) as late Oxfordian-
Fig. 30 - Calcareous nannofossil distribution chart of the Guidaloca section.
Kimmeridgian for the base of the Sant’Anna section.

In the upper part of the Guidaloca succession (GD-D interval), the nannofossil assemblage is still characterised by abundant Watznaueria, but important changes are observed. Schizosphaerella spp., L. crucicentralis and L. hauffii disappear from the assemblage. The continuous presence of Compsphaera mexicana TREJO, 1969 ssp. mexicana and Compsphaera mexicana TREJO, 1969 ssp. minor BRALOWER & COOPER, 1989, both first occurring in the uppermost Kimmeridgian (BRALOWER et alii, 1989; BOWN & COOPER, 1998), was observed from the base of this interval. The sporadic occurrence of the early Nannoconus (probably referable to N. compressus BRALOWER & THIERSTEIN in BRALOWER et alii, 1989 at m 0.5 and 2.6) was also recorded. This assemblage allows us to recognize, at the base of the GD-D interval, at least part of the C. mexicana Zone (NJ 20; BRALOWER et alii, 1989). The NJ 20 Zone spans the early to middle Tithonian, from the Chron CM 22n to the Chron CM 20, and includes the lower part of the Chitinoidella calpionellid Zone (BRALOWER et alii, 1989).

The occurrence of Polycostella beckmannii THIERSTEIN, 1971 and Microstaurus chiastus (WORSLEY, 1971) GRÜN in GRÜN & ALLEMANN (1975) was recorded at m 2.60, and that of Hexalithus noelae LOEBLICHT & TAPPAN, 1966 at m 3.5. The first occurrences of M. chiastus and H. noelae are used by BRALOWER et alii (1989) to establish the nannofossil zone NJK and the subzone NJKa respectively. The NJK Zone crosses the Jurassic-Cretaceous boundary, from the Chron CM 20 to the Chron CM 17 (BRALOWER et alii, 1989). The NJK Zone displays a dramatic change in the nannoplankton community, with the first occurrence of the early Nannoconids and the disappearance of N. compressus.

This Zone has been correlated to the interval from the Chitinoidella Zone to the Calpionellids Zone B. The NJKa Subzone spans the late Tithonian, from Chron CM 20 to Chron CM 19, and it is correlatable to part of the Chitinoidella Zone up to the Calpionellids Zone A (CHANNELL & GRANDESSO, 1987; BRALOWER et alii, 1989; BOWN & COOPER, 1998). The GD-D interval spans therefore the middle-upper Tithonian, according to the nannofossil assemblage, and corresponds to the NJ 20 Zone - NJ Ka Subzone of BRALOWER et alii (1989) and to the Chitinoidella Zone to the Calpionellids Zone A interval of CHANNEL & GRANDESSO (1987). A younger age is further excluded because of the presence in the topmost sample of C. mexicana minor, which is known to disappear in the uppermost Tithonian (BRALOWER et alii, 1989).

Appendix III - Radiolaria

A. BARTOLINI

Eleven radiolarian samples from sections GD-B and GD-C have been analysed. In the intervals GD-A and GD-B, the integrated radiolarian and calcareous nannofossil data have permitted to constrain the age of this interval which is poor in ammonites. In the lower part of the GD-C section radiolarian levels are intercalated with ammonite levels, allowing for the direct calibration of the radiolarian assemblages with ammonite biozonation.

Radiolarians were extracted from samples first using HCl, to remove the carbonate component, and then diluted (1%-5%) HF. Radiolarians are generally poorly to moderately preserved. The radiolarian unitary association zonation (UAZ) and taxonomy of BAUMGARTNER et alii (1995) are used here. In the Fig. 5 all the identified taxa have been reported, along with the UAZ established for each sample.

The radiolarian assemblage of sample GD-B 5.05 can be attributed to the UAZ 7-8 (upper Bathonian-lower Oxfordian). However, because of the presence of the nannofossil Cyclagelosphaera wiedmannii in the underlying interval GD-A, this sample cannot be older than the Bathonian/Callovian boundary (see MATTIOLI, Appendix II, this volume). Samples from the GD-B 5.65-6.70 interval can be referred to the UAZ 8 (middle Callovian-lower Oxfordian). Samples GD3–GD6 have been attributed to the UAZ 9-10. The radiolarian association of sample GD-B 6.80 indicates the UAZ 9-10. The radiolarian association of sample GD-C O.05 can be referred to the UAZ 9-11 (middle Oxfordian-lower Kimmeridgian). The radiolarian association of sample GD-C 1.10 and 2.10, in particular, indicate the UAZ 11. In BAUMGARTNER et alii (1995) the UAZ 11 has been “tentatively correlated with a late Kimmeridgian-early Tithonian age, based on the following occurrence with age-diagnostic fossils: at DSDP Site 534A, sample 106-1, 29 cm, this UAZ is found just below the Kimmeridgian/Tithonian boundary according to dinoflagellates. In the Sierra Ricote Section, UAZ 10-11 have been found immediately below upper lower Tithonian (Burkhardiceras Zone) ammonites”. At Guidaloca, ammonites have been recovered in the section GDC (see appendix I). The interval 0 to 2.70 m can be assigned to an indeterminate Divisum - Compsum Zone (lower-middle Kimmeridgian). The direct correlation between radiolaria (samples GDC 1.10 and GDC 2.10) and ammonites at the Guidaloca section shows, therefore, an older age for the UAZ 11.
Appendix IV - Jurassic Calpionellid assemblages

J.E. CARACUEL, G. PARISI & G. ANDREINI


Jurassic calpionellid assemblages at the Guidaloca section are recorded in the interval GD-D (Fig. 32). As a whole, the microfacies is moderately rich in calpionellids, although highly variable in detail, with alternating calpionellid-bearing levels and intervals enriched in reworked Saccocoma or Globochaete+Cadosina. Tests are poorly preserved, frequently corroded, namely the collar area, which makes taxonomy sometimes uncertain.

We studied 50 visual fields in every thin-section (around 15) for obtaining statistical data of the species distribution through the lower to upper Tithonian interval. We recorded assemblages belonging to the Chitinoidella (Dobeni and Boneti Subzones in the uppermost lower Tithonian) and the Crassicollaria (Remanei, Intermedia and Catalanoi Subzones in the upper Tithonian) Zones.

The Chitinoidella Zone starts with the record of microcrystalline calpionellid tests (Chitinoidella dobeni and boneti group), before the FAD of hyaline loricas. The base (Dobeni Subzone) is dominated by C. dobeni. Upwards, C. boneti increases, counterbalancing C. dobeni in the Boneti Subzone. In both subzones, the percentage of calpionellids is always lower than 5%. According to previous studies in the area, there is no record of two-walled calpionellids (Praetintinnopsella). This could be related to the extreme corrosion or re-
crystallization of the tests which may preclude their proper identification, generating some potential confusion between *Praetintinnopsella* and small specimens of *Tintinnopsella carpathica* (Olóriz et alii, 1995). Alternatively, this can be interpreted as due to a depositional hiatus in the lowermost upper Tithonian (Simplispinctes ammonite Zone), since the correlatable Chitinoidella Bermudezi + Praetintinnopsella Andrusovi Subzones (see Grün & Blau, 1997) are both unrecorded. This has also been observed in other localities across the Mediterranean region, all dominated by Rosso Ammonitico, as in SW Spain (Olóriz et alii, 1995; Caracuel, 1996), and, probably, in neighboring areas of W Sicily like Monte Inici (Cecca et alii, 2001).

The Crassicollaria Zone (=A Zone, in Remane, 1963) starts with the FAD of hyaline tests until the “bloom” of isometric *Calpionella alpina* in the lowermost Berriasian (base of Calpionella Zone=B Zone, in Remane, 1963). Highly corroded calpionellid-poor assemblages characterize the Remanei Subzone, which include small *Tintinnopsella remanei* and *carpathica* and low-diversity *Crassicollaria*. In this interval, the generalized lack of the collar area of calpionellids makes a taxonomic distinction difficult between *Crassicollaria* and small-sized *Tintinnopsella*. In the Intermedia Subzone the percentage of calpionellids increase and the *Crassicollaria* diversifies, now including the *intermedia*, *brevis*, *massutiniana*, *parvula* and *colomi* groups. This is also where *Calpionella alpina* and homeomorph *elliptica* are first recorded. In the upper subzone (Catalanoi Subzone, *Crassicollaria* disappears, except for *colomi*, being replaced by Remaniella, with the groups *catalanoi*, *ferasini* and *duranddelgai*.
STOPS 5 TO 7 - THE TRAPANESE SUCCESSION OF MONTE ERICE: A RAMP TO PELAGIC PLATFORM TRANSITION

L. Martire

Monte Erice, formerly Monte San Giuliano, on top of which the ancient village of Erice lies, is a prominent morphological feature of the landscape of westernmost Sicily. From 800 m of altitude, abrupt cliffs border this triangular ridge from the sea, to the North and West, and from the Trapani plain to the East and South. These cliffs roughly follow Cenozoic master faults and correspond to extensive outcrops of Mesozoic carbonate rocks.

This sector of the Trapanese Domain shows a Jurassic stratigraphic succession that significantly differs from that of other classical Trapanese sections (Montagna Grande, Monte Kumeta, Monte Inici, Rocca Busambra). The common element is the thick sequence of peritidal Lower Jurassic limestones (Inici Fm.) followed by a Lower to Upper Jurassic succession of pelagic facies that mark the drowning of the platform. The pelagic succession, however, is much thicker and siliceous than elsewhere and has been consequently considered indicative of more basinal conditions (Wendt, 1971b; Guunta & Liguori, 1972, 1973). We will informally refer to this succession as the Erice formation.

The aims of the following stops (Fig. 33) are on one hand to visit some classical sections and fossiliferous localities, and on the other to highlight sedimentological features which strongly suggest that a new paleogeographical reconstruction is in order. Two sections will be visited on the southern side of Monte Erice, displaying how important the paleostructural control was on the three-dimensional development of lithosomes and on the deposition of certain peculiar beds.

Fig. 33 - Location of sections visited in Stops 5, 6 and 7.

STOP 5 - ANTICA ERICE: BIOSILICEOUS AND NODULAR LIMESTONES WITH RESEDIMENTED BEDS

L. Martire & G. Pavia

The palaeontology and the stratigraphy of this section were described by Wendt (1971b). Additional data, however, are now available mainly thanks to the progresses made in carbonate sedimentology. The section is located below the Venus Castle, along a dirt road heading eastwards from the Cappuccini monastery (Fig. 34).

Level 1 - The top of the Inici Fm. is locally crossed by cm-wide vertical dykes filled with pink or red micritic sediments, bearing scattered ostracod shells and sometimes separated by isopachous cement rims.

Covered tract (about 6 m).

Level 2 (3.5 m) - The covered tract masks the boundary with the overlying Erice fm. It starts with a massive body of limestones characterized by a high degree of internal complexity. They are in fact riddled by neptunian dykes to such an extent that it is not always clear which is the host rock and which is the dyke filling. Different textures may be observed, from whitish mudstones to greenish and red crinoidal packstones, also with lithoclasts of filament-bearing wackestones and fragments of Fe-Mn oxide crusts. This documents a complex history of polifase rock fracturing, sediment infilling, and cement precipitation for these early layers of pelagic sediments. Moreover, an angular unconformity with a change of dip of about 10° is clearly detectable between these limestones and the underlying Inici Fm. The age of this massive bed is uncertain due to its scarce fossil content, although Wendt (1971b, pp. 59, 60) collected here some middle to late Aalenian ammonites (Brasilia bradfordensis and Graphoceras concavum zones). A general late Toarcian to early Bajocian age is
likely for this level, based on circumstantial stratigraphic evidence.

Covered tract (about 10 m).

Level 3 (11.7 m) - Strikingly regular alternations of grey cherty limestones and greenish marls. Limestone beds are 15-20 cm thick and consist of wackestones with filaments, echinoderm debris and sponge spicules and rhaxes (Fig. 35). Sparse *Inoceramus* prisms also occur. Sponge spicules are only seen in the partially silicified portions, which still retain their original texture. Chert nodules are highly irregular in shape and seem to follow large burrows (*Planolites*, *Thalassinoides*). They have a patchy distribution pattern due to the preferential silicification of smaller *Chondrites* burrows (Fig. 36). The calcareous portions of rock experienced a certain degree of mechanical and chemical compaction, as is documented by the flattening of filaments, mostly parallel to bedding, and the presence of dissolution seams. Both these compactional features are missing in the cherts, indicating that silicification was an early diagenetic process. A less common type of thin limestone beds, (with beds less than 10 cm thick), also occurs, consisting of packstone to grainstone with abundant echinoderm debris and subordinate filaments and peloids; syntaxial cements commonly occur around echinoderms. Several marl interbeds actually consist of clay-rich packstones with fitted crinoidal fragments. Glaucanite and phosphate grains are widespread throughout Level 3, and are particularly common in the crinoidal grainstones.

Covered tract (about 0.5 m) possibly corresponding to a minor fault.

Level 4 (8.2 m) - Wacke- and packstones rich in *Bositra* shells plus echinoderm debris. Compared to Level 3, beds are thicker, both marl interbeds and grainstone layers are less frequent, chert nodules, cream to brown in colour, are bigger and more vitreous, have sharp, rounded edges, and do not show the spotted pattern. The rock is lighter coloured and brownish. Cherts are absent in the middle part of the interval.

Level 5 (11.5 m) - Very similar to Level 4, but beds are even thicker (up to 40-50 cm), cherts occur both as nodules, several decimetres across, and as ribbons.

Covered tract (about 4 m). Approximately corresponding to this stratigraphic level, in nearby localities, a beautiful hardground was described by WENDT (1971b, p. 60). It is characterized by an irregular erosional surface and by firm ground burrows penetrating the underlying *Bositra* packstones; both the surface and the walls of the burrows are stained by limonite. The overlying bed is rich in taphonomically reworked ammonite moulds; among the taxa listed by WENDT, *ptychophylloceras flabellatum*, *Prohecticoceras* spp., *C adamantites extinctus*, *Choffatia* cf. *uriniacensis*
Fig. 36 - Antica Erice section. Cherty limestones of Level 3. Note the spotty aspect of these cherts due to a dense network of Chondrites burrows.

indicate the mixing of middle to (?) upper Bathonian fossils.

Level 6 (3 m) - Same lithology as Level 3, with spotted cherts.

Level 7 (5.4 m) - Wacke- and packstones with Bositra shells and echinoderm debris in beds 30-40 cm thick. Compared to the underlying levels, cherts are missing except for a 30 cm thick bed, and nodular intervals occur.

Covered tract (about 2 m).

Level 8 (5 m) - This level groups an array of different lithologies. The “background” lithology is represented by cherty limestones or by nodular limestones. The former consist of wacke- to packstones with minute Bositra debris, abundant radiolarians, small peloids and sparse sponge spicules and echinoderm fragments. Chert nodules and ribbons are very common. Radiolarians are preserved as chalcedony moulds also in the calcareous part of the rock. The nodular limestones, instead, are composed by fine-grained packstones with echinoderm fragments, peloids, and scattered Bositra debris. Fitted packstones crossed by dissolution seams occur as intermodal matrix. Interbedded with these lithologies are discrete beds 10-30 cm thick with sharp bases and normal grading. At the base they are composed of coarse grainstones to rudstones. The grains are represented by echinoderm coarse debris and angular lithoclasts composed of various lithologies: wackestones with filaments, echinoderms or Globochaete, coarse peloidal grainstones with calcareous algae (Thaumatoporella), fenestral mudstones, sucrosic dolostones. These grainstones/rudstones pass upward to finer packstone/grainstones with abundant peloids and Bositra and echinoderm debris. Both intervals have millimetre-thick parallel laminae and are frequently silicified, and they give rise to planar chert beds light brown in colour. The upper part of the beds consists instead of wacke- to packstones with abundant radiolarians, Bositra debris, small peloids and sparse sponge spicules and echinoderm fragments. Mm-thick laminae, both convex- and concave-up, are referable to hummocky cross stratification with a swell spacing of about 50 cm (Fig. 37). Chertification occurs also in these intervals, producing thin layers of black chert.

Level 9 (1 m) - Greenish limestones with a nodular structure at the base and becoming massive towards the top. They consist of wackestones with Fe-oxide stained protogloboigerinids, echinoderm debris, calcitized radiolarians, and peloids. A stromatolitic lamination is locally recognizable. Internodular matrix on the contrary is a fitted packstone with fine echinoderm debris and peloids. Ammonite moulds occur, including Tornquistes sp. and Lytoceras gastaldii, both indicating the middle Oxfordian (Perispinctes plicatilis Zone).

Covered tract (about 1 m).

Level 10 (6.7 m) - Similarly to interval 8, cherty limestones, locally nodular, alternate with grainstones. Differences include: (a) Grainstone beds are thinner (usually less than 10 cm) and finer grained; peloids are the most abundant grains and are associated to superficial oolites, coated bioclasts and benthic foraminifera (miliolids), while lithoclasts are absent. (b) Cherty limestones contain Saccocoma debris and display also well washed peloidal-bioclastic grainstone textures.

Level 11 (1.25 m) - A single bed of light coloured limestone, clearly recognizable in the landscape all around Monte Erice, which consists of a coarse grainstone with peloids, oolites, thick-shelled bivalves, echinoderms, calcareous algae (Thaumatoporella), corals and lithoclasts of finer grained peloidal and ooidal grainstones. No remarkable sedimentary structures are observable, except for some parallel laminae in the middle part.

Level 12 (1.9 m) - Similarly to interval 10, thin beds of peloidal grainstones are interbedded with
Saccocoma-bearing nodular limestones. The latter always have grain-supported textures, from fitted packstones to well-washed grainstones with peloids, Saccocoma and other echinoderm fragments overgrown by coarse syntaxial sparry cement. Chert is missing. At the top, a single bed, 55 cm thick, of graded peloidal-oolitic grainstones occurs.

Level 13 (5 m) - Peloidal and Saccocoma-bearing packstones to well-washed grainstones organized in nodular beds or occurring as tabular beds with sharp base and top, sometimes with parallel lamination. Poorly preserved ammonite moulds are locally present. Chert nodules and ribbons occur in discrete beds, but are relatively uncommon.

The section continues in the vertical cliff below the Castello di Venere, where regular thin beds of whitish limestones similar to Level 13 are exposed for about 15 m.

Except for levels 1 and 2, we will not observe the Jurassic succession in this section because access to outcrops is difficult. We will have a close view to levels 3 and 4 walking back towards Erice on the tarred road and then, after a covered tract, to Level 11 (Fig. 38). The Level 11 is beautifully exposed here, reaching 3.8 m in thickness and consisting entirely of rudstones with no evidence of grading. Clasts are up to 15 cm across and, similarly to the microrudstones present within Level 8, are composed of various lithologies ranging from grey to greenish wackestones with radiolarians or with echinoderm and Bositra debris, locally silicified, to light coloured grainstones with peloids, oolites, rounded intraclasts and abundant bioclasts including calcareous algae and mioloid foraminifera (Fig. 39). Large, partly silicified, bioclasts are represented by thick-shelled bivalves, like ostreids, and colonial corals (Fig. 40). Above this megabed, the same white Saccocoma-bearing limestones of Level 12 are present, and extensively crop out in a small abandoned quarry along the road.

**Facies Interpretation**

The Jurassic succession of the Erice area has always been interpreted as the result of deposition in basinal conditions (WENDT, 1971b; GIUNTA & LIGUORI, 1972). This interpretation was mainly based on the greater thickness and ubiquity of siliceous facies compared to the most typical Trapanese Rosso Ammonitico. Strongly contrasting views, on the contrary, were proposed for the Late Jurassic megabed: WENDT (1971b) considered it as an episode of shallow water sedimentation, whereas GIUNTA & LIGUORI (1972) interpreted it as a gravity flow coming from an adjacent structural high. Our new data perhaps suggest a different interpretation. The main features displayed by the Erice fm. may be summarized as follows:

- Grain-supported textures, often well-washed, are very common if not even prevailing over mud-supported ones. Early cementation is quite common especially in echinoderm- and Saccocoma-rich beds, giving rise to large syntaxial overgrowths. Both these features suggest currents periodically active on the sea floor.
- Bioturbation (large Chondrites, Planolites, Thalassinoides) is widespread and intense, often enhanced by silicification. This infaunal activity is probably the reason for the thick bedding, and indicates that the sea floor was well-oxygenated.
- Remains of benthic organisms, such as echinoderms, occur at all levels in the succession, often in the form of well-washed bioclastic sands.
- The siliceous skeletal fraction of the cherty beds is mainly represented by sponge spicules. Radiolarians are clearly recognizable only in the upper part of the section (from Level 8), in association with spicules. Cm-sized, rounded calcareous masses with a
three-dimensional framework of spicules have been found in the Erice Difali section, and suggest that the spicule-producing communities were living in the close vicinities.

- Sharp-based, sometimes graded grainstones with peloids, oolites and skeletal grains of shallow platform biota (calcareous algae, miliolids) are clearly a product of resedimentation. The occurrence of hummocky cross stratification provides a crucial palaeobathymetric constraint, indicating that storms were responsible for sedimentation of these beds. The scarcity of hummocky cross stratified beds possibly indicates a depth close to the lower limit of storm wave base (150-200 m?), where only the most severe tempests could organize the ambient sediment into hummocks, whereas storm-induced turbidity currents periodically resulted in deposition of carbonate sands.

All these features suggest an outer ramp depositional environment, where slow background pelagic sedimentation was overprinted by typical ramp processes like the reworking and winnowing of autochthonous sediments by water currents (storm-induced?), and the active offshore export of sediments. Variations in the litho- and biofacies therefore probably reflect changes in the sedimentary dynamics of the shallower, inner parts of the ramp.

In this picture, the megabed occurring at the top of the succession must reflect a single catastrophic event taking place, however, at relatively shallow depths. Being composed of variable proportions of peloids, oolites and lithoclasts, up to cobble size, it is suggestive of a process impinging on an inner ramp where it could stir up loose sediment at the sea floor, and deeply erode early cemented shallow buried beds. The suspended material was then transported offshore. Given the huge volume of material involved, suggesting a catastrophic event rather than a storm, the hypothesis of a tsunami is here proposed to explain the deposition of the megabed. Tsunamis are rather common phenomena nowadays and even though their effects onshore are better known and studied, also the sedimentary record of the backflow in offshore environments is now being fully recognized (e.g. SHIKI & YAMAZAKI, 1996). After inundation of the coastal zone by abnormally high waves, in fact, the water flows back forming strong return currents that, depending on local coastal morphology, may become channelized (EINSELE, 1998). This results in deep localized erosion and deposition of discontinuous, ruditic deposits. Such a phenomenon could explain the abrupt thickness variations of the megabed, and the variable proportions of pebbles and cobbles from place to place.

The interfingering of typical pelagic facies (ammonite-bearing nodular limestones, radiolarian cherty wackestones) with outer ramp sequences (peloidal-oolitic storm layers, crinoidal pack- to grainstones, spicule-rich cherty limestones) is a good evidence of the peculiar paleogeographic position of the Erice sector in the Jurassic. This can be envisaged as lying between pelagic plateaus (Trapanese Domain) and a shallow carbonate platform (Panormide Domain?) from which carbonate sands, litho- and bioclasts had to be derived.

**STOP 6 - SOUTHERN SIDE OF MONTE ERICE: THICKNESS CHANGES IN THE "ERICE FORMATION"**

L. MARTIRE

This stop has essentially a panoramic purpose. From this spot we can observe most of the Middle-Upper Jurassic succession, continuously exposed on the southern side of Monte Erice, overlying the white shallow platform limestones, in very thick even beds, of the Inici Fm. Some reference intervals can be recognized in the distance: the Bathonian hardground at about 28 m above the low wall; the minor cliff corresponding to thick bedded, non-cherty limestones with Callovian to Oxfordian ammonites (the main object of Substop 7.2); the white massive rudstone megabed. A section measured here, in the vicinities of Fontana Difali, demonstrates that the thickness of the succession between the top of the Inici Fm. and the megabed (about 180 m) is much greater than at Antica Erice (about 80 m). Moreover, it is clearly seen that this drastic thickness change takes place entirely within the pre-Bathonian strata (Fig. 41). A view toward the southern side of Monte Erice, facing the town of Trapani, reveals that, in the surroundings of Fontana Difali, the spectacular cliff made of Inici Fm. ends abruptly along a subvertical surface (Fig. 42). It partially corresponds to a Cenozoic fault that downthrows the western block with an approximately E - W strike, *i.e.*
subparallel to the slope. Nevertheless, the Erice fm. which crops out to the North, above the cliff termination, is affected by only minor faulting, with offsets of no more than few metres, and is easily followed laterally. A closer view to the cliff termination reveals that the top of the Inici Fm. is characterized by a staircase geometry which is onlapped by echinoderm-bearing strata referable to the Erice fm. Several steps, each some metres high and with steep or even overhanging walls, represent the surface which separates the Inici and Erice formations: a total relief of over 20 metres can be measured.

This surface preserves, virtually unmodified, the rugged sea floor topography on which the earliest post-drowning deposits were sedimented. The stepwise geometry cannot be the product of erosional processes alone, both subaerial and submarine, and is here interpreted to represent a Jurassic fault scarp zone possibly modified by gravity-induced, superficial block gliding before being covered by pelagic/outer ramp sediments.

STOP 7 - FONTANA DIFALI: THE MIDDLE JURASSIC FOSSILIFEROUS LOCALITY OF G.G. GEMMELLARO AND J. WENDT

G. PAVIA

At the “Difali Fountain” the excursion will split in two topics: 1) the onlap of the Erice fm. over the stepped angular unconformity on the Inici Fm.; 2) the fossiliferous Bathonian to Oxfordian section along the Sant’Anna road, up to the tsunamiite at the top of the succession.

In the paleontological literature, Fontana Difali is a well-known toponym from which, in the past times, some fossiliferous beds yielded a huge number of mollusc remains, among which the Toarcian-Aalenian ammonites described by GEMMELLARO (1886) and partly revised by CRESTA (1997). The Toarcian-Aalenian bed is missing in the present-day outcrops, despite the frequent exposure of the marl/limestone alternations of the Erice fm., which perhaps suggests that it was a lens with poor lateral continuity, less than 1 metre thick (DE GREGORIO, 1886). The lenticular bed was obviously exposed along the road cut at Gemmellaro’s time; later, in the 1930’s, a hydraulic tunnel, dug some metres above the present-day fountain.
crossed the fossiliferous layer (fide WENDT, 1971b, p. 59). From loose blocks, some of which are still found in the scree below the road, WENDT (op. cit.) recorded an ammonite assemblage corresponding to the one reported by Gemmellaro, including Pleydellia aalensis, Catullocceras dumortieri, Planammatoceras tenuisigne, Euaphtuboceras amaltheiforme, Haplopleuroceras eximium. These forms indicate a mixing of latest Toarcian to late Aalenian ammonites. Samples of this level show that it consists of packstones to grainstones with peloids and echinoderm debris and cm-sized intraclasts heavily stained and coated by Fe-Mn oxides. Another fossiliferous bed had to exist, and is now only represented by displaced blocks that yielded ammonites of the lowermost Bajocian such as Otoites sp. (WENDT, 1971b; S. CRESTA, pers. comm.).

It is impossible to locate exactly these fossiliferous lenses within the Erice succession. Nevertheless, field evidence, the state of preservation of fossils, thoroughly reworked taphonomically, and the textural characteristics observed in loose samples, suggest that they represent sediments and fossils eroded from highstanding areas, such as the Antica Erice high, and transported into the depocenter of the Difali sector, at different times during the early Middle Jurassic, at least twice around the Aalenian-Bajocian boundary. In the light of these findings, it is possible to infer that the first bed of the Erice fm. at Antica Erice, Aalenian in age, correlates with largely covered, lenticular beds occurring about 80 m above the base of the Erice fm. in the Erice Difali section (Fig. 41). This evidences that most of the thickness variations seen across the “Erice basin” occur in the Pliensbachian-Aalenian time interval, and become less pronounced upsection. Starting from the Bathonian, in fact, similar sedimentation rates are documented across the area, indicating a complete levelling of the paleotopography inherited by middle Early Jurassic extension.

Substop 7.1- Contrada Difali: the pelagic draping of a fault scarp at the top of the Inici Fm.

L. MARTIRE & F. LOZAR

Here we will have a close view to the onlap of the Erice fm. over the stair-stepped angular unconformity representing the top of the Inici Fm. (Fig. 43). Neogene reactivation of the Jurassic faults triggered severe dolomitization of the rocks, making a recognition of the original lithologies difficult. However, bedding style and the presence of echinoderm plates, which are not affected by dolomitization, allow to separate the Inici fm. Echinoderm-bearing dolostones in medium to thick (20-70 cm) even beds abut a nearly vertical wall made of massively bedded peritidal cyclothems of the Inici Fm. (Fig. 44). Upsection, the dolomitization is less pervasive and, in addition to the always abundant echinoderms, belemnites and brachiopods may also be recognized; chert nodules are also locally present.

In the uppermost metres of the Inici Fm. some interesting features are worth noting. Within the Inici limestones, massive bivalves (Megalodonts?) are clustered to form dm-thick coquinit beds. Some of the shells have been dissolved and the resulting cavity filled by a rim of radiaxial cement followed by blocky spar. In the highest step it is possible to observe the sharp, knife-edge contact between the mudstones to peloidal packstones with spar-filled fenestrae of the Inici Fm. and

Fig. 44 - Erice Difali section. Stratigraphic, subvertical unconformable contact between the massively bedded Inici limestones in the background and the well bedded basal Erice fm. in the foreground.
the greenish peloidal packstones with echinoderm and thick-shelled bivalve fragments of the Erice fm. The surface itself is stained green by glauconite and is irregular on a very small, millimetric, scale. No grain, however, is truncated suggesting that the Inici limestones were not completely cemented. A few metres to the right, the last step wall shows the most convincing evidence for an Early Jurassic age of this irregular paleosurface. Breccia deposits, in fact, seal the top of the Inici fm. (Fig. 45). Both the clasts and the matrix are dolomitized but some loose echinoderm fragments are still recognizable in the matrix, arguing against a post-Mesozoic tectonic origin and, by contrast, supporting the hypothesis of a Jurassic sedimentary breccia. Dissolution vugs, several centimetres across, occur at the very top of the Inici fm. and are filled by a greenish sediment which, in spite of the complete dolomitization, may be referred to the base of the Erice fm. A pre-drowning history of subaerial exposure may be inferred on the basis of these structures. Marl/limestone alternances overlie the cited greenish-light brown packstones (9 m thick) and are exposed, although partly covered, for about 20 m. Limestones consist of packstones and wackestones with peloids, sponge spicules, echinoderms and thick-shelled bivalve fragments with scattered chert nodules. Macrofossils are unfortunately almost entirely missing: only a nautiloid (Paracenoceras sp.) was recovered from the top of the outcrop.

Calcic nannofossil analysis performed on the lowest non-dolomitized beds (approximately 20 to 25 m above the base of the Erice fm.), despite overall poor preservation, allowed to recognize the following taxa: Crepidolithus crassus, Mitroolithus jansae, M. lenticularis, Biscutum dubium, Lotharingius hauffii. This assemblage is referable to the Lotharingius hauffii Zone (Mattioni & Erba, 1999), spanning the upper Pliensbachian-lower Toarcian interval. However, the absence of Lotharingius sigillatus and of Caliculus spp. indicate the lower part of the zone, i.e. the upper Pliensbachian, Biscutum finchii Subzone. This calcareous nannofossil subzone roughly corresponds to the ammonite Pleuroceras spinatum Zone.

**Substop 7.2 - Sant’Anna road: Bathonian to Oxfordian ammonite biostratigraphy**

C. D’Arpa, A. Galacz, L. Martire, G. Melendez & G. Pavia

The section is exposed along the untarred road that, from the Erice-Trapani road, goes to S. Anna (Figs. 46, 47).

Level 1 (20-30 cm) - The section commences with the Bathonian ammonite-rich bed already described at Antica Erice. It consists of Bositra packstones/grainstones also containing Fe-stained protoglobigerinids, peloids and echinoderm fragments. The fossil assemblage of this level was recently described by Galacz (1999), who concluded that ammonites on the whole indicate a very short phase of condensation within the latest early Bathonian. This is suggested by the co-occurrence of taxa like Morphoceras macrescens,
Asphinctites pinguis and "Tulites" tuwaiquensis. This is the first report in the Western Tethys for these typical Arabian forms. New collecting indicate the presence of middle Bathonian persphinctids which seem to enlarge the time-span of condensation. Furthermore, fossils bear sound evidence of taphonomic reworking, such as glauconite coatings, septal fractures, discontinuities between internal mould and matrix, abrasion surfaces of the internal moulds, i.e. the most significant signs of taphonomic condensation within a mixed fossil assemblage (GOMEZ & FERNANDEZ-LOPEZ, 1994). Taxonomic study and detailed taphonomic analysis of the whole ammonite sample collected in past (WENDT, 1971b) and in recent times from the condensed layer cropping out across the whole Erice area have been undertaken by GALACZ and PAVIA (in progress). This bed is important because it is the type-level of some of Gemellaro's ammonites, like Lissoceras monachum and its possible junior synonym L. ventriplanum.

Levels 2 to 6 (685 cm) - This tract of section is represented by a monotonous, faintly bedded succession of Bositra packstones/grainstones with peloids and echinoderm fragments. Beds are up to 170 cm thick, but thin interbedded marls and marly Bositra-rich packstones also occur.

Level 7 (235 cm) - Texturally similar to the previous one, this interval is characterized by the interbedding of massive and nodular layers. Glaucous grains are present. In the lower part, the presence of Lissoceras sp. indicates the upper Bathonian.

Level 8 (40 cm) - This bed is easily distinguished because of its easy weathering and unique nodular structure. Calcareous nodules are composed of wackestones with Bositra, protoglobigerinids, Globochaetae and calcite-filled radiolarian moulds; nodules are subspheical and less than 3 cm in diameter, and they have sharp boundaries with the matrix, which consists of marly packstones with Bositra, echinoderms and peloids. These features strongly suggest gravity flow of un lithified sediment carrying early cemented nodules. Some nodules are actually internal moulds of ammonites, affected by intense taphonomic reworking and usually unidentifiable; one specimen of Rehmannia (Loczycceras) reissi nevertheless indicates the bed is not younger than the earliest middle Callovian.

Level 9 (147 cm) - In spite of a homogeneous lithology, consisting of Bositra packstones, this interval is of primary importance for paleontology and biostratigraphy. It has been subdivided into six beds, some of which yielded ammonite moulds and are here described separately.

- Bed 9c - One specimen of Putealiceras cf. trilineatum indicates the basal upper Callovian.
- Bed 9e - This bed produced a specimen of Paraspidoceras (Struebinia) sp., indicating the lower part of the middle Oxfordian, (?) basal Perisphinctites plicatilis Zone. A glauconite-coated discontinuity surface occurs between beds 9d and 9e, which corresponds to a gap spanning most of the upper Callovian and the whole lower Oxfordian.

- Bed 9f - This is the richest fossiliferous bed in this section, bearing typical Mediterranean phylloceratids like Holcophylloceras zignodianum, Sowerbyceras tortisulcatum, along with Tornquistes kobyi, P. (Dichotomosphinctes) antecedens, Passendorferia cf. tenuis, Sequeirosia bocconii, Euaspidoceras cf. fontannes. The assemblage represents the upper Perisphinctes plicatilis Zone, P. (Dichotomosphinctes) antecedens Subzone of the middle Oxfordian.

- Bed 9g - This bed is easily distinguished because of its easy weathering and unique nodular structure. Calcareous nodules are composed of wacke- to packstones with prevailing radiolarians plus small peloids and echinoderm fragments. The radiolarians may be preserved as calcite spar-filled moulds or as micritic moulds; incomplete infilling of moulds gives rise to geopetal structures. Stromatolitic laminae are locally observed in the nodules. The matrix consists instead of a packstone with peloids and
echinoderms. Beds 25 to 31 in the outcrop correspond to levels 10a to 10g in Fig. 46. Their paleontological-biostratigraphical features are as follows:


- Beds 10b-d - The fossil assemblages are very poor. Besides frequent *Sowerbyceras tortisulcatum*, only one specimen of *Gregoryceras transversarium* was recovered, which documents the homonymous zone, though with no possibility to differentiate between the *P. (D.) rotoides* or *P. (Dichotomosphinctes) schilli* subzones.

- Bed 10e - Several specimens of *Gregoryceras fouquei* and *Passendorferia* cf. *uptonioides* (Fig. 48) allow to refer the bed to the *P. (Dichotomoceras) bifurcatus* Zone, at the base of upper Oxfordian.

- Bed 10f - The occurrence of *Orthosphinctes* gr. *ariniensis* in association with *Euaspidoceras* gr. *hypselum* indicates the *Epipeltoceras bimammatum* Zone.

- Level 11 (240 cm) - Greenish siliceous limestones and interbedded thin, fissile marls follow through a transitional boundary. These limestones consist of wacke- to packstones with abundant radiolarians, and subordinate sponge spicules and rhaxes: all these skeletal grains are preserved in chalcedony. Small, flat chert lenses occur, displaying the same spotted pattern already seen in the Antica Erice section, due to silicification of *Chondrites* burrows.

- Level 12 (11.40 m) - This interval can be separated from the underlying one for two main reasons: 1) the occurrence of thin-bedded, light-coloured peloidal grainstones; 2) the occurrence of more abundant chert, also in 15 cm thick ribbons.

**Fig. 48** - Erice S. Anna section. Bed 10f with ammonites of the upper Oxfordian, *P. (D.) bifurcatus* Zone: *Euaspidoceras* sp. and *Passendorferia* cf. *uptonioides*.

Level 13 (130 cm) - Single, massive bed with a sharp, flat base. It is the same resedimented megabed already seen in the Antica Erice section and interpreted as a tsunamiite. Differently from the two previous outcrops, where it is either all fine-grained (Antica Erice) or completely ruditic (tarred road to Erice), the megabed here is well graded from a lithoclastic rudstone, with subrounded clasts up to 2-3 cm across, to a peloidal-oolitic-bioclastic grainstone at the top. Parallel laminae are visible in the middle and upper parts.

Level 14 - *Saccocoma*-rich nodular limestones with chert nodules follow for several metres.

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**INTRODUCTION TO STOP 8:**

**THE JURASSIC/CRETACEOUS SUCCESSION OF THE SACCENSE DOMAIN**

M. MARINO, C. MURARO & M. SANTANTONIO

Peculiar Jurassic sequences cropping out in various sections across the Sciacca area (south-western Sicily) are ascribed to the Saccense domain (Fig. 49) (see CATALANO, this guidebook, for tectonostratigraphic setting). The Jurassic deposits overlie several thousand metres of platform limestones and dolomites of Late Triassic age (Sciacca Fm.).


In general, an evolution can be seen from a peritidal carbonate platform (Inici Fm.) to a pelagic carbonate platform, indicating that post-drowning sedimentation occurred here on a morpho-structural high, which we call the Sciacca Plateau. As a result, the post-Inici pre-Calpionellid limestone succession is no more than about 60 m thick, often much less. The currently accepted lithostratigraphy, largely informal, comprises the following units (CATALANO & D'ARGENIO, 1990; VITALE, 1990) (bottom to top): Inici Fm. (Late Triassic *p.p.*, *Lias* *p.p.*), Crinoideal limestone (*Pliensbachian-Toarcian*?), *Bositra* limestone (*Bathonian-Callovian*?), *Bositra* limestone (*Bathonian-Callovian*?), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), *Pygope* limestone (*Tithonian* *p.p.*), *Bositra* limestone (*Bathonian-Callovian*?), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*), *Pygope* limestone (*Tithonian* *p.p.*), nodular and ammonitiferous limestone (*Oxfordian-Kimmeridgian*).

Our recent field investigations have highlighted a great variability of facies, thickness and geometries of the
Jurassic sediments, while improved biostratigraphy produced tighter constraints for tracing time-correlation lines across the whole depositional system.

As a general remark, the Jurassic succession of the Sciacca area is characterized by the absence of thick basinal deposits and of typical deeper-water sediments like Middle-Upper Jurassic radiolarian cherts. Moreover, the recognition in the field of angular and non-angular unconformities, and of synsedimentary faults in the Inici Fm., strongly suggest the plateau was structurally composite.

At Contrada Diesi the Lower Jurassic carbonates are paraconformably overlain by the thinnest and most condensed (and cephalopod-rich) Bajocian-Bathonian to Tithonian succession, which suggests this represents a subenvironment closer to the plateau-edge (SANTANTONIO et alii, 1996), more subjected to winnowing and erosion. Elsewhere across the plateau, the lowest pelagic deposit above the Inici Fm. is a very thin (0-30 cm) discontinuous bed of crinoid-brachiopod-benthic foraminiferal wackestone whose age is still uncertain. A discontinuous centimetre to decimetre thick ammonite-rich polymetallic black crust (hardground), with latest Toarcian/Aalenian ammonites (DI STEFANO et alii, 2002b) then follows, locally capping the Inici Fm. directly. The minimum age of drowning of the Inici platform in the Sciacca area is therefore conservatively latest Early Jurassic, but could be somewhat older (Pliensbachian/early Toarcian?) depending on the age given to the crinoidal wackestone.

Sectors of the Inici platform were tilted during the Early Jurassic, as in the Contrada Monzealese area (DI STEFANO et alii, 2002b; see also Field Trip Guide B2), suggesting the presence of a south-dipping system of listric faults few km's south of the Quarry at Contrada Diesi. This seems consistent with the presence of deeper basins more to the south, in the present-day offshore of Sciacca (ANTONELLI et alii, 1991; CATALANO et alii, 1995b). Less important phases of extension also occurred during the rest of the Jurassic and are marked by neptunian dykes, filled either with Middle Jurassic thin-shelled bivalve and protoglaber-inid-rich mudstones, or with Late Jurassic Saccocoma mudstones.

Substop 8.1 – “Quarry at Contrada Diesi – Section I” (Early Jurassic-early Tithonian)


INTRODUCTION

The succession is wonderfully exposed in a very large quarry. One of the most striking features here is the perfect geometrical concordance at the paraconformity between the Inici Fm. and the overlying pelagic deposits. Neptunian dykes filled with pelagites are evident across the walls of the quarry, cross-cutting the shallow water carbonates.

The total thickness of the exposed Jurassic pelagic sediments in the area is about 18 m, and these have been examined for facies analysis and biostratigraphy. The lower portion was dated through ammonite stratigraphy, while calcareous nannofossil stratigraphy was used for the upper part. The studied sections provide a good opportunity to compare different kinds of biostratigraphic subdivisions (Ammonites, Calpionellids, and Calcareous Nannofossils), even if a real integrated biostratigraphy was impossible due to the lack of age-significant ammonites in the middle portion of the section and of well preserved nannofossils in its lower portion.
“Contrada Diesi I” section

Fig. 50 – Contrada Diesi quarry, Section I.
LITHOSTRATIGRAPHY AND MICROFACIES ANALYSIS

The local succession (Fig. 50) can be subdivided into six informal lithostratigraphic intervals, (top to bottom):

1) bioclastic platform limestone (Inici Fm.);
2) bioclastic limestone;
3) calcisiltitic limestone;
4) stromatolitic calcarenitic limestone;
5) pebbly calcarenite;
6) reddish-grey nodular marly limestone;

Bioclastic Platform Limestone (Inici Fm. - Lower Jurassic)

The uppermost part of the carbonate platform succession is made of thick bedded (~60 cm) bioclastic limestone, with peloids, intraformational lithoclasts, oncolites and algae. The microfauna is represented by *Siphovalvulina* sp., *Textularia* sp., *Litiosepta* sp., *Ammobaculites* sp., *Cayeuxia* sp., *Trocholina* sp., *Glomospira* sp., *Textulariids* and *Valvulinids*, with associated gastropods, bivalves and echinoderm fragments. The last metre of bioclastic limestone has fenestral lamination. The top of the carbonate platform is locally marked by a reddish surface and by a discontinuous, 1-2 cm thick black stromatolitic crust.

The highest beds of the Inici Fm. are cross cut by mono- and polyphase neptunian dykes of different age ranging from latest Early Jurassic (or lower Middle Jurassic) to the Late Jurassic. Most of them are filled by thin-shelled bivalve packstone to wackestone and their age cannot better be defined than as Middle Jurassic. Older dykes (latest Early Jurassic or lower Middle Jurassic) include a yellowish mudstone with echinoderm fragments and platform-derived clasts with abundant *Textulariids*, *Valvulinids*, Ostracods, *Siphovalvulina* sp. and *Thaumatoporella* cf. *parvesciculifera* (RAINERI). The youngest (Late Jurassic) consist of a microbreccia in a matrix made by reddish packstone containing echinoderms, bivalves and *Lamellapthychus* sp.; the clasts in the microbreccia are mudstones with radiolarians and sponge spicules and wackestones with thin-shelled bivalves, *Ophthalmiidae*, *Saccocoma* sp., protoglobigerinids, *Globochaete* sp. and *Spirillina* sp.

Only one dyke is evidently connected to a synsedimentary fault with a very modest throw (less than one metre), Middle Jurassic in age. It is filled with a breccia, whose matrix is a light brown packstone with thin-shelled bivalves and echinoderm fragments. Clasts are of shallow water limestone, of thin-shelled bivalve mudstones, and of mudstone, packstone and wackestone with peloids, intraclasts, *Globochaete* sp., *Stomiosphaera* sp., echinoderm fragments and foraminifers (rare protoglobigerinids, *Valvulinids* and *Nodosariids*).

As mentioned above, carbonate platform sediments are paraconformably overlain by pelagites through a sharp surface corresponding to a stratigraphic hiatus.

**Bositra limestone** (Bathonian-middle Oxfordian p.p.)

The pelagic succession starts with a 6.75 m thick massive ochre to reddish biogenic calcisiltite to calcarenite; it is generally a packstone, more rarely a wackestone, with abundant thin-shelled bivalves often chaotically arranged. Peloids and intraformational lithoclasts are also present. Ammonites were collected from the first centimetres up to 5.86 m from the base. They indicate the lower Bathonian (Zigzag Zone), upper Bathonian (Progracilis and Retrocostatum Zones), lower Callovian (Gracilis Zone), and middle Callovian (Coronatum Zone). The facies is essentially the same for 5 m from the contact with the platform deposits; sheet cracks sub-parallel to bedding occur locally. The most representative microfossils in this portion are foraminifers (rare small protoglobigerinids, *Textulariids*, *Valvulinids*, *Spirillina* etc.), *Stomiosphaera* sp., ostracods and rare radiolarians, while echinoderm fragments are common throughout. *Globochaete* is ubiquitous throughout the section.

Upwards a facies change is recorded due to the occurrence of ellipsoidal wackestone intraclasts, several centimetres across. The internal moulds of ammonites sometimes have a different texture with respect to the embedding sediment, suggesting *in situ* reworking. Thin-shelled bivalves are here rarer than in levels below, while the frequency of echinoderm fragments increases; finer-grained levels bear common *Globochaete* sp. and large *Protoglobigerina* specimens. At 6.30 m *Neocampylites delmontanus* (OPPEL) is the lowest record of an Oxfordian ammonite.

At 6.75 m a discontinuity surface is locally marked by a black LLH stromatolite. This physical discontinuity is a distinctive horizon that can be followed along the whole quarry front.

**"Calcisiltitic limestone"** (middle Oxfordian p.p.-upper Oxfordian)

Above the crust a level particularly rich in ammonites, all evenly oriented parallel to bedding, is a useful marker level. Many ammonites bear a stromatolitic cap, but some have domes on both sides, an indication of reexhumation and reellation. This level records the disappearance of thin-shelled bivalves, coincident with a bloom of protoglobigerinids.

The uppermost 2.05 m of this interval are made of a reddish calcisiltitic limestone, impregnated by ferruginous minerals. Upward the colour shades into light brown.

**"Stromatolitic" calcarenitic limestone** (Kimmeridgian-lower Tithonian p.p.)

This is about 3 m thick, massive, with stromatolites occurring both as isolated domes and as LLH continuous
structures. Weathering enhances cryptagal lamination, as well as randomly oriented skeletal remains like belemnites and echinoids. Ammonites are frequently capped by stromatolitic domes. These are also observed above small clasts and brachiopods. At 8.80 m Orthosphinctes cf. laufenensis (SIEMIRADZKI) marks the first occurrence of Kimmeridgian ammonites; 20 cm above, Benacoceras sp. occurs. From 9.00 to 9.90 m no significant ammonites have been recovered, while at 10.00 m Nebrodites cafisi (GEMMELLARO) still indicates the lower Kimmeridgian. The texture is a laminated packstone with abundant echinoderm fragments. Protoglobigerinids are less frequent in levels dominated by echinoids. At the top of the interval, coarse calcarenites (often grainstones) bear rounded intraclasts. Microfossils include Globochaete sp. (mostly in finer-grained levels), Spirillina sp., Stomiosphaera sp., Involutina sp., Lenticulina sp., Turrisspirillina sp., Ophthalmidiids, Lagenids, and protoglobigerinids. Echinoderm debris and Lamellapthychus fragments also occur. In the lower part of this unit (~at 9.75 m from the base) the first occurrence of Saccocoma sp. is recorded. At 11.30 m the FO of Conusphaera mexicana minor BOWN & COOPER marks the lower Tithonian. 

Pebbly calcarenite (lower Tithonian) 
Uphill the section continues for a thickness of nearly 2 m, with alternating conglomeratic and sand-sized crinoidal levels (also with belemnites, echinoid spines, and bivalves). Discontinuous stromatolitic levels are also present. The FO of Conusphaera mexicana mexicana TREJO and of Polycostella beckmannii THIERSTEIN are recorded at 12.40 m and at 12.70 m, respectively. These two forms indicate the lower Tithonian. The FO of Cadosina sp. is recorded at the top of this interval. 

Grey-reddish nodular marly limestone (lower Tithonian) 
This unit consists of about 4 m of grey-reddish nodular and marly limestone in thin beds. The nodular limestone is a packstone with crinoidal debris, internal moulds of ammonites and aptychi. Nodules are made of mudstone/wackestone, their contacts often being of stylolitic nature. Nodules were probably the product of in situ reworking by burrowers. The microfauna includes foraminifers, mainly Lenticulina and Spirillina, radiolarians, cadosinids and Saccocoma. The lithofacies change to marly limestone coincides with the FO of Hexalithus noeliae and Nannoconus compressus. Unfortunately, ammonites are only represented by long-ranging representatives of Phylloceratids and Lytoceratids. 

STROMATOLITE-CAPPED AMMONITES 
Ammonites capped by stromatolitic domes on both sides, randomly oriented or lying parallel to bedding, are frequent in this section between 6.7 m and 12 m from the base. Ammonites were transformed into subsphaeroidal objects through growth of a thick laminated envelope. They are relatively common within mud-dominated pelagic environments, and have been reported in several papers (STURANI, 1964, 1969, 1971; WENDT, 1970; JENKYNS, 1971; BERNOLLI & JENKYNS, 1974; MASSARI 1979, 1981, 1983; CLARI et alii, 1984; BALLARINI et alii, 1994) describing condensed successions from Tethyan Jurassic intrabasinal highs (pelagic carbonate platforms, sensu SANTANTONIO, 1994).

All the domes belong to the SH type (or rarely to the SS type), according to the classification of LOGAN et alii (1964). In most cases it is possible to exclude the SS type because only a minor percentage of specimens shows laminae enveloping the nucleus completely. Consequently, the final objects must have been produced by the growth of hemispheroids one at once on each side. Thin and polished sections show that ammonites were partially eroded before encrustation, suggesting early diagenesis and frequent reelaboration (Fig. 51).

Grey-reddish nodular marly limestone (lower Tithonian) 
This unit consists of about 4 m of grey-reddish nodular and marly limestone in thin beds. The nodular limestone is a packstone with crinoidal debris, internal moulds of ammonites and aptychi. Nodules are made of mudstone/wackestone, their contacts often being of stylolitic nature. Nodules were probably the product of in situ reworking by burrowers. The microfauna includes foraminifers, mainly Lenticulina and Spirillina, radiolarians, cadosinids and Saccocoma. The lithofacies change to marly limestone coincides with the FO of Hexalithus noeliae and Nannoconus compressus. Unfortunately, ammonites are only represented by long-ranging representatives of Phylloceratids and Lytoceratids. 

Substop 8.2 – “Quarry at Contrada Diesi – Section II” (late Kimmeridgian-early Valanginian) 


INTRODUCTION 
This substop serves to observe the uppermost part of the Jurassic limestone and the marly-nodular deposits around
Fig. 52 - Contrada Diesi quarry, Section II.
around the Jurassic/Cretaceous boundary. This succession differs slightly from that exposed in section 1 because the stromatolitic interval is here replaced by a calcarenitic/calcisilitic level. In both sections the change from dominant limestone to marly nodular limestone is placed in the upper part of the lower Tithonian.

A 26 m thick section is well exposed above this lithologic boundary, containing the Jurassic/Cretaceous boundary within the "Calcari a Calpionelle" unit (Fig. 52).

LITHOSTRATIGRAPHY AND MICROFACIES ANALYSIS

The section can be subdivided into three informal lithostratigraphical units:

3) "Calcari a Calpionelle" (top);  
2) marly limestone;  
1) calcarenitic/calcisilitic limestone (bottom).

Calcarenitic/calcisilitic limestone (upper Kimmeridgian-lower Tithonian p.p.)

The base of the section is represented by a light brown calcarenitic/calcisilitic limestone, ~6 m thick, bearing Pseudowaagenia haynaldi, Taramelliceras gr. compsum and Aspidoceras gr. acanthicum (early late Kimmeridgian). In thin section this unit is a wackestone with Saccocoma sp., radiolarians, echinoderm fragments, gastropods and protogloboiognerids. In the first metres Saccocoma increases, while protogloboiognerids decrease. The FO of Nannoconus and Conusphaera mexicana mexicana occurs at 3.5 m.

Marly limestone (lower Tithonian p.p.-upper Tithonian p.p.)

About 2 m of grey-yellowish nodular marly limestone with thin cherty interbeds. The dominant texture is a wackestone with Saccocoma sp., radiolarians and echinoderm fragments. At 6.30 m Saccocoma sp. decreases while Cadosinids increase. The FO of Nannoconus compressus occurs at 6.15 m. Upsection the nodular limestone, in 5-10 cm thick beds, is replaced by white well bedded limestone. At 8.15 m Corongoceras sp. indicates the base of the upper Tithonian.

"Calcari a Calpionelle" (upper Tithonian p.p.—upper Valanginian)

This unit crops out for about 18 m in the section. In the upper part of the section thin clayey levels and marly limestone alternate, a typical feature of the "Calcari a Calpionelle". It is a calpionellid wackestone with rare echinoderm fragments, radiolarians and rare foraminifers (Textulariids, Valvulinids). The first occurrence of calpionellids (Crassicollaria intermedia, Calpionella alpina) at 8.50 m indicates the upper Tithonian (Crassicollaria Zone) according to GRUN & BLAU, 1997. Saccocoma sp. disappears in the uppermost part of the upper Tithonian.

At 9.50 m from the base, the FO of Remaniella duranddelgai (base of the Calpionella Zone) marks the Jurassic/Cretaceous boundary. The calpionellid assemblage with C. intermedia, C. brevis, C. masmutiniana and C. alpina, remains unchanged until 15.00 m. At 14.50 m "Corongoceras" sp. occurs and, from 14.50 to 15.50 m, a rich calcareous nanofossil assemblage (abundant N. steinmanni steinmanni, C. cuvillieri, W. barnesae, C. margerelli, C. wiedmannii, very rare C. mexicana mexicana and Z. cooperii) indicates the early Berriasian. Other Cretaceous biozones indicate the latest Berriasian (Calpionellopsis Zone, uppermost part, 15.5 m from the base) and the early Valanginian (Calpionellites Zone, lowermost part, 16.50 m). At 23.50 m Tirnovella alpillensis also indicates the lowermost Valanginian. Toward the top of the section, at 25 and 25.25 m belemnites (Duvalia lata) occur and, at the very end of the section (25 m) common specimens of Olcostephanus spp. suggest an upper Valanginian age.

Calpionellid biostratigraphy indicates that the base of the upper Tithonian is not recorded. Moreover, the reduced thickness of the Berriasian, the lack of most of the Calpionella and Calpionellopsis Subzones and of the whole middle Berriasian suggest that very low sedimentation rates often turned into erosion.

For more detail on Sections 1 and 2 of Cava Diesi, see Excursion B2 in this Guidebook.

STOP 9 – MONTE GENUARDO:
EARLY TO MIDDLE JURASSIC
EVOLUTION OF A PERIBASINAL SECTOR OF THE SICANIAN DOMAIN – AN INTRODUCTION

R. BUCEFALO PALLIANI, A. BARTOLINI, P. CENSI,  
M. CHIARI, P. DI STEFANO, P. FERLA,  
M. GULLO, G. MALLARINO, E. MATTIOLI,  
C. MELI, G. PARISI & S. SPEZIALE

The Monte Genuardo succession is peculiar in western Sicily as it records the early drowning of a Late Triassic carbonate platform margin, and its conversion to a slope-to-peribasinal area connected to the Sicanian Basin, as a response to extensional tectonics round the Rhaetian-Hettangian boundary (DI STEFANO & GULLO, 1987). Moreover a thick basaltic layer occurs within the Jurassic succession, offering a good example of the widespread Jurassic magmatism of western Sicily. The aim of this stop is to show i) a large-scale natural section of the platform-escarpment transition along the eastern slope of the mountain (Substop 9a), ii) a well studied
section of Pliensbachian cherty calcilutites (Substop 9b), and iii) the basaltic volcanics (Substop 9c).

Monte Genuardo, near Sciacca, represents one of the tectonic units which are embricated in the external zone of the western Sicily Chain (Figs. 53, 54). The sedimentary sequence consists of a thick (~1500 m) Upper Triassic to Neogene succession of carbonates and siliciclastics (Masche, 1979; Di Stefano & Gullo, 1987).

At the base of the sequence, a thick interval of platform dolostones of Late Triassic age is exposed. They are overlain through an angular unconformity by Jurassic-Lower Cretaceous slope to basinal deposits, consisting of reworked oolitic calcarenites, crinoidal limestones, radiolarian cherty limestones with thick basalt layers, radiolarites, siliceous limestones and marls, calpionellid limestones and Aptychus marls. Upper Cretaceous-Eocene megabreccia-bearing Scaglia and Oligocene-Miocene marls and calcarenites follow. They are covered by terrigenous molasse type deposits, gypsum, marls and gypsarenites of late Tortonian-Messinian age. Upwards the succession is capped by

Globigerina marls (Trubi) and clays and calcarenites of Pliocene and Pleistocene ages (Fig. 55).

The Monte Genuardo unit crops out as a polyphasically deformed, south-verging ramp-anticline (Fig. 54). The southern limb, overturned in places, is displaced by minor thrusts and overthrust Miocene and Lower Pliocene covers of the Pizzo Telegrafo unit, a more external structural unit belonging to the Saccense Domain (Catalano et alii, 1978; Di Stefano & Vitale, 1993, 1994).

Based on its Mesozoic stratigraphy and on its relationships with the adjacent structural units, the Monte Genuardo unit has been considered as a part of the northern margin of the wide Triassic platform domain of the Sciacca area (Saccense Domain), adjacent to the Sicanian Basin (Di Stefano & Gullo, 1987). The Lower Jurassic succession has been interpreted as the filling of an intraplatform basin dissecting this margin and merging laterally with the Sicanian Basin (Di Stefano & Gullo, 1987).

Substop 9.1 - Eastern cliffs of Monte Genuardo: Early Liassic conversion of a carbonate platform margin to a slope-peribasinal area

P. Di Stefano, M. Gullo & G. Mallarino

A natural cross-section of the Upper Triassic-Lower Jurassic succession is exposed along a north-south oriented fault escarpment, bounding the eastern sector of Monte Genuardo (Fig. 56). The main features observed here are:

1) The angular unconformity between the Upper Triassic platform strata and the overlying Liassic deposits.

2) The large-scale stratal patterns of the oolitic limestones above the unconformity, interpreted as a carbonate apron fed by off-platform oolitic-skeletal shedding.

3) The upward transition of the clastic wedge to radiolarian cherty limestones (Calcare di S. Maria del Bosco), indicating the shut down of the oolitic supply in the Carixian due to drowning of the adjacent platform.
The lower part of the section consists of thick-bedded, peritidal dolostones of Late Triassic age (Sciacca Fm.). Although facies recognition in these deposits is hampered by dolomitization, stromatolitic and fenestral dolostones cyclically alternating with thick beds with mollusc moulds are locally still visible. Westwards, the peritidal facies is replaced by reef dolostones, whose thickness in outcrop ranges from a few tens of metres up to 200 m. Even though the facies change between the reef and lagoonal-tidal deposits is obscured by tectonics, a retrogradation of the reef dolostones on the peritidal levels may be inferred. The dominant facies in the reef dolostones is a sponge boundstone and skeletal rudstone, as described by Di Stefano et alii (1990). Calcareous sponges such as Peronidella sp., Cystotalamia sp., Follicatena irregularis, Cryptocoelia sp., Panormida sp., Cheilosporites tirolensis, associated with chaetetids and rare corals occur as primary framebuilding organisms. Encrusting sponges, hydrozoans and spongiosstromata crusts are also frequent. The filling of the intrabiolithitic cavities consists of peloidal pack/grainstones with foraminifers like Galeanella panticae, and Altinerina meridionalis. The sponge boundstones are interpreted as central reef area deposits, while the rudstones represent the reef detritus characterizing the reef flank and fore-reef zones. The microfacies recognized correspond in general to those of the Late Triassic reef complexes of the Alpine-Mediterranean region (Flügel, 1981), and show striking sedimentological and palaeontological similarities with those of the coeval reef complexes of the Panormide carbonate platform (Abate et alii, 1977; Senowbari-Daryan et alii, 1982; Di Stefano et alii, 1990). The presence of reef deposits confirms the palaeogeographical location of the Monte Genuardo unit in a marginal sector of the Triassic platform.

The platform strata are truncated at an angle of about 10° by a deep and irregular erosional surface. Along the surface small dissolution cavities are filled by reddish silt and could be related to subaerial exposure.

Upwards, a succession up to 100 m thick of Lower Liassic resedimented oolitic calcarenites with thin radiolarian cherty calcilutite interbeds follows (Fig. 56). This unit, named the Calcari oolitici di Monte Genuardo (COMG) by Di Stefano & Vitale (1993), consists of grainstones with partly micritized ooids, botryoidal lumps and grapestones along with an abundant skeletal fraction consisting of foraminifers (textularids, lituolids, valvulinids and miliolids), brachiopods, molluscs and echinoderms (Fig. 57). Calcareous algae such as Thaumatoporella parvovesiculifera, “Cayeuxia” spp. and dasycladalean fragments are also common. Bed thickness ranges from 3 up to 40 cm and normal grading and parallel lamination are common. The calcitutite interbeds, up to 3 cm thick, are mudstone/wackestone with radiolarians, sponge spicules, foraminifers (Lenticulina sp., Spirillina sp.) and rare crinoid ossicles. “Chips” of radiolarian wackestone are frequently concentrated at the base of the calcarenite beds (Fig. 57). In places coarse debrite beds containing Upper Triassic, reef-derived extraclasts occur. Large scale offlap geometries and the orientation of some channel-filling calcarenite beds in the lower zone indicate a roughly northeastward progradation of the COMG. The presence of Paleoasycladus sp. (mentioned by Mascle, 1979) supports a Lower Liassic (Sinemurian) age for the COMG, not excluding a possible Hettangian age for the lowermost beds. According to Di Stefano & Gullo (1987) the facies
associations are typical of slope apron settings (Mullins & Cook, 1986; Colacicchi & Baldanza, 1986). The oolitic-skeletal shedding implies the presence of an adjacent, healthy carbonate platform (e.g. Inici Formation). The off-platform transport of loose carbonate mud and sand originated at a carbonate platform edge was triggered most probably by currents initiated by storms, giving rise to alternations of sand sheets and periplatform ooze. Several recent and ancient examples suggest the progradation of carbonate platforms is related to an excess of carbonate production during sea-level highstands (Schlager & Chermak, 1979; Bosellini, 1989). No direct relationships with the inferred productive carbonate platform are observable at Monte Genuardo, but examples of large-scale progradation of Liassic carbonate platforms are well known from the subsurface of the Hyblean plateau in eastern Sicily (Antonelli et alii, 1991).

Towards the top this unit grades into radiolarian cherty calcilutites known as the Calcari di Santa Maria del Bosco (CSMB, Substop 9.2).

Substop 9.2 - Santa Maria del Bosco: Integrated biostratigraphy (calcareous nannofossils, palynology and radiolarians) from an Early-Middle Jurassic peribasinal area in the Sicanian Basin

R. Bucefalo Palliani, A. Bartolini, M. Chiari, P. Di Stefano, E. Mattioli & G. Parisi

Introduction
The focus of this substop will be on the Calcari di Santa Maria del Bosco (CSMB). Three small sections (S, S1 and S2) were studied along a road on the northern side of Monte Genuardo.
of Monte Genuardo, in order to define facies and biochronology of this unit. In particular the S1 section outcropping close to the old abbey of Santa Maria del Bosco will be examined. The abbey was severely damaged by the earthquake of 1968 (Fig. 58).

Preliminary biostratigraphic results from the overlying Radiolarite unit (Casa Gurgo section) will also be illustrated. A thick basaltic unit (pillow lavas) is intercalated between the CSMB and the radiolarites (see Substop 9.3).

LITHOSTRATIGRAPHY AND MICROFACIES
Calcari di Santa Maria del Bosco (CSMB) (Figs. 59, 60 and 61)

Lithology consists of white-pale brown well bedded limestones with chert in nodules and ribbons. Calcarenitic levels occur mainly in the lower part of the sections, followed by marly levels. These calcarenites show low angle cross lamination and are mainly constituted by echinoid fragments.

The lithofacies is a radiolarian wackestone with sponge spicules, foraminifers and echinoid fragments. The marls bear a well preserved foraminiferal assemblage characterised by Paralingulina gr. tenera, Marginulina prima, Berthelinella sp., Brizalina sp. and Falsopalmula sp. Benthic foraminiferal assemblages belong to the A, B, and BC types established by NOCCHI (1992). The A assemblage is characterised by Miliolina, Involutinina and Lagenina, sponge spicules, crinoid articles and echinoid fragments. It is difficult to establish if the foraminifers of this assemblage are autochthonous or allochthonous because some reworking from surrounding structural highs must conservatively be admitted. The B assemblage is characterised by Lagenina and Textularina, radiolarians, echinoid fragments, sponge spicules and large ostracods. The A and B assemblages are tipically found in Carixian-lower Domerian sediments in the Umbria-Marche area (NOCCHI, 1992). The BC

Fig. 58 - Geological map of the Santa Maria del Bosco area and location of the studied sections.

Fig. 59 - Lower (a) and middle (b) part of the S1 section.
### Monti Genuardo

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**Fig. 60 - Lithobiostratigraphic scheme of the Monte Genuardo studied sections.**

The assemblage is characterised by agglutinant siliceous foraminifers (*Glomospirella*), calcareous-hyaline foraminifers (sculptured *Lagenina* and *Lenticulina*) and ostracods. This assemblage is common in the upper Domerian-lowermost Toarcian of the Umbria-Marche Basin (Nocchi & Bartolini, 1994), and a similar (epifaunal) life-strategy is inferred both for agglutinated and calcareous-hyaline foraminifers. Several species are ubiquitous in the Mediterranean region and in the Liassic European epicontinental platform (Nini et alii, 1997; Nocchi et alii, 1999). The BC assemblage is indicative of a more distal and deeper environment with respect to the A and B assemblages.

The litho-biofacies of CSMB are comparable to the Corniola Fm. of the Umbria Marche Basin (Colacicchi et alii, 1999; Mattioli et alii, in press).

**Biostatigraphy**

*Calcereous nannofossils*

Samples were prepared by simple mechanical fragmentation of a small volume of rock, dilution with water, spreading onto a cover glass and drying in a stove. Cover glasses were attached to slides with Rhodopass. Smear slides were prepared as homogeneously as possible, so that nannofossil abundance in different slides be comparable. Observations were done under a light polarising microscope, at 1250X magnification. Nannofossils, both coccoliths and the *incertae sedis* Schizosphaera spp., were counted in each slide in a variable number (200 to 400) of views. The surface of one field of view is $2.01 \times 10^{-2}$ mm$^2$. Total and relative abundance recorded in each sample were then divided by the number of views examined; the abundance per field of view is reported in the Fig. 62. As a product of this semiquantitative analysis, 4 classes of abundance were established (Fig. 62).

Preservation of nannofossils was evaluated on the basis of the overgrowth/dissolution effects, according to Roth (1984). Despite the variable degree of preservation, nannofossils were identifiable in all the studied samples, and three classes of preservation were established:

- good - no or only light overgrowth and/or dissolution;
- moderate - a light dissolution of delicate forms and/or loss of the delicate central area structures;
- poor - some coccoliths were severely affected by dissolution, some other coccoliths and *Schizosphaera* spp. are overgrown, but specific determination is still possible.

Eighteen samples were studied in the Monte Genuardo (S1) section, which was continuously sampled at regular intervals.
In the Monte Genuardo S1 section, the assemblage is quite rich and diversified in all the studied samples, preservation is generally moderate to good and only a few samples have a poor preservation. *Schizosphaerella* spp. varies from common to abundant, as commonly recorded in other Tethyan areas. Different species of the genus *Mitroolithus* (namely *M. jansae*, *M. lenticularis* and *M. elegans*) and of the genus *Similiscutum* (*S. orbiculus* and *S. cruciulus*) are frequent to common in the majority of the samples. This is a typical Tethyan assemblage (BOWN, 1987), so we shall make reference to the biochronological scheme of MATTIOLI & ERBA (1999) for comparisons.

Different calcareous nanofossil events were
Fig. 62 - Distribution chart of the nannofossil taxa recorded in the S1 section. Age attribution is based on calcareous nannofossil assemblages and events. Nannofossil zones are based on Mattioli & Erba (1999).

<table>
<thead>
<tr>
<th>Nannofossil Zones (Mattioli &amp; Erba, 1999)</th>
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<tbody>
<tr>
<td>Nannofossil Subzones</td>
</tr>
<tr>
<td>S. cruciulus</td>
</tr>
<tr>
<td>NJT 4</td>
</tr>
<tr>
<td>NJT 4b</td>
</tr>
<tr>
<td>NJT 5a B. finchii</td>
</tr>
<tr>
<td>NJT 5b L. sigillatus</td>
</tr>
<tr>
<td>NJT 5 L. hauffii</td>
</tr>
</tbody>
</table>

- rare: 1 to 10 nannofossils in 200 fields of view
- frequent: 11 to 25 nannofossils in 200 fields of view
- abundant: 26 to 50 nannofossils in 200 fields of view
- common: 51 to 200 nannofossils in 200 fields of view

- Schizosphaerella spp.
- Crucirhabdus primulus
- Parhabrotholithus liasicus
- Tubirhabdus patulus
- Crepidolithus crassus
- Mitrolithus jansae
- Mitrolithus lenticularis
- Mitrolithus elegans
- Similiscutum cruciulus
- Similiscutum orbiculus
- Similiscutum precarium
- Mazaganella pulla
- Mazaganella protensa
- Biscutum grande
- Biscutum finchii
- Biscutum dubium
- Biscutum novum
- Crepidolithus granulatus
- Crepidolithus cavus
- Lotharingius hauffii
- Lotharingius froroi
- Lotharingius barozii
- Ductiuic constans
- Bussonius prinsii
- Lotharingius sigillatus
recorded in the S1 section, mainly first occurrences (FOs). At the base of the section the probable FO of *Biscutum finchii* (1.3 m) is followed by the FO of *Lotharingius hauffii* (2.25 m). According to Mattioli & Erba (1999), these two events characterise the base of the upper Domerian, and the FO of *L. hauffii* can be used to trace the base of the Tethyan nannofossil Zone NJT 5 (NJT 5a Subzone). Within this subzone, different nannofossil events were recorded, all known to occur in the upper Domerian (De Kaenel et alii, 1996; Bown & Cooper, 1998; Mattioli & Erba, 1999): namely the FO of *Lotharingius barozii*, *Lotharingius frodoi*, *Crepidolithus cavus* and *Diductius constans* (6.8 m) and the FO of *Bussonius prinsii* (11.4 m). In sample 14.9 m, the FO of *Lotharingius sigillatus* is recorded. This event, which marks the base of the nannofossil Subzone NJT 5b, characterises the uppermost Domerian or the lowermost Toarcian. We can therefore use this FO to place the Domerian/Toarcian boundary in the Monte Genuardo S1 section (Fig. 62).

In the S. Maria del Bosco area, another section, and isolated samples (namely S2 and SV1) prevalently near the basalts were analyzed (Fig. 63).

Sample S 4.60 m, because of the presence in the assemblage of *Similiscutum* (*S. orbiculus* and *S. cruciulus*) which appears at the very base of the Carixian, and of *Crepidolithus pliensbachensis*, which disappears in the middle Carixian, is indicative of an early to middle Carixian age, NJT 4a nannofossil Zone (Mattioli & Erba, 1999).

The assemblage in sample S 6.30 m contains *Lotharingius hauffii*, which first occurs in the upper Domerian.

This sample is therefore referred to the nannofossil Zone NJT 5a, upper Domerian.

The sample S 7.20 m, besides the different species already recorded in the previous sample, also bears *L. sigillatus* and *Calyculus* spp. Both these species usually appear in the Tethyan domain either in the uppermost Domerian or at the very base of the Toarcian. This nannofossil assemblage is characteristic of the NJT 5b nannofossil Subzone (Mattioli & Erba, 1999).

The two samples S2 bear a nannofossil assemblage characterised by the presence of *B. finchii* and *L. hauffii*, and that seems to correspond to the NJT 5a nannofossil Subzone, upper Domerian (Mattioli & Erba, 1999) (Fig. 63).

The sample collected within the volcanic episode (SV1) contains a poor nannofossil assemblage, in which however *L. and M. jansae* have been recorded. The age of this sample is therefore comprised between the FO of *L. hauffii* (upper Domerian) and the last occurrence of *M. jansae* (lower Toarcian, Fig. 63).

**Fig. 63** - Distribution chart of the nannofossil taxa in the S, S2 e SV1 sections. Age attribution is based on calcareous nannofossil assemblages and events. Nannofossil zones are based on Mattioli & Erba (1999).

**Dinoflagellate cysts**

Three samples have been processed for palynological study (S1 1.30, S1 2.25, S1 5.80); in order to illustrate the organic-walled microfossil assemblages and palynofacies composition of the base of the succession. The palynological slides have been obtained by the standard procedure involving mineral acid treatment, oxidative maceration and sieving using 10-µm mesh (Wood et alii, 1996).

A peculiar palynofacies has been recorded in sample S1 1.30, almost entirely composed of abundant fungal remains (90%) (Fig. 64) and algal spores with subordinate palynomerals, inertinite, cuticle and dinoflagellate cysts. The dinoflagellate cysts, *Mendicodium* sp. and *Umbridiinium* cf. *mediterraneense*, first occur in the Tethyan Realm during the early Pliensbachian.

This organic composition can be referred to as “fungal spike” (sensu Eshet et alii, 1995). The fungal remains exhibit wide morphological variety, and the assemblage comprises *Spinotremesporites* sp., *Striadosporites* sp., *Clenosporites* sp., *Parmathyrites* sp.,
Dictyosporites sp., Callimothalassa pertusus and numerous chains of fungal cells (Fig. 64).

A similar event characterised by a marked increase in fungal remains has been documented in several localities of the Mediterranean area during the late Pliensbachian, sometimes ranging up to the transition to the early Toarcian (BUCEFALO PALLIANI & CIRILLI, 1993; BUCEFALO PALLIANI et alii, 1998). This event can be tentatively considered as a stratigraphical signal, probably linked to the lower Jurassic trasgression which, in specific paleoenvironments, produced an increase of organic resources for saprotrophs, favouring fungi proliferation (BUCEFALO PALLIANI & CIRILLI, 1993).

The organic facies from samples S1 2.25 and S1 5.80 are mainly composed by inertinite and hyphae of fungi.

Radiolarians

In the section S near the basalts several samples of chert were collected, but all the examined samples are barren. Also in section S1, the collected samples are barren or yield badly preserved radiolarians. Only one sample, 00SB, yielded radiolarians (Sethocapsa sp., Triactoma sp., Pantanellium sp.), but they are not significant biostratigraphically.

CASA GURGO (RADIOLARITES UNIT)

This section, badly exposed and folded, consists of about 15 m of greenish siliceous limestones alternating with marls and bedded cherts.

The calcareous nannofossil content is very poor - only one sample (R3bis) is productive. Because of the presence of Watznaueria barnesae, that first occurs at the
base of the Bathonian, and of common Discorhabdus, whose last common occurrence is recorded in the Bathonian of the Umbria-Marche area, sample 3bis can be dated as Bathonian. This datum is in agreement with the age provided by radiolarians.

Eight samples were collected for radiolarian analysis. All the examined samples yield well preserved radiolarian assemblages. The ages of the dated samples are the following: Sample 4065 latest Bajocian-early Bathonian (UAZ. 5) for the occurrence of Stichocapsa robusta MATSUOKA and Unuma latusicostatus (AITA); sample 4066 early Bajocian-early Oxfordian (UAZ. 3-8) for the presence of Acaeniotylopsis variatus variatus (OZVOLDOVA); sample 4067 early Bajocian-early Callovian (UAZ. 3-7) for the occurrence of Acaeniotylopsis variatus variatus (OZVOLDOVA) and Linaresia beniderkoulensis EL KADIRI; sample 4070 early Bajocian-early Bathonian (UAZ. 3-5) for the occurrence of Higumastra gratiosa BAUMGARTNER and Unuma latusicostatus (AITA) (BAUMGARTNER, 1995).

RESULTS

Lithofacies analysis and biostratigraphic data in the Calcari di Santa Maria del Bosco Unit allow to differentiate a lower part, Carixian in age, that is characterised by reworked intra-basinal skeletal material, mostly consisting of crinoidal sands; in this part neither ooids nor platform-derived skeletal grains are found. These, by contrast, dominate in the underlying unit (COMG). This variation in carbonate supply indicates a termination of the adjacent carbonate platform in late Sinemurian or earliest Carixian times.

In the upper zone of the CSMB (Domerian-lower Toarcian) the lithofacies types testify a normal pelagic deposition with low sedimentation rates and authoconthous faunas.

Age and sedimentary evolution of the CSMB are well comparable to other Middle Liassic deep-water deposits from Sicily such as the Modica Formation (Hyblean plateau and southeastern Sicily offshore) (RONCHI et alii, 2000) or the equivalent limestones known from the Marineo Basin (see Stops 13-14, this volume). These deposits are also comparable with the Corniola Fm. of the Umbria-Marche Basin. Recent data from this latter area suggest that this variation coincides with a maximum flooding coupled to a probable eutrophication and a temperature decrease below the tolerance threshold of benthic organisms inhabiting the carbonate platforms (PARISI et alii, 2001; MATTIOLI et alii, in press; MORETTINI et alii, in press).

On the top of the Calcari di Santa Maria del Bosco, the thick unit of basaltic pillow lavas and hialoclastites records a magmatic event that predates the onset of biosiliceous sedimentation (siliceous limestones and radiolartes) in this sector. Biostratigraphic data from the lower zone of the radiolaritic unit indicate an early Bathonian, or possibly even Bajocian age. The magmatic event is thus constrained between the middle Toarcian and the Bajocian. However, due to the magmatic event itself, part of the underlying succession could have not been locally preserved.

Substop 9.3 - Pillow lava at Monte Genuardo, and the Jurassic magmatism in western Sicily

P. Ferla, P. Censi, C. Meli & S. Speziale

INTRODUCTION

Western Sicily has a wealth of basaltic rocks (FABIANI, 1926; TREVISAN, 1937; SCHERILLO, 1935; FLORIDIA 1954; VIANELLI, 1964, 1968) whose origin is related to the extensional geodynamic system affecting this portion of the African continental margin throughout the Mesozoic (LUCIDO et alii, 1978; MASCLE, 1979; BELLIA et alii, 1981; CATALANO et alii, 1984; SPEZIALE, 1997). These rocks crop out within the various tectonic units of the Maghrebide Chain along the Madonie and Sicani Mts., and in the Palermo and Trapani areas (Fig. 65).

Distinctive for the Jurassic Period, these extrusive igneous synsedimentary events show evidence of intense magmatic activity within the deep-basin area throughout an interval spanning the Middle to the Late Jurassic, during deposition of the “Rosso Ammonitico” formation.

In the relatively more stable area of the carbonate shelf, as in the Jurassic Panormide Domain, the only evidence of this magmatic activity is the addition of volcanic ash to the karst-bauxites developed above emergent areas (Mt. Gallo Bauxites) (Fig. 66).
At least fifteen of the most representative outcrops of extrusive igneous rocks in different tectonic units, over a wide area, show striking similarities in chemical composition, settling, post-magmatic alteration and petrological affinity (origin).

**GEOLOGICAL SETTING**

The majority of the outcrops are basically pillow-lavas bodies (Fig. 67), locally thickened to several hundred metres to resemble volcanic sea-mounts, such as the exposures near Giuliana, or Mt. Genuardo near Contessa Entellina (Fig. 68). These pillowed masses are commonly associated with dykes probably corresponding to original pipes, and intercalations or lateral changes into tephra to hyaloclastitic sequences.

**ALTERATION**

In these rocks chemical alteration (Vianelli, 1964, 1968; Speziale, 1997) is quite common owing to the extensive interaction between lavas and seawater: the common petrographic term “palagonitization”, meaning hydrothermal alteration under marine conditions, is etymologically derived from the toponym “Palagonia”, a locality in the Pliocene Hyblean Mts. Chemical transformations of the outer glassy rims of the pillows lead to modifications in the bulk rock chemistry and result in the crystallization of newly formed alteration minerals or pseudomorphs after original phenocrysts.

The alteration paragenesis basically accounts for a hydrothermal event and shows mineralogical differences due to the physico-chemical changes of the fluid.

High-temperature alteration minerals are basically Mg-Fe2+-Al-chlorite (diabantite), formed at nearly 250 °C in association with newly formed albite while, at lower temperatures, mixed layers with expanding minerals are common. The latter are mostly Fe-Mg-smectites, ranging in composition from saponite (Fe2+, Mg) to nontronite (Fe3+), or vermiculites, at times interlayered with an illitic component.

These basic rocks therefore show a remarkable secondary enrichment in K, as evidenced by its marked positive anomaly in the incompatible elements pattern.

Nevertheless this geochemical trend is not homogeneously distributed among the exposures, nor even within the very same outcrop (Mt. Genuardo): less altered or dyke rocks, although containing traces of biotite and anorthoclase, show relatively negative K-anomaly when compared to Primordial Mantle.

In the Mt. Genuardo, Giuliana and Mt. Bonifato (Alcamo) basalts it is possible to discover among the pillows rimmed crystallizations of quartz, calcite and ground blue-green matter almost completely composed of pure Fe-Mg-illite known as Celadonite. Zeolites of various kinds, depending on the temperature reached, down to the low temperature Na-K end-member phillipsite, are also reported.

These rocks commonly reveal an extensive process of carbonation with pure calcite pseudomorphs after original phenocrysts, or as filling amygdales within the original vesicular lava, together with small dykes and veins.

Textural observations and isotopic data lead to the well founded idea that some carbonate amygdales within the less vesicular lavas or doleritic rocks be fragments of carbonate rocks molten under deep conditions and...
unmixed with the basaltic magma (LUCIDO et alii, 1980). Furthermore the isotopic data also indicate the presence of hydrothermal carbonates coming from seawater-rock interactions (SPEZIALE, 1997). This hypothesis is confirmed by incompatible trace element trends that testify a “basaltic” imprinting for calcite crystallization whose Ca⁺ is supplied by the original volcanic rocks (in press).

Petrography

These volcanic occurrences are mostly basaltic rocks showing porphyritic texture with phenocrysts set in a matrix varying from glassy, hyalopilitic, intersertal, to sub-ophitic, depending on the part of a pillow considered, and changing into ophitic in the dyke-shaped bodies.

Mineral compositions were obtained by electron microprobe analyses. Observed equilibrium phenocrysts are basically olivine (Fo₉₃), plagioclase (An₆₃), augitic clinopyroxene with Ti-rich rims, Fe–Ti oxide and apatite, according to the order of crystallization inferred by geothermometric determinations (SPEZIALE, 1997). Clinopyroxenes mainly show typical compositions of slightly alkaline magmas (Ti vs Ca+Na a.f.u.) while weakly sub-alkaline end-members are rarely detected. Sub-calcic pyroxenes are typically absent while some more differentiated rocks towards trachy-basalts bear zoned phenocrysts, andesinic plagioclase in groundmass (An₄₂–₃₇) and traces of biotite and anorthoclase (Mt. Bonifato, Segesta).

Geochemistry

Chemical composition (XRF for major elements and ICP-MS for trace elements) is strongly affected by the extensive alteration process. Nevertheless, applying fitting petrochemical calculations in order to minimize the effect of alteration chemical input, it is possible to infer an original basaltic nature for these rocks. These results are also confirmed by the array of immobile during-alteration trace elements.

The Light Rare Earth Elements pattern (LREE) does not show remarkable variations among fresh and altered rocks, indicating an overall conservative process for these elements.

The basaltic magmatism can also be distinguished using the well-known Zr/Ti vs. Nb/Y diagram where almost primitive basalts (less altered rocks with very low K₂O, H₂O and CO₂, can display mg#=Mg/(Mg+Fe²⁺) ≈0.70) can be recognized. The latter also show Nb/Y ratio ranging from 0.6 to 1.2 (Fig. 69).

Less altered rocks show normalized REE pattern (Fig. 70) with enrichment and linear array compared to

---

**Fig. 68** - Schematic geological map of the Monte Genuardo (Contessa Entellina) showing basaltic outcrops (black) (Middle Jurassic) (after DI STEFANO & GULLO, 1986).

**Fig. 69** - Zr/TiO₂ vs Nb/Y diagram (after WINCHESTER & FLOYD, 1977) for various representative Jurassic volcanic rocks; closed squares: alkali basalt; open squares: sub-alkalic basalt; triangle: Mt. Genuardo.

**Fig. 70** - Chondrite C₁-normalized REE pattern (after MCDONOUGH & SUN, 1995) for Jurassic volcanic rocks from western Sicily.
Chondrite-C1, (La)\textsubscript{N}=60-120, pointing to LREE increase compared to HREE (Ce/Yb)\textsubscript{N}=5-9, all typical characters of slightly alkaline transitional magma (the rare case of slightly sub-alkaline transitional magma is not considered here).

The Ce negative anomaly detected at times can be related to rock-seawater interaction. Some more differentiated samples have the same REE enrichment pattern and a slight positive Eu anomaly (e.g. Vicari, Censi et alii, 2000).

All analyzed volcanic rocks fall within the Within Plate Basalts field (OIB) according to Th/Zr vs Nb/Zr diagram (Fig. 71).

Incompatible elements patterns lie very close to the OIB (HIMU-EMII), while samples with sub-alkaline trend (Scillato and Roccapalumba) fall between OIB and E-MORB (Fig. 72). The OIB attribution was confirmed by several incompatible element ratio analyses (according to Weaver, 1991; Allègre et alii, 1995).

These features indicate magma derivation from limited melting of a peridotitic enriched mantle (Speziale, 1997) similar to the Hyblean Mantle (Rocchi et alii, 1998) although related to slightly greater partial melting processes.

**CONCLUSIONS**

The western Sicily Jurassic magmatism is typical of continental “within-plate” areas subjected to extension and lithospheric thinning. This was related to a rift phase that affected the marginal parts of the African continent in the Jurassic, producing alkali basalts, coming from an enriched mantle (OIB-HIMU) (Rocchi et alii, 1998), [Nb/Y=1.1-3.0; (Ce/Yb)\textsubscript{N}= 8-13] in the outer and more stable portions of the Hyblean Mts.

In western Sicily transitional alkali-basalts [Nb/Y=0.6-1.3; (Ce/Yb)\textsubscript{N}= 6-9] occur followed by transitional tholeiitic flows corresponding to a progressive involvement of more depleted and superficial upper mantle portions.

**STOP 10 - ROCCA ARGENTERIA:**

**A COMPLEX NETWORK OF JURASSIC TO MIOCENE NEPTUNIAN DYKES**

L. Martire & D. Montagnino

Rocca Argenteria is located at the western end of the Rocca Busambra mountain ridge (Fig. 73), described in classical papers by Wendt (1964, 1971a). His sketches of the numerous neptunian dykes occurring within the Lower Jurassic platform limestones (Inici Fm.), in fact, soon became a classic textbook example for this topic. The mechanisms and environments of generation and filling of fissures will be discussed in this stop. Cross cutting relationships among different generations of dykes can be observed in many outcrops, but are spectacularly exposed in an abandoned quarry on the northern side of Rocca Argenteria.
Substop 10.1 - Outlook of Pizzo Nicolosi

The whole Rocca Busambra-Rocca Argenteria-Rocca Drago ridge represents an outstanding feature in the landscape of this region. It is characterized by abrupt cliffs, up to some hundred metres high, surrounded by intensely cultivated, gentle hills made of softer rocks which are gently incised. These correspond mostly to Miocene marls that either represent the sedimentary cover of the carbonate Mesozoic Trapanese units, or the coeval sedimentary cover of other paleogeographic-structural domains thrust over the Trapanese Units (e.g. CATALANO et alii, 1996). Pliocene high angle faults, with a probable strike slip component (GHISETTI & VEZZANI, 1984), cut through the tectonic pile exposing the Mesozoic successions.

From Rocca Argenteria we have a beautiful view of the north-western cliff of Pizzo Nicolosi. Here a very anomalous stratigraphic contact exists between the Inici Fm. and the Upper Cretaceous Scaglia Fm. (Fig. 74). The differences in colour and bedding style, well seen in the distance, mark the striking angular unconformity between the thin bedded pink marly limestones of the Scaglia, and the massively bedded whitish Inici Fm. The Scaglia is characterized in cross section by a festoon geometry filling up a steep-sided depression incised for a few hundred metres within the Inici Fm. This structure was already described by GIUNTA & LIGUORI (1975), who considered it a submarine canyon, and by LONGHITANO et alii (1995) who on the contrary interpreted it as a tectonic structure due to a post-Cretaceous transtensional phase. We must disagree with both authors because while, as LONGHITANO et alii argue, it is hard to imagine submarine erosion of completely lithified platform limestones, it is on the other hand evident that the Inici-Scaglia contact is stratigraphic. This means that the Late Cretaceous pelagic sediments draped an already existing depression. Our interpretation is that a Late Cretaceous tectonic phase, possibly with a strike slip component, generated a fault-bounded, steep-sided, graben that was onlapped and filled by the Scaglia sediments. The higher degree of compaction of the Cretaceous marly beds in the axial and deepest portion of the depression accentuated the angular unconformity and resulted in the festoon geometry (Fig. 75). The Pizzo Nicolosi structure
is a clear direct evidence of a Cretaceous synsedimentary tectonic phase affecting the sea floor paleotopography and hence the geometry of lithosomes.

**Substop 10.2 - The dykes of the Rocca Argenteria quarry**

In the Rocca Argenteria quarry (Fig. 76) we will observe the expression of synsedimentary tectonic activity in the subbottom rock column in the form of a complicated and dense network of polyphase dykes. The dykes are easily seen along the quarry front because of the colour contrast with the encasing whitish Inici limestone. Based on cross-cutting relationships, several generations of fissures can be recognized (Figs. 77, 78a). These are (youngest to oldest):

4) A set of high angle fractures steeply dipping to the N. Several of them actually correspond to faults that displace key beds in the Inici Fm. Locally, several different concave-up faults merge into one single larger fissure giving rise to a sort of half-flower structure. This geometry is an evidence of the strike slip component associated with extension. This fracture system is so dense that it results in a pervasive brecciation of the white Inici limestone. The fissures, up to some decimetres wide, are filled with a breccia with clasts of the Inici limestone floating in a dark red matrix. The latter consists of an unevenly dolomitized wackestone with glauconite grains and abundant globigerinids referable to the Middle Miocene. The geometry and density of the fissure network strongly resembles the dykes associated with Plio-Pleistocene extensional fault scarps described in the Straits of Messina by Montenat et alii (1991).

3) Gently (about 30°) southward dipping fractures filled with red, dolomitized sediments. No detailed biostratigraphic study has been made on these dykes; the foraminiferal assemblage, however, is probably older than the Miocene and could be Paleogene in age.

2) Fissures filled with pink mudstones to wackestones, roughly parallel to those described in 3) but smaller-scale (10-15 cm wide), more irregular in shape and much less frequent; they contain globigerinelloids and hedbergellas referable to the upper part of the Lower Cretaceous.

1) Mainly bedding parallel, cm-large fractures, filled with dark red mudstones (probably Rosso Ammonitico) with scattered small echinoderm fragments. All these crosscutting dykes document a history of fissure opening and filling which lasted for a very long time span, from the Early Jurassic to the Miocene, i.e. approximately 170 M.y. This is interpreted as an evidence that Rocca Busambra was never buried very deep.
Fig. 78 - Sketch of the Rocca Argenteria quarry front showing the complex cross-cutting relationships of several generations of neptunian dykes (a), and close ups of fillings of cavities not related to fracturation (b, c).

deeply before the Middle Miocene, so the same rock succession, i.e. basically the Inici Fm. plus thin blankets of Jurassic-Cretaceous pelagic sediments, was always very close to the sea floor, being easily subjected to all the fracturation events associated with the tectonic evolution of the Siculomaghrebide chain. This evolution started in the Early Jurassic with the rifting of a continental margin, later switching to a passive margin in the Late Mesozoic and last, due to inversion of plate motions, to a convergent margin with associated foredeep basins (e.g. CATALANO et alii, 1996).

In addition to the spectacular network of dykes, other features at Rocca Argenteria, pre-dating the dykes, are, as far as we are aware of, unique for western Sicily. Pink to red layers, over 50 cm thick, are clearly recognizable within the Inici Fm. succession along the quarry front, where they contrast with the generally whitish peritidal limestone (Fig. 78b). The red colour is due to the presence of a dense network of cavities filled with red sediments. The encasing limestone is reddened for a thickness of some millimetres; this effect fades away from the cavity wall. Individual cavities may have two different shapes: 1) Roughly bedding-parallel, elongate cavities; they extend laterally for several metres, have a vertical width that usually is of about 1 cm or less, and are interconnected through oblique branches to form a complex network. 2) Closely spaced, rounded to lobate cm-sized cavities. The walls of these cavities are very irregular and pitted on a small scale (Fig. 79).

Much less frequent but very interesting are cavities several decimetres large and high, with rounded margins.

These cavities are filled with different sedimentary and diagenetic products (Figs. 78c, 80). From base to top:
1) Pinkish sediment consisting of a wackestone with lithoclasts of the typical peloidal-bioclastic grainstones of the Inici Fm., and with abundant fragments of acicular calcite cement crusts.
2) Very dark red mudstones, locally containing articulated and disarticulated ostracod shells and opaque,

Fig. 79 - Rocca Argenteria. Polished slab of a reddish bed in the Inici Fm. Cm-sized dissolution vugs are filled geopetally with several generations of red sediments and white calcite cements.

Fig. 80 - Rocca Argenteria. Large dissolution cavity with complex infilling.
mineralized grains with a pseudoolitic structure.

3) Cm-thick rim of white radiaxial calcite cement.

4) Brown red sediment with textures variable from mudstones to \textit{Saccocoma} grainstones. Rare unidentifiable ammonite moulds occur in these sediments, that are referred to the Late Jurassic.

5) Orange red mudstones to wackestones, usually rich in Upper Cretaceous globotruncanid foraminifera. Rare unidentifiable ammonite moulds occur in these sediments, that are referred to the Late Jurassic.

The largest cavities show all of these infillings, whereas the smaller ones may record different combinations of two or more generations, the cement rim being usually always present.

Mineralogical, X-ray analyses of the insoluble residue of all the red sediments occurring in this succession has revealed that the pink and dark red sediments, that pre-date the cement rim and that represent the first sediments overlying the floor of the cavities, containing kaolinite which instead is lacking in all the other fissure infillings. Moreover, stable isotope analyses have evidenced that the white limestones of the Inici Fm. and the pink and dark red internal sediments show C and O values lighter than Jurassic and Cretaceous pelagic sediments. In particular, $\delta^{18}O$ values of the former are comprised between -1.3 and -2.6 $\%_{o}$ PDB whereas the latter are never lighter than -0.5 $\%_{o}$ PDB.

Altogether, the described features seem to point to an Early Jurassic subaerial exposure period resulting in dissolution phenomena proceeding along, and enlarging, preexisting features of the peritidal limestone such as birdseye pores, sheet cracks and fractures, but generating also larger cavities. This complex fissure system was floored by sediments mixed with the products of subaerial weathering (Terra Rossa). The thick rim of isopachous marine fibrous cement suggests an active circulation of supersaturated marine waters in the cavity system during the drowning of the platform, preating infiltration of pelagic Jurassic sediments. Deposition of the Rosso Ammonitico sealed the sea floor and prevented further communication with the sea bottom. Most of the cavities consequently were not filled completely. The Late Cretaceous fracturation event, however, created new fissures that worked as paths for sediment infiltration below the bottom, and the still open portions of dissolution vugs could be filled up completely.

Rocca Argenteria therefore seems to be one of the best localities for observing Jurassic karst features, providing new data in support of the subaerial hypothesis proposed, together with other ones, by Di STEFANO & MINDSZENTY (2000) for interpreting the jagged, Kamenitza-like surface at the top of the Inici Fm.

STOP 11 - ROCCA DRAGO: MESOZOIC PELAGIC SEDIMENTATION OVER THE FAULTED MARGIN OF A PELAGIC PLATFORM

L. MARTIRE, C. BERTOK, G. PAVIA & C. SARTI

Substop 11.1 - The “normal” Rosso Ammonitico succession

The Rosso Ammonitico at Rocca Drago is quite thin (generally less than 1.5 m), and has strongly variable stratigraphic features especially in its lower part (Figs. 81, 82). It consists of discontinuous beds that pinch out over short distances. This is clearly evidenced by (1) the laterally discontinuous occurrence of a bed (Level 1) sandwiched between the top of the Inici Fm. and the distinctive, ubiquitous, crust of Fe-Mn oxides, (2) the local superposition of Level 3 directly above the Inici Fm., due to the local absence of Level 2. A complete Rosso Ammonitico section, overlying the top of the Inici Fm., is composed by the following levels:

Level 1 (about 10 cm) - Wackestones with filaments and echinoderm debris. intraclasts are abundant and are, like many bioclasts, coated by thick crusts of Fe-Mn oxides. Euhedral K-feldspar crystals, up to 1.5 mm long, provide an evidence of volcanic activity, as already reported by JENKYS (1970).

A several centimetres-thick crust of Fe-Mn oxides occurs at the top of this level, or it directly overlies the pinnacled top of the white Inici limestone in places where Level 1 is missing (Fig. 83). This crust is characterized by a millimetric lamination and by dome-shaped morphologies strongly resembling stromatolitic structures (\textit{Frutexites}). Within this laminae, worm-like encrusting Foraminifera, possibly referable to \textit{Toiypanmina} and/or \textit{Gypsina}, show noteworthy similarities with those...
cm across are common to abundant; they generally consist of wackestones with protoglobigerinids, bivalves, gastropods and calcite radiolarian moulds, and their peripheries are intensely micritized. Moreover, they are coated by mm-thick *Frutexites*-like crusts of Fe-Mn oxides, that locally may be so well developed as to produce Fe-Mn oncoids of more than 10 cm in diameter.

**Level 4 (40 cm)** - The upper boundary of the Rosso Ammonitico is not exposed in this section. The last bed of Rosso Ammonitico is about 40 cm thick and consists of massive stromatolitic wackestones with protoglobigerinids, gastropods, small peloids, *Globochaete* and calcite radiolarian moulds. Several firm ground burrows cross this bed, and are filled with coarser-grained packstones with echinoderm and *Saccocoma* fragments. The first occurrence of frequent *Saccocoma* probably indicates the Kimmeridjian.

Both subvertical and subhorizontal neptunian dykes are recognizable within the Inici Fm. and the lower part of the Rosso Ammonitico. These dykes may be filled with different sediments, representing different Jurassic Rosso Ammonitico facies. Cross-cutting relationships demonstrate a polyphase generation of dykes. Some of the subvertical ones, moreover, are associated with displacements by several decimetres of the Inici-Rosso Ammonitico boundary, and thus must correspond to Jurassic extensional faults. The corresponding fissures reached the sea floor and were filled with loose pelagic sediments sucked down into the open fissure system. In addition to the Jurassic dykes, others are filled with globotruncanid-rich wackestones of the Upper Cretaceous Scaglia Fm.

**Substop 11.2 - The “anomalous” Scaglia-Inici contact**

Proceeding eastward, along the southern side of Rocca Drago, the Inici-Rosso Ammonitico boundary runs in the higher part of the cliffs where it has a 10° NW dip. In the lower cliffs, where only the Inici Fm. should be cropping out, limited patches of whitish, marly limestones referable to the Scaglia Fm. overlie the Inici limestone through a marked angular unconformity. The contact surface is very irregular, with vertical or even overhanging tracts, and is sealed by Scaglia sediments with no evidence of tectonic movements. There is thus a primary stratigraphic contact of the Cretaceous marly limestones on an erosional surface deeply cutting through the Jurassic succession. Stratigraphical and geometrical relationships between sedimentary bodies are the same as those observed at Pizzo Nicolosi (Substop 10.1). The Cretaceous sediments represent the filling of a tectonic depression, of which only the highest part of one shoulder is observable here.
Substop 11.3 - The “anomalous” Rosso Ammonitico succession

Further to the east, Rosso Ammonitico sediments are visible again for a thickness of about 1.5 m. This outcrop, however, differs from the one seen in Substop 11.1 for some aspects:

1) Beds show a 40° SW dip that sharply contrasts with the gentle, NW dip of the main outcrop (Fig. 84).

2) The visible succession is entirely composed of Saccocoma-bearing Upper Jurassic packstone or wackestones. Calpionella alpina has been detected in the last bed, which must therefore be upper Tithonian or even lower Berriasian. The lower part of the Rosso Ammonitico (see 11.1) is missing. The internal structure of beds is massive, the sole inhomogeneities being represented by firm-ground burrows and by spar-filled cavities up to 1 cm large, that seem to be due to creeping of semilithified sediments. The top of this Rosso Ammonitico section is an erosional discontinuity surface, with bivalve borings and glauconite or Fe-Mn oxide enrustations, overlain by Upper Cretaceous Scaglia sediments which here are only few decimetres thick (Fig. 85).

3) Climbing uphill, these rather steeply dipping Rosso Ammonitico beds overlie subhorizontal Inici beds and no trace of the Fe-Mn oxide crust is detectable.

Moreover, limited patches of early Kimmeridgian ammonite-rich micritic limestones filling perched ponds occur in the flat part of the steps incised within the Inici Fm. (Fig. 86).

This situation may be explained by calling upon the pelagic draping of a Jurassic paleoslope or low-angle escarpment, giving rise to the facies association C (composite pelagic) described at the erosional margins of pelagic carbonate platforms by Santantonio (1993), and duplicating the typical geometries of epi-escarpment deposits as described in the Apennines by Di Bucci et alii (1994) and by Santantonio et alii (1996). Very similar geometrical and stratigraphical relationships were also beautifully described by Purser & Plaziat (1998) on the footwall slopes of rifted margins in the Red Sea region. The steep dip of the “anomalous” Rosso Ammonitico beds is thought to approximately parallel the original dip of an escarpment which likely corresponded to a fault plane activated by Late Jurassic extension (Fig. 87 b). This proves that the dissection of this part of the
Substop 11.4 - The “anomalous” Scaglia-Rosso Ammonitico contact

Turning around the Rocca Drago ridge, just before reaching its flat top, another anomalous stratigraphic contact is worth noting. A sort of sharp- and steep-sided “trench”, about 1.5 m large and 2 m deep, some metres long, is cut within the Rosso Ammonitico and filled with whitish marly limestones referable to the Scaglia Fm. (Fig. 87c). Upslope, in the apical part of this gutter-shaped Scaglia body, the contact with the underlying Rosso Ammonitico limestones is a sharp, smooth, semicircular surface which implies a considerable degree of erosion within a lithified substrate. Gullies of comparable size have been described in the rift escarpments of the Red Sea; the exact mechanics of erosion, however, considered the pelagic sedimentary environment, remains enigmatic.

Substop 11.5: Lower Kimmeridgian fossiliferous dyke

On top of the Rocca Drago ridge the “normal” Ini-rosso Ammonitico succession is observable again. Our attention will here be focused on a bedding-parallel dyke that occurs just at the Ini-rosso Ammonitico boundary. It is up to 20 cm large and is filled with a parallel-laminated coarse-grained wacke- to packstone rich in echinoderm and bivalve fragments, gastropods and abundant *Lenticulina*. Locally, however, it is constituted by a greenish-grey mudstone very rich in lower Kimmeridgian ammonites (Fig. 88), with specimens wonderfully preserved down to the finest and most delicate outer ornamentation.

The ammonite assemblage is under study by C. Sarti, who gives the following preliminary report. This fossiliferous locality was already mentioned by Cecca & Pochettino (2000), who described the exceptional frequency of *Metastreblites* taxa. The collection consists of more than 500 specimens; the following list documents the taxonomic diversity of this assemblage, which at present totals 57 taxa with an unusual number of new species:

- *Sowerbyceras silenum*
- *Calliphyloceras polyolcum*
- *Calliphyloceras benacense*
- *Holcophylloceras zignodianum*
- *Lytoceras montanum-orsinii* juv.
- *Lytoceras polycyclum*
- *Glochiceras (Lingulaticeras) tenuifalcatum*
- *Glochiceras (Lingulaticeras) Jialar*
- *Metastreblites olorizi*
- *Metastreblites praesemiformis*
- *Streblites levipicta*
- *Streblites tenuisculptus*
- *Tarameliceras gr. hemipleurum* (m)
Taramelliceras (Metahaploceras) sp.
Idoceras sautieri (m).
Idoceras balderum largiumbelicatum (m)
Idoceras spp. nov.
Presimoceras sp.
Nebrodites macerrimus
Nebrodites hospes
Nebrodites agrigentinus
cfr. Pseudosimoceras sp. juv.
Orthosphinctes gr. polygyratus
Progeronia gr. capillaceus (m)
Crussoliceras sp.
Sutneria batelleri
Sutneria rebholzi
Sutneria spp. nov.
Simosphinctes (Ceratosphinctes) spp. indet.
Simosphinctes (Sutneria) spp. nov. (m)

Based on the co-occurrence of G. fialar, M. olorizi, I. sautieri, Presimoceras spp., N. hospes, N. agrigentinus, the fossil assemblage can be precisely referred to the lower Kimmeridgian, Mesosimoceras herbichi Zone, Presimoceras stenonis Subzone (sensu SARTI, 1993), corresponding to the uppermost Metahaploceras strombecki Zone (sensu OLORIZ, 1978). The most common taxa are S. silenum, about 50 per cent of the whole sample, and subordinately Idoceras, Presimoceras, Nebrodites. Idoceras is the taxonomically best represented ammonite, even with some new species. Particularly interesting is the frequency of microconch forms, among which several species of Sutneria and Simosphinctes. The assemblage is mainly constituted by fossils of reduced to middle size (maximum 100 mm in diameter). Many specimens are complete of adult peristome, with delicate lappets in the case of microconchs, or reach normal size like S. silenum, M. olorizi, N. agrigentinus, etc.; they are however associated with juvenile to mid-grown individuals.

In conclusion, the fossil assemblage fails to record any kind of selective transport - only the largest forms are absent due to sieving controlled by the size of the neptunian fissure. In other words, due to the contemporaneous presence of both immature and adult forms, and of macro- and microconchs, the fossil assemblage of the lower Kimmeridgian neptunian dyke of Rocca Drago can be assimilated to a taphonic population of type 1 (sensu FERNANDEZ-LOPEZ, 1995), being constituted by accumulated or locally resedimented fossils. It thus represents an unusually rich representation of the communities living on that structural high, possibly in rather shallow water as documented by the frequency of gastropods.

Substop 11.6 - Cretaceous slide scar at the top of the Rosso Ammonitico

A last stop will be made on the westernmost side of the Rocca Drago ridge in order to show the effects of the above cited Late Cretaceous tectonic phase. A gentle slope, extensively exposed, cuts through the subhorizontal Rosso Ammonitico beds giving rise to a stepped morphology (Fig. 89). Some features are diagnostic to reconstruct the mechanisms that generated this slope:

1) bivalve borings occur at the top of the Rosso Ammonitico, showing that it corresponded to an ancient lithified sea-floor;
2) another “gutter”, of comparable size to the one seen in Substop 11.5, is incised within the Rosso Ammonitico limestones and filled with Scaglia sediments;
3) subvertical dykes, 10 cm wide, approximately striking E-W, i.e. parallel to the slope dip, correspond to displacements in the Rosso Ammonitico beds and are filled again with Scaglia sediments and radiaxial cements.

All these features point to a Late Cretaceous slope failure, which resulted in the sliding of a wide but probably thin block of Rosso Ammonitico along a gently dipping detachment surface. This slide scar was bored by endolithic organisms and scoured by mechanical agents to give rise to narrow “gutters”, and then draped by Scaglia pelagic sediments.

In conclusion, the long history of neptunian dyke openings and fillings observed at Rocca Argenteria is recorded at Rocca Drago as a history of important changes in the paleotopography of the sea floor (Fig. 87a-c). Starting in the Late Jurassic, in fact, Rocca Drago became the margin of a pelagic carbonate platform which, surprisingly enough, was non-depositional during the whole Early Cretaceous, i.e. in the time interval corresponding elsewhere to the deposition of the

Fig. 88 - Rocca Drago. Sample of greenish-grey mudstone from the neptunian dyke at the top of the Rocca Drago ridge. Note the richness of ammonites, Sowerbyceras silenum being the most common fossil.
Fig. 89 - Rocca Drago. Gently dipping, stepwise surface incised within the Rosso Ammonitico and corresponding to a Late Cretaceous slide scar.

Lattimusa Fm. In the Late Cretaceous it was again dissected by faults and experienced failures at its oversteepened slopes. All this resulted in the generation of an isolated highstanding ridge draped by thin veneers of the Scaglia Fm., a unit that was much thicker in the adjacent basins that are now mostly covered under the Neogene sediments, an exposed example being the Pizzo Nicolosi “canyon”.

STOP 12 - PIANA DEGLI ALBANESI: DEEP-WATER SLOPE TO BASIN IMERESE DOMAIN, RELATIONSHIPS BETWEEN CARBONATE PLATFORM AND BASIN SEDIMENTATION

A. BARTOLINI, R. BUCEFALO PALLIANI, M. CHIARI, P. DISTRIFANO, E. MATTIOLI & G. PARISI

INTRODUCTION AND GEOLOGICAL SETTING

The Piana degli Albanesi area is located in the southern sector of the Palermo Mountains. In this area a large thrust sheet that derives from the Tertiary deformation of the Imerese paleogeographic Domain crops out. This structural unit consists of Carnian to Eocene deep water carbonates and cherts, with repeated clastic-carbonate intercalations. Facies analysis of these clastics clearly points to a derivation from the Carnian-Eocene platform carbonates of the Panormide Domain. During the Mesozoic and Paleogene, the Imerese Domain is interpreted to document a slope to peribasinal environment adjacent to the Panormide carbonate platform (CATALANO et alii, 1996).

This stop offers a snapshot of Jurassic sedimentation in this domain through observation of a Lower Jurassic succession belonging to the Crisanti Formation (*Auct.*).

This formation consists of varicoloured marls and calcilutites, siliceous limestones and bedded cherts bearing several clastic-carbonate layers and locally also volcanic levels. The age of this formation ranges from the Early Jurassic to the Late Cretaceous. Among the clastic-carbonates two major intercalations, several tens of metres thick, outcrop. The older is dated as Tithonian–Early Cretaceous (*Ellipsactinia* limestone), and the...
younger is Albian-Cenomanian (*Orbitolina* limestone) in age. The total thickness of the Crisanti Fm. ranges from about 200 up to 400 m. It overlies a thick (up to 500 m) unit of resedimented dolostones, grouped into the Fanusi Fm., containing reworked late Carnian-Rhaetian *Halobia*-bearing cherty limestones (Scillato Fm). The upper boundary of the Crisanti Fm. is marked by a discontinuity surface overlain by uppermost Cretaceous-Eocene reddish calcilutites (Scaglia-type) with planktonic foraminifers (Caltavuturo Fm.).

**LITHOSTRATIGRAPHY**

The studied section crops out along the bypass road close to the small town of Piana degli Albanesi (Fig. 90). It belongs to the lower part of the Crisanti Fm., and is late Sinemurian-late Domerian in age, based on calcareous nannofossil and dinoflagellate cyst biostratigraphies (Fig. 91). The outcrop, from 0 to 10 m, is characterised by grey marls alternating with laminated limestones rich in radiolarians and sponge spicules and with frequent resedimented carbonate beds. The base of the section is characterised by a thick graded calcirudite-calcarenite, 2.8 m thick, interpreted as a turbidite. The lithoclasts consist of sponge boundstones, and of peloidal-ooid-oncoid grainstones bearing a benthic foraminifer assemblage with *Hirsutospirella pilosa*, *Cucurbita brevicollum*, *Siphonophora* sp., *Kaeveria fluegeli* and *Galeanella* sp. (Fig. 92). Microproproblematics like *Actinotubella* sp., *Microtubus communis* and *Radiomura* sp. are also present. Both the microfacies types and the foraminiferous assemblages are typical of Upper Triassic reefs and are commonly found in the Norian-Rhaetian reefs bordering the Panormide Platform (Senowbari-Daryan *et alii.*, 1982; Di Stefano, 1990). Rare wackestones with radiolarians, miliolids and *Ophthalmidium* are also found.

In the calcarenitic turbidites interbedded upwards (7.50 and 10.50 m) the abundance of "pelagic" elements increases and these prevail over the platform-derived elements (Fig. 93). Chert occurs here as nodules. The lithoclasts of the two calcarenitic turbidites are the same as those of the 2.8 m thick bed described above. The bioclasts consist of echinoid fragments, crinoid remains and foraminifers. The upper part of both levels grades into wackestone with radiolarians and sponge spicules representing autochthonous pelagic sedimentation. The marls and limestones exhibit abundant radiolarians, rare hyaline foraminifers represented by elongated and flat morphotypes (*Marginitina spinata*, *Paralingulina* gr. *tenua*, *Vaginulina* sp., *Frondicularia* sp.), rare agglutinated foraminifers (*Glomospira* sp., *Glomospirella* sp.) and rare ostracods.

At 10.50 m a white cherty level marks the middle part of a detrital bed (60 cm thick) (Fig. 94).

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Fig. 91 - Piana degli Albanesi section.

Fig. 92 - Microfacies of the Upper Triassic reef-derived elements in the lowermost calcirudite-calcarenite bed: a) sub-angular lithoclasts of peloidal-foraminifer grainstones and "spongiostromata" crusts in a brownish silty matrix with radiolarians and echinoid fragments; b) *Hirsutospirella pilosa* *ZANINETTI et alii.*, X 40; c) *Siphonophora* sp., X 40.
Fig. 93 - Microfacies of the Early Jurassic, a) Lithoclastic packstone, with aggregate grains, echinoid fragments and lithified carbonate fragments; b) Transition of fine-grained clastic limestone into radiolarian wackestone; c) Bioclastic and aggregate grains wackestone with ooids; d) Wackestone with radiolaria and sponge spicules; e) Fine-grained wackestone with benthic foraminifera, Lenticulina (1) Paralingulina (2) and bioclastic Meandrospiridae (3); f) Radiolarian wackestone with lithified carbonate fragments (lithoclasts) of shallow-marine facies.

Following the irregular top surface of this bed, the most siliceous facies of the Crisanti Fm. occurs. It is characterised by dark grey-black, laminated siliceous limestones interbedded with dark grey or red siliceous-marls. Lamination consists of millimetric intercalations of black organic material, radiolarians and sponge spicules. This part of the section bears evidences of gravitational instability in the form of intraformational truncation surfaces and unconformities, and slumps. Its age is still poorly constrained, but can be roughly assigned to the Toarcian-Bathonian interval.

**BIOSTRATIGRAPHY**

Dating of the lower portion of the succession is based on the integrated study of calcareous nanofossils and dinoflagellate cysts.
CALCAREOUS NANNOFossils

The base of the section (3 to 6 m) (Fig. 95) has given a rich and diversified nannofossil assemblage, in which Parhabdolithus liasicus, Parhabdolithus robustus, Crepidolithus crassus, Crepidolithus pliensbachensis, Mitrolithus lenticularis and Mitrolithus elegans dominate, being common to abundant. Other significant species are: Similiscutum cruciulus, which first occurs at the very base of the Carixian, and Crepidolithus timorensis, reportedly a ?Sinemurian form (small Crepidolithus of COBIANCHI, 1992; LOZAR, 1995; BOWN & COOPER, 1998). The interval from 3 m to 6 m is therefore uppermost Sinemurian or, more probably, close to the Sinemurian/Carixian boundary, NJT 4a nannofossil Subzone (MATTIOLI & ERBA, 1999).

The interval from 8 m to 9.50 m has a different nannofossil assemblage, due to the disappearance of characteristic Sinemurian-Carixian forms (P. robustus, C. pliensbachensis, C. timorensis). These are replaced by Crepidolithus cavus, Lotharingius barozii and Lotharingius frodoi. All these species first occur in the upper Domerian, NJT 5a nannofossil Subzone (MATTIOLI & ERBA, 1999) (Fig. 95).

DINOF Lagellate Cysts

The samples underwent standard palynological procedure (WOOD et alii, 1996) and yielded a variable organic residue, mainly composed of inertinite and fungal remains. This organic composition suggests a poor preservation of the organic material. The rare dinoflagellate cysts recorded in samples PCR 7, PCR 10 and PCR 15 belong to the long-ranging genera Nannoceratopsis and Mendicodinium. In the Tethyan domain Nannoceratopsis first appears in the lower Pliensbachian and in the upper Pliensbachian it becomes widespread in the Boreal Realm (BUCEFALO PALLIANI & RIDING, 1999). This genus exhibited a marked increase in abundance and species diversity during the late Pliensbachian (WOOLLAM & RIDING, 1983; DE VAINS, 1988; DODEKOVA & TCHOUMATCHENKO, 1989; RIDING & THOMAS, 1992; FEIST-BURKHARDT & WILLE, 1992; ILYINA et alii, 1994; POULSEN, 1996).

Species of Mendicodinium have been reported from the lower Pliensbachian and lower Toarcian of different Tethyan areas (central Italy, Greece, Hungary and Portugal) (BUCEFALO PALLIANI, 1996). According to BUCEFALO PALLIANI (1996), the base of the Pliensbachian in the Tethyan Realm is marked by the first occurrence of a plexus of small species of Mendicodinium with varied ornamentation.

RESULTS

Integrated biostratigraphy yielded a continuous stratigraphical documentation ranging from the upper Sinemurian to the upper Domerian.

The Sinemurian-Pliensbachian transition, tentatively placed around metres 7-8, is mainly based on the first occurrence of a lower Pliensbachian dinoflagellate cyst assemblage.

The calcareous nannofossil and dinoflagellate cyst assemblages exhibit significant similarity with coeval
assemblages from the Tethyan Realm (MATTIOLI & ERBA, 1999; BUCEFALO PALLIANI & RIDING, 1999).

The lowermost part of the section (uppermost Sinemurian or Sinemurian/Carixian in age) is characterised by the abundance of thick reseidated carbonate beds rich in Late Triassic reef-derived clasts. These breccias probably document an active tectonic phase that resulted in margin collapse in the adjacent Panormide carbonate platform. During the Pliensbachian detrital levels decrease in thickness, and they are mainly characterised by abundant echinoids, crinoids and dominantly open sea calcareous hyaline foraminifers. This suggests the partial drowning of part of the carbonate platform during the Pliensbachian. Upwards, the disappearance of these clastic levels could indicate the end of neritic carbonate production. This latter event may be linked to a more generalised palaeoenvironmental crisis of carbonate platform production, as documented in other Tethyan areas (PICOtti & COBIANCHI 1996; COBIANCHI & PICOtti, in press; MATTIOLI et alii, in press; MORETTINI et alii, in press).

STOP 13 - PORTELLA DELLE GINESTRE PARKING LOT: TECTONOSTRATIGRAPHIC SETTING AND JURASSIC LITHOSTRATIGRAPHY OF MONTE KUMETA

P. DI STEFANO & G. MALLARINO

Among the Jurassic outcrops of the Trapanese domain from western Sicily, Monte Kumeta offers a well-established example of the complex synsedimentary dynamics along a stepped pelagic escarpment adjacent to a structural high. A rough coincidence between the palaeoescarpment and the present-day southern slope of the mountain allows a 3D observation of the discontinuous Jurassic facies distribution on an articulate palaeotopography, which was continuously rejuvenated by tectonic and gravitational synsedimentary deformation. Stops 13 to 15 will focus on some aspects of this complex sedimentary history. In particular Stop 13 is an introduction to the stratigraphic and structural setting of the area. Stop 14 (divided into substops) describes the main steps of the Liassic conversion from a Bahamian-type platform to a pelagic escarpment. Stop 15 (also divided into substops) focuses on the evolution of the escarpment during the Late Jurassic.

Monte Kumeta is located in the central zone of an E-W trending ridge (hence named the Kumeta Ridge) extending for about 20 km in western Sicily. This ridge belongs to a major structural unit of the Sicilian-Maghrebian chain in the southern sector of the Palermo Mountains (Fig. 96).

The stratigraphy of Monte Kumeta has been treated in several studies following CAFLISH (1966) and MASCLE (1979). WENDT (1964, 1969) provided detailed data on the stratigraphy of the Jurassic strata.

The base of the succession (Fig. 97) consists of more than 300 m of Lower Liassic peritidal to open-shelf limestones and dolostones (Inici Formation Auct.) that are cut across deeply by sedimentary dykes. Three main lithofacies associations were distinguished in the Inici formation, named Inici M1, M2 and M3 (Di STEFANO et alii, 2002a). Inici M1 groups peritidal cyclothems, while Inici M2 and M3 consist of oolitic-skeletal and peloidal-skeletal grainstone/packstone respectively. The Inici Fm.

Fig. 96 – Structural map of the Monte Kumeta ridge showing the location of Stops 13-15.
overlies a thick, (unexposed) substrate of Upper Triassic platform dolostones and is unconformably overlain by the Calcari a Crinoidi unit which consists of white to pink encrinites, up to 15-20 m thick, of Pliensbachian age.

Pelagic sediments of Late Liassic-Tithonian p.p. age follow upward. They are informally named as “Rosso Ammonitico” (corresponding to the Buccheri fm. from southeastern Sicily) and can be easily subdivided into three units (ABATE et alii, 1990; Di STEFANO & MINDSZENTY, 2000).

a) A lower unit (RAI = Rosso Ammonitico inferiore) made of up to 6 m of massive, reddish condensed limestone spanning the Toarcian up to the middle Oxfordian.

b) An intermediate cherty unit (Membro Radiolaritico intermedio, MRI) characterized by 0 to 15 m thick varicoloured, bedded cherts and radiolarian marls of middle Oxfordian-early Kimmeridgian age.

c) An upper unit (RAS = Rosso Ammonitico superiore), consisting of 10 to 15 m thick reddish nodular limestones and Saccocoma-limestones of Kimmeridgian-early Tithonian age, with megabreccia and pebbly mudstone intercalations.

Upper Tithonian-Neocomian calpionellid-bearing cherty calcilutites (“Lattimusa” Auct.) and Lower Cretaceous to Eocene aprtchus marls and calcilutites (Hybla Formation and Scaglia = Amerillo Fm.) follow upward. A deep disconformity at the top of the Scaglia is sealed by the Calcareniti di Corleone (RUGGIERI, 1966) of Burdigalian-Langhian age, that are followed in turn by the Marne di San Cipirello Fm. (RUGGIERI & Sprovieri, 1970) of Serravallian-early Tortonian age.

The Jurassic pelagic units are well exposed in a relatively small area on top of Monte Kumeta and on its southern slope (Fig. 98). In this area most of these units taper northward. Moreover, as seen in Fig. 100 A, on the very top of the mountain several units are missing and the RAS unconformably overlies a thin layer of RAI, resting in turn on the Inici M2.

In sectors adjacent to Monte Kumeta, a continuous view of the Jurassic deposits is hampered by Late Miocene thrusting (CAFLISH, 1966; CATALANO et alii, 1978) and later (Pliocene) right-lateral transpression (GHISETTI & VEZZANI, 1984). The Jurassic palaeotectonic heritage seems to have also played an important role in the tectonic evolution of this sector (Di STEFANO et alii, 2002a). At present the Kumeta Ridge appears as an E-W trending positive flower structure bounded to the north and south by wrench-fault zones (Fig. 96). Transverse geological cross-sections along this structure (ABATE et alii, 1990; Di STEFANO & MINDSZENTY, 2000) show the southern flank of a hemi-anticline that is gently arched along its E-W axis and repeatedly cut across by NW-SE and SW-NE faults (Fig. 99).

Eastward the Monte Kumeta succession is tectonically overlain by the Imerese structural units, that consist of deep-water slope-to-basin Mesozoic-Tertiary carbonates and cherts and Upper Oligocene-Lower Miocene Numidian Flysch (CAFLISH; 1966; ABATE et alii, 1978). The thrust contact is well exposed at Monte Leardo on the eastern sector of the ridge (Fig. 96).

North of the ridge the Monte Kumeta succession is downfaulted and largely covered by the Imerese nappes. Also, to the south, the Mesozoic strata are covered by Tertiary formations. Help in the understanding the southward development of the Jurassic sediments is provided by subsurface data from the Marineo well, drilled about 5 Km ESE of Monte Kumeta. The Jurassic succession penetrated by this well has been interpreted as the filling of an infraliassic basin (Marineo basin,
It consists of about 400 m of radiolarian and sponge spicule-bearing cherty limestones that are sandwiched between the Inici Fm. and the overlying Toarcian to Upper Jurassic ammonitic limestones. Based on its stratigraphic position, the age of this unit could be Sinemurian to Pliensbachian. Similar deposits are well known in the subsurface of eastern Sicily (Hyblean Plateau), where they are grouped into the Modica Fm. and can be compared to the Corniola Fm. of the Umbria-Marche Basin.

A recently published geological section across the Kumeta Ridge and the Marineo well, based on seismic profiles (AVELLONE et alii, 1998), indicates that the severe Tertiary deformation occurring between these two sectors has not altered substantially their mutual paleogeographic relationships. However, the amount of lateral displacement along the wrench-fault system, and the lateral extent of the Liassic basinal sediments in the subsurface south of the Kumeta Ridge is still poorly known.

STOP 14 - BIRTH AND DYNAMICS OF A JURASSIC SUBMARINE ESCARPMENT AT MONTE KUMETA

P. DI STEFANO, A. GALÁČZ, G. MALLARINO, A. MINDSZENTY & A. VORÓS

The reconstruction of the facies architecture in the Lower-Middle Jurassic succession of Monte Kumeta, coupled with a detailed biostratigraphy, allows a definition of the dynamic and genetic factors controlling the conversion of a Bahamian-type carbonate platform into a pelagic escarpment (DI STEFANO et alii, 2001, 2002a).

In this sector, the Inici Fm. records a change from tidalites to oolites (from restricted, interior lagoon to a more open, sandy depositional environment), that may probably be due to the birth of a basin south of Monte Kumeta in Hettangian-Sinemurian times. The existence of such a basin has already been put forward by
Monte Kumeta

A

Stop 15

B

Stop 14

Fig. 99 - Geological section across Monte Kumeta (mod. from Di Stefano & Mindszenty, 2000). A and B indicate the location of stratigraphic columns in Fig 100.

CATALANO & D'ARGENIO (1982b) based on borehole data. The oolitic limestones (named Inici M2) are overlain by earliest Carixian bioclastic grainstones and packstones with micritized grains and by wackestones with radiolarians and sponge spicules, organized into thin sand prisms (Inici M3). The decrease of carbonate productivity indicated by these sediments records the dissection of the platform and the subsequent isolation of a submarine topographic high in the Monte Kumeta sector.

Though based only on indirect evidence, it is suggested that a tectonically controlled escarpment must have existed between the Monte Kumeta "high" and the basin. Progressive northward retreat of this scarp resulted in the conversion of a shallow platform sector into a gradually steepening slope, along which the distribution of sediments was controlled by repeated tectonic and gravity-induced modifications of the substrate topography. The vertical and lateral changes and geometrical relationships of the recognized lithofacies suggest that they were deposited on a stepped surface which was repeatedly rejuvenated by basinward-dipping normal faults (Fig. 101).

This scenario is clearly reflected in the relationship of the "normal" platform strata with the overlying Calcari a Crinoidi of Carixian/Domerian p.p. age. The encrinite bodies also are wedge-shaped, as they thicken towards the south while filling the first generation of neptunian dykes (Fig. 102).

The top of the Calcari a Crinoidi is marked by a peculiar jagged dissolution surface with dm-scale pinnacles capped by a thick ferromanganese crust (Di Stefano & Mindszenty, 2000). The formation of this peculiar surface could have been controlled by complex changes in water chemistry, probably related to the early Toarcian anoxic event and subsequent bioerosion. The crust itself is dissected by faults with throws ranging from decimetres to metres, sometimes organized into small-scale positive flower structures. In the hollows/depressions of this highly irregular substrate, the Rosso Ammonitico inferiore (RAI) of Bajocian to middle Oxfordian age was deposited. The RAI deposits display a clearly onlapping relationship to the encrinites and to the carbonate platform beds. Their thickness rarely exceeds 4 to 5 m, and they also occur as neptunian dykes filling a dense network of fissures.

As indicated by an intense brittle deformational event that dissected the upper levels of the RAI, during late Callovian and Oxfordian times a burst of synsedimentary tectonics resulted in a steepening of the slope. This produced deformation (slumping and sliding) of the semi-lithified and un-lithified sediments along the Monte Kumeta escarpment.

Four localities, here indicated as Substops 141-4, were selected in order to demonstrate some details of the complex Early and Middle Jurassic stratigraphic evolution of this sector of the Trapanese domain.

Fig. 100 - Schematic columns showing lateral variations of the Jurassic lithostratigraphic units at Monte Kumeta. For location of A and B see Fig. 99.
Substop 14.1 - “Cava Cerniglia”

In this quarry the extraction of Jurassic rocks has been more or less continuous during the last 20 years. The actual quarry floor is roughly NS-oriented, elongate, rectangular in plane view with three main levels. The most interesting and longest, continuous wire-cut surface, offering the best dip-section, is exposed along the western wall of the lowermost level (Fig. 103). More features, like fossiliferous horizons, are well seen also at the higher levels. The most important features observed on the present-day’s quarry face and on the wire-cut blocks lying around are:

1) The RAI lithofacies, their lateral variations and the unconformable contact between the RAI and its substrate, marked by the serrate Mn-encrusted surface.

2) The effects of synsedimentary tectonics (fractures, faults, neptunian dykes, in situ breccias, gravity-driven mass-movements, like slumps and debris-flows).

3) Fossils, mainly ammonites condensed on the discontinuity surfaces.

Warning! Because of continuous working, descriptions and photos in this guidebook may not correspond in all details to the actual state of the wire-cut surface.

**LITHOFACIES IN THE ROSSO AMMONITICO INFERIORE**

The oldest unit exposed by recent quarry works near the bottom of the northern wall is the Inici M3. Above it, the white Calcari a Crinoidi follow through a sharp (bio) eroded contact. This unit is about 10 m thick. Towards the top, this formation shows an intergranular porosity filled by syntaxial overgrowth cements and reddish micrite, whereas downwards the porosity is filled only by the syntaxial cement. The Calcari a Crinoidi are also cut by several generations of dm to m scale sedimentary dykes oblique or parallel to the bedding planes and filled by various sediments obviously derived from the overlying succession. Along the upper contact between the Calcari a Crinoidi and the overlying RAI, the unusually well-preserved dissolution surface with dm-scale rectangular pinnacles occurs. In pockets among these pinnacles the earliest pelagic sediments of the RAI (micritic limestone with goethite-encrusted bio/lithoclasts) are preserved. Rare ammonites recovered from the interpinnacle material indicate the lower Toarcian (*Harpoceras serpentinum* Zone). The pinnacles and Toarcian sediments are equally covered by a thick ferromanganese crust which forms a mineralized hardground up to 10 to 15 cm thick.

Above the conspicuous Mn-Fe crust follows the Bajocian to Oxfordian section of RAI, having noticeable thickness variations and onlap geometries related to the underlying palaeotopography and to synsedimentary deformation. A profile measured close to the entrance of the quarry was selected to display most of the lithofacies identified so far:

**Red pseudonodular cephalopod limestone (RAIa)**

It is a dark red to red calcilutite overlying the main Fe-Mn crust and containing abundant Mn oxide-coated
**Pink wavy cross-bedded limestone (RAIb)**

It is separated from the underlying RAIa by a few cm thick discontinuous horizon of laminated goethitic marls. At places where the RAIa is absent (local relative topographic highs) the wavy cross-bedded limestone may directly overlap the thick Mn-Fe encrusted dissolution surface. The western wall of the quarry shows very well that the cross-bedded limestone has a lenticular geometry. Its thickness varies from a few up to 70 cm within a distance of about 40 m, reaching the maximum at about the middle of the present-day NS oriented wall, then it decreases again to a few centimetres in the NW corner of the middle quarry-level (Fig. 103). It consists of alternating laminae of coarser and finer, well-sorted, bioclastic grain/pack/wackestone with peloids, abundant *Bositra* sp. and other mollusc fragments, few benthic and planktonic foraminifers, ostracods, *Globochaete* sp.; small ammonites, gastropods, echinoderm fragments and
bioeroded lithoclasts. Small-scale wavy cross-lamination interpreted as current-ripple lamination is obvious at places. Sedimentary structures (current ripple lamination, grading) and lateral and vertical facies relationships suggest that the bioclastic sand was deposited episodically from swift currents on the otherwise starving sediment surface.

The uppermost few cm of this unit are a red, massive wackestone. Above, a laminated goethitic marl horizon follows, with abundant burrow fills and - in the more calcareous parts - with a rich late Bathonian [Hecticoceras (Prohecticoceras) retrocostatum] fauna (DI STEFANO et alii, 2002a). Such laminated layers occur frequently at different stratigraphic levels of the RAI. They consist of thin, about 1 mm, often torn-apart (sheared) laminae of yellowish brown goethitic/smectitic clay, and of thin laminae of micrite, all cemented by coarse sparry calcite grown perpendicular to the walls of the interlaminar space. Lithoclasts deriving from these deposits are often embedded in neptunian dyke fillings. Interpretation of the observed textures requires more than one episode of deformation following early compaction of the clay/marls deposits. The first phase of deformation may have been downslope creep, resulting in small-scale bed-parallel displacement of the ductile clay/marl laminae, generating interlaminar cavities where diagenetic fluids could precipitate the palisade calcite.

Red pseudonodular marly limestone (RAIc)

It is a reddish calcilutite characterized by a pseudonodular texture due to presence of early diagenetic nodules, ammonite moulds and bioturbation traces. The dominant microfacies is a bioclastic packstone/wackestone with radiolarians, less abundant thin-shelled bivalves, thicker, heavily bioeroded fragments of assorted molluscs, benthic forams, echinoderm fragments, peloids, rare micritic lithoclasts, embedded in a partly microsparry “matrix”. Also this unit shows considerable lateral thickness variations (from 0 to 90 cm), apparently compensating for the previous relief created by the lenticular geometry of the RAlb. It is subdivided by several bed-parallel goethitic marl intercalations. The number of the goethitic marl horizons varies according to the above mentioned thickness variations. The upper part of RAIc is particularly rich in large ammonites and is characterized by a series of Mn-coated condensation horizons. The most peculiar of them, about 5 cm below the contact with the overlying red/grey nodular marls, shows widely-spaced thin (1 to 3 cm) finger-like pinnacles of a bioeroded surface, coated by a thin Mn-oxide film. The height of these pinnacles is up to 5 cm. Ammonites recovered from this unit indicate the middle Callovian (Reineckeia anceps Zone). The contact of RAIc with the overlying red/grey nodular marl (RAId) is sharp, marked by a thin discontinuous Mn-oxide crust with clear evidence of microbial activity (laminated, bulbous structures).

Red/grey nodular marls (RAId)

The basal part of it is distinctly nodular and more calcareous than the upper section, while the upper part grades into the overlying radiolaritic unit. The microfacies is a wackestone with micropeloids, shell fragments, radiolarians, sponge spicules, bioeroded echinoderm fragments, abundant planktonic and a few benthic forams. Nodules here show evidence of having been resedimented by gravity flows. Evidence for mass transport includes slump structures and concentration of early diagenetic nodules to form “pebbly mudstone” layers. As indicated by belemnite assemblages, and by calcareous nannofossil and radiolarian biostratigraphy this unit can be assigned to the lower Callovian-middle Oxfordian (MARIOTTI, in press and this volume, field trip B2).

SYNSEDIMENTARY DEFORMATIONS AND ASSOCIATED FEATURES

One of the most evident features to be observed in this quarry is the response of sedimentation to repeated events of deformation.

Neptunian dykes

The earliest event of fracturing affecting the Calcari a Crinoidi clearly predates the formation of the main Fe-Mn crust. Fractures may be both vertical to subvertical or bed-parallel, and their width varies from centimetres to metres. The irregular walls of the fractures and the rounded appearance of the host rock blocks suggest that the sediment was not completely lithified when it underwent deformation. Some fissures have a polyphase filling suggesting either reopening of the same space or gradual filling by different sediments. In places,
subvertical dykes are connected to swarms of thin fractures with the same filling, thus giving rise to an in situ breccia texture. The thin fractures are interpreted as injection dykes (MONTENAT et alii, 1991). A later generation of fractures cutting across the main Fe-Mn crust has been dated as late Bajocian due to the occurrence of characteristic brachiopods [Appringia cf. alontina (DI STEFANO)].

Most subvertical dykes show an homogeneous orientation (E-W, NW-SE) pointing to a tectonic control for their opening (MALLARINO, 2002, in press).

Other deformational structures
A brittle deformation event affected the Calcari a Crinoidi, also displacing the Fe-Mn-encrusted pinnacled surface. The rejuvenated topography controlled the deposition of the lower part of RAId. One of the related features was detected and documented in the late 90’s as a m-scale flower-like positive structure with associated clear onlap relationship of RAI lithofacies. In the upper two levels of the quarry it is still possible to see the effects of this articulate topography, like the direct contact between the upper part of RAId (middle Callovian) and the underlying Fe-Mn encrusted Calcari a Crinoidi, and the merging of the goethitic marl horizons intercalated in the RAI into one level.

Another spectacular feature of “Cava Cerniglia” is a later brittle deformation event clearly postdating RAId and resulting in ductile deformation of at least a part of the overlying upper Callovian-lower Oxfordian red/grey nodular marls (RAIc). This was particularly evident along the western quarry face in 1999, so it could be described in some detail (see Fig. 103). The faults are predominantly E-W to WNW-ESE striking normal faults, pointing to an overall extensional regime and resulting in cm- to m-scale displacements. Minor reverse faults indicate local compression. The observed ductile deformation of the nodular marl (RAId) is clearly related to the above described tensional event. The distribution of slumps and associated gravity-driven debris flow deposits suggests that this faulting rejuvenated the local palaeotopography by steepening the palaeo-slope toward the present-day south.

The contact between Inici M3 and the overlying Calcari a Crinoidi is characterized by a sharp surface (Fig. 104c-d) along which small-scale bioerosional cavities can be observed in places. Rare, cm-scale subvertical dykes filled with crinoidal sands can also be seen on the wire-cut surface. Otherwise the contact surface is criss-crossed by several generations of cm-sized neptunian dykes filled either by a yellowish calcilutite with angular lithoclasts, or by calcite cements and varicoloured silt. The surface is also repeatedly cut by several subvertical faults, producing cm-scale displacements that postdate the deposition of the Calcari a Crinoidi. The thickness of the Calcari a Crinoidi ranges from about 1.5 up to 4 m. The upper boundary of this unit is a sharp, stepped unconformity sealed by RAI deposits.

In the lower part of the eastern side of the quarry, the RAI deposits onlap a m-scale palaeorelief of Calcari a Crinoidi. Here the RAI covers a thick Fe-Mn crust. Higher up, on the wire-cut wall a step of about 40 cm is observable (Fig. 104b). It is interpreted as the result of local downslope collapse of the topmost beds of the Calcari a Crinoidi, during the deposition of the RAI. The downslope collapse phenomena seem to have been favoured by bed-parallel neptunian dykes in the upper part of the unit, which served as detachment surfaces. The mechanical removal of joint-bound blocks gave rise to a stepped surface sealed by the RAI limestones (stepped unconformity, sensu WINTERER & SARTI, 1994). The overlying RAI contains dm-scale lithoclasts either of Mn-Fe-coated pinnacles or fragments of the Fe-Mn crust. These lithoclasts are obviously derived from adjacent upslope areas which were exposed and eroded at those times. Sections of ammonites observed in the lower RAI indicate a Bajocian age for the sediment filling the stepped unconformity.

The general relations and depositional geometries as observed in “Cava A” and the adjacent areas clearly points to the lateral (northward) pinching out and onlap of the Inici M3 and of the Calcari a Crinoidi on a stepped surface of Inici M2. The resulting palaeotopography was repeatedly rejuvenated also in this case during the deposition of the RAI, producing multiple unconformities.

Substop 14.2 - “Cava A”

This is a small, abandoned quarry along the road about 300 m west of “Cava Cerniglia”, formed by two nearly perpendicular wire-cut surfaces (Fig. 104b). These surfaces expose:

i) the contact between Inici M3 and the overlying Calcari a Crinoidi;

ii) the Calcari a Crinoidi top, here marked by a stepped surface without pinnacles;

iii) the stepped unconformity of the RAI deposits.

This is a small (about 6x6 m) outcrop on the gently sloping hillside. Features to be observed are:

i) contact between Inici M3 and the overlying RAI (the Calcari a Crinoidi are missing);

ii) downslope transport of Mn-encrusted broken pinnacles by submarine debris-flows along the exposed surface of the Inici M3.

The base of the section exposes an about 1 m thick section of the topmost zone of the Inici M3, consisting of
Slumped red-gray nodular marls with broken pinnacles, belemnite concentration and debrite intercalations

Bositra packstone partly slumped with large angular pinnacled lithoclasts

laminated marls

Bositra packstone debrite

Reddish bioclastic wackestone with Fe-Mn nodules

Fig. 105 - Stratigraphic log of a measured section at “Cimitero dei pinnacoli” (after Di Stefano et alii, 2002).

a radiolarian and sponge spicule-bearing wackestone with scattered oncoids and small benthic forams. The Inici M3 top is a sharp surface draped by the RAI deposits. Along the surface a step of about 1 dm is filled up by a reddish pelagic calcilutite with some cm-sized Fe-Mn nodules concentrated at the base. Both the Inici M3 and the step-filling calcilutite are abruptly overlain by a ~40 cm thick debrite consisting of a red calcilutite matrix which supports dm-sized broken pinnacles of Calcari a Crinoidi that are coated by Fe-Mn crusts (Fig. 104f-g). Ammonites occurring in the matrix indicate an upper Bajocian age for this debrite bed. A few cm thick Bositra lumachella overlies this bed, also filling fractures in the underlying beds. Well preserved ammonites in these fracture-filling sediments indicate a late Bathonian [Hecticoceras (Prohecticoceras) retrocostatum Zone] age.

A 40 cm thick bed of goethitic sheared clays with abundant trace fossils follow upward. It is overlain by a centimetric alternation of reddish Bositra bioclastic grain/packstone to thinly-laminated bioclastic wacke/mudstone, showing at places structures related to soft sediment deformation. Along this bed also bears a large block of Fe-Mn encrusted Calcari a Crinoidi (Fig. 105).

The last exposed unit upward is the varicoloured marly calcilutite (RAI1d). As in “Cava Cerniglia”, this unit is slumped, bearing pebbles of red calcilutites and abundant belemnites and aptychi. The observed features indicate a long-lasting downslope mass transport of RAI deposits embedding also lithoclasts mainly derived from the pinnacled surface of the Calcari a Crinoidi.

It is suggested that the upslope morphology was a stepped surface exposing in places the Fe-Mn-encrusted pinnacled discontinuity. The pinnacled debrites point to an intense mechanical erosion of the Calcari a Crinoidi in the upslope area, also postdating the formation of the dissolution surface.

Substop 14.4 - “Cava Palo”

“Cava Palo” is a small, abandoned quarry at about the middle of the slope of Monte Kumeta. Along the south-facing E-W trending quarry wall a sharp unconformity between Inici M2 and the RAI can be observed in detail (Fig. 104a).

Features to be observed:

i) The oolitic limestone of Inici M2 cut across by vertical/subvertical and subhorizontal, sometimes polyphase neptunian dykes filled by several generations of varicoloured calcilutites.

ii) The uneven stepped, at places Mn-encrusted contact between Inici and RAI without intervening Inici M3 and/or Calcari a Crinoidi.

iii) The draping of the basal layers of RAI above the stepped surface.

iv) A palaeotopographic depression filled by alternating layers of a Bositra-rich calcilutites and laminated goethitic-marly/clayey horizons.

Inici M2 consists of well-sorted bioclastic/oolitic grainstones with Paleodasycladus and Thaumatoporella. Reddish calcilutites from the overlying RAI penetrate a dense network of fractures and infiltrate in places an intergranular porosity in the grainstone. Between Inici M2 and the RAI deposits neither Inici M3 sediments, nor the Calcari a Crinoidi occur in this section. This is a common relationship observed on the upper slope of Monte Kumeta.

The Inici surface is characterized by dm-scale fault steps predating the RAI deposition. Additionally, later small faults displace the unconformity surface and the overlying RAI. On the Inici surface a discontinuous Fe-Mn crust occurs, from which middle and upper Toarcian ammonites were collected (F. Macchioni, pers. comm., 2000). Upwards, a bed about 20-40 cm thick rests on this stepped morphology. It contains scattered fragments derived from the main Fe-Mn crust, and in places, angular fragments of Inici.

The articulate palaeotopography in the eastern part of the quarry shows a m-scale depression filled up with alternating Bositra-rich limestone and laminated goethitic-marly/clayey horizons which laterally pinch out completely. The Bositra limestone exhibits a distinct normal gradation given by a concentration of randomly
oriented shells at the base, passing upwards into a very fine bioclastic pack/mudstone with small oriented fragments of thin-shelled bivalves. They are interpreted as channel-filling microturbidites.

The local section is topped by a bed of reddish Bositra limestone, about 80 cm thick. Higher up, along the present-day slope, thinly-laminated Bositra limestones and the varicoloured marly limestone of the RAId can be also observed. E-W trending subvertical neptunian dykes with a polyphase filling cut across the Inici limestone both in the western and eastern termination of this quarry.

STOP 15 - LATE JURASSIC EVOLUTION OF THE SUBMARINE ESCRAPMENT AT MONTE KUMETA

M. MARINO, U. NICOSIA, & M. SANTANTONIO

As anticipated in the previous stop, Monte Kumeta represents an escarpment tract marginal to a Jurassic intrabasinal high – a product of Early Jurassic extensional tectonics (MARIOtti et alii, 2001). This stop is aimed at analysing the facies, sedimentary features and geometries of the upper Callovian-Tithonian deposits, and their bearing on the reconstruction of the geodynamic evolution of this structure during the Late Jurassic. Reference to an “escarpment” is here due to the fact that the post-drowning deposits rest unconformably on an erosional surface that truncates bedding of the peritidal substrate.

The upper Callovian-Tithonian succession is characterised by carbonate and siliceous deposits and by mixed pelagic condensed/resedimented deposits that rest unconformably both on the shallow water limestones of the Inici Fm. and on the Rosso Ammonitico Inferiore (RAI). Resedimented deposits also bear lithoclasts that are made up of carbonate platform limestone (Inici Fm.) and of pelagic carbonate. All these features match the “composite pelagic association” of SANTANTONIO (1993), which is typical of escarpments bordering pelagic carbonate platforms. The lack of a condensed pelagic succession conformably lying on the Inici Fm. (“pelagic condensed facies association” of SANTANTONIO, 1993), and the volumes of resedimented material imply that much of the original depositional system, most noticeably the top of the palaeostructure representing the source area of clastics, is unpreserved.

The palaeoescarpment is now NE-SW dipping, as shown by the NE-SW thickening of the different units (see also the previous stop). The carbonate and siliceous pelagic deposits pinch out towards the top of Monte Kumeta, where only the Inici Fm. crops out (Fig. 106). These geometries indicate that the present-day western area corresponds to the distal sector of the Jurassic structure, while the present-day eastern area corresponds to its proximal sector.

Besides possessing a wedge geometry, the Upper Jurassic post-radiolarite succession (Rosso Ammonitico Superiore – see below) characteristically bears spectacular evidence of mass transport and sediment instability in the form of slumps, intraformational truncations, and shallow growth faults. This demonstrates that following partial sealing of the Early-Middle Liassic escarpment topography by the Rosso Ammonitico Inferiore, the area became a slope that was locally oversteepened. The Rosso Ammonitico Superiore apparently behaved here as a detached body with respect to the substrate. Its “thin-skinned” deformation might either have been the product of sea-bottom instability (slow creep to sliding) triggered by gravity alone, or the surficial response to faulting in the substrate. No Late Jurassic faults, however, can positively be documented at Monte Kumeta.

The presence of clasts of Inici Fm. in the succession requires sourcing from submarine outcrops of the pre-drowning carbonates. This demonstrates that, along this relatively low-angle escarpment, draping by pelagic deposits was discontinuous due to the occurrence of non-depositional spurs of peritidal bedrock.

LITHOSTRATIGRAPHY

The local post-Inici Fm. Jurassic succession consists of four lithostratigraphic units (from bottom to top):

Rosso Ammonitico Inferiore (RAI)

Only the uppermost lithofacies of this unit [upper Callovian-middle Oxfordian red/grey nodular marls (RAId)] is here considered (see Stop 14). The analysis of this lithofacies is included with this stop because it is indispensable for the interpretation of the Late Jurassic stratigraphy and geodynamic evolution of the Monte Kumeta structure. It is composed of nodular limestones and brown to yellow-greenish marls, with an impressive amount of belemnites, aptychi, corals, crinoids, rhycholites, echinoderm fragments and shark teeth. The RAId crops out discontinuously and its best exposure is in the “Cava Cemiglia” (see Substop 14.1). There it overlies the uppermost hardground of the RAI, assigned to the Callovian (Anceps Zone). Slumps may occur at the base of the RAId, and at the top resedimented levels embed clasts of the Inici Fm. and soft clasts derived from the RAI itself (see previous stop). At the top, some levels are silicified, probably due to a diagenetic underbed effect of the overlying cherty sediments.
In the eastern area, where the Membro Radiolaritico Intermedio (MRI) wedges out, this lithofacies is directly overlain by the resedimented deposits of the Rosso Ammonitico Superiore (see below). In the very proximal sector, it is “squeezed” among large resedimented blocks of a local breccia (see Substop 15.4).

The belemnite assemblage, calcareous nannoplankton and radiolarians reveal a late Callovian-middle Oxfordian age (MARIOTTI, in press; see this Guidebook field trip B2).

*Membro Radiolaritico Intermedio* (MRI) (middle Oxfordian-lower Kimmeridgian)

Cherts and cherty limestone, greenish-grey at the base and reddish at the top. This unit is clearly wedge-shaped, reaching its maximum thickness (about 15-20 m) in the SW sector of Monte Kumeta; the unit pinches out north-eastwards, and disappears 200 m from the top of the mountain, abutting a local escarpment tract. No evidence of resedimentation is observable. Biostratigraphic data will be discussed in the Substop 15.1.

*Rosso Ammonitico Superiore* (RAS) (?lower Kimmeridgian-lower Tithonian)

This unit exhibits the greatest lithofacies variability. It consists of an apparently heterogeneous complex of breccias, very fine to coarse calcarenites, nodular limestones, and sand-sized echinoid skeletal debris. Along the palaeoescarpment these rock types are organised into different sedimentary bodies. Resedimented deposits (mainly megabreccias) predominate in the proximal sector, where they unconformably overlie the RAI sediments, these latter lying in turn unconformably on the Inici Fm. The megabreccias terminate eastwards against the carbonate platform limestone which here forms a west facing cliff, rising for about 30 m to constitute the top of the mountain.

![Fig. 106 - Schematic representation of the stratigraphic setting of the Jurassic deposits of Monte Kumeta, as reconstructed along an E-W transect.](image-url)
At the very base, a polygenic breccia with decimetre to metre-sized clasts rests on the radiolarian cherts through an erosional contact. This breccia crops out in several places, and it is well seen in the eastern sector of the mountain (Substop 15.1).

The lowest sedimentary body (RB I) consists of a massive matrix-supported breccia (about 5 m thick). The clasts are decimetre to metre across, and they are referable both to the Inici Fm. (very angular) and to its pelagic cover (angular to rounded). The breccia thins out westward within a distance of few tens of metres. The massive breccia is covered by a nodular pebbly mud- to siltstone also wedging out to the west (see Substop 15.3).

A second rock body (RB II), up to 6 m thick, is composed of echinoid calcarenite. Some of these calcarenite beds have downlap terminations towards the west.

The third rock-body (RB III), which will not be examined in detail in this field-trip, is composed mainly of bedded calcarenite; more distally, several pebbly mudstone levels occur. Calcarenites bear assemblages with regular and irregular echinoids, whereas aptchi, ryncholites and crinoids are found in pebbly-mudstone levels, in the lower beds. Towards the top, this unit is mostly made of Saccocoma-rich calcarenites. In the lower portion of the RB III, intraformational truncations and cut-and-fill erosional contacts among beds are visible; however, the upper part of the section has beds with a regular tabular geometry. Up-section, and distally, evidence for sediment gravity flow decreases, and nodular limestone is dominant, thickening westwards.

Ammonites provide biochronological constraints for the base of the RAS; the basal breccia bears upper Kimmeridgian ammonites (Pseudawaagenia acanthomphala) at the base of the RAS, and of a late Callovian-middle Oxfordian belemnite assemblage at the top of the RAI (RAId) serve to better constrain its age.

The nannoplankton assemblages found in samples from this unit are characterised by Lotharingius crucicentralis, L. hauffii, Retecapsa incompta, Cyclagelosphaera margerelii, C. deflandrei, C. wiedmannii, Watznaueria ovata, W. britannica, W. barnesae, W. manivitae. Schizosphaerella is not present in the assemblage, which could be referred to the Oxfordian-lower Kimmeridgian, before the last occurrences of Lotharingius crucicentralis and L. hauffii.

**Lattimusa Fm. (upper Tithonian-Berriasian)**

Calpionellid-rich mudstone and wackestone; at the base sediments are nodular and ill-bedded, and they seem to onlap the underlying deposits; up section, beds are tabular. This unit crops out only in the western and southwestern sectors, about 500 m from the top of Monte Kumeta. Only the lower part of the formation was sampled.

**SUBSTOPS 15.1-5**

These substops lie along a W-E transect, corresponding to a distal to proximal transect of the Jurassic structure.
Substop 15.2 - The base of the RAS

M. Marino, N. Mariotti & U. Nicosia

The substop is located on the northern side of Monte Kumeta, near the forestry observation tower.

In this substop it is possible to observe a megabreccia resting directly on the uppermost beds of the MRI, here made of reddish radiolarian cherts, with alternating calcisiltite levels, about 1 cm thick. This breccia represents the base of the RAS unit, and contains a megaclast, about 1 m across, of peritidal limestone (Inici Fm.).

The breccia represents the first evidence of the restart of resedimentation processes after the quiet interval in which undisturbed cherty sediments were deposited. This indicates rejuvenation of the local sea-bottom topography, possibly linked to a tectonic phase.

Substop 15.3 - Geometries of resedimented beds

P. Di Stefano, M. Marino, N. Mariotti, U. Nicosia & M. Santantonio

A few tens of metres westwards along the northern side of the mount, abandoned quarry works allow observation of the 5 m thick lateral equivalent of the breccia seen in the previous stop. This is the lower part of lobe RB I (see above; Fig. 107). It is an heterometric and polygenic breccia, bearing clasts of the Inici Fm. (very angular) and of the RAI. The clasts are scattered and the deposit is mud rich and matrix-supported. This might indicate either a) collapse and disruption of an Inici + RAI + RAS escarpment-tract succession, followed by downslope mass flow with still unconsolidated RAS acting as a cohesive matrix, or b) freefall of clasts of Inici and of RAI from a submarine outcrop into the RAS, followed by slow creep, or c) freefall of clasts of Inici from a submarine outcrop into the RAS, followed by sliding along a detachment surface cutting a RAI + RAS
succession. Interpretation c) implies conversion into a mud-supported debris flow of an originally clast-supported rockfall deposit.

Moving toward the southern side of Monte Kumeta, the second sedimentary body (RB II) of the RAS is beautifully exposed. It is a regularly bedded echinoid calcarenite. In this stop the westward downlap of these beds is clearly visible (Fig. 108).

The downlap geometry suggests lateral accretion of the echinoid-calcarenite that prograded over RB I. More to the west, slumping is observed in more mud-rich beds. Their snout and dip of the axial planes indicate transport towards western quadrants.

Substop 15.4 - Syn- and early post-depositional deformation structures

P. Di Stefano, M. Marino, N. Mariotti, U. Nicosia & M. Santantonio

A bedded nodular limestone rests on the massive breccia of RB I, showing synsedimentary or early post-sedimentary deformation, growth faults and collapse structures.

The growth faults (Fig. 109) are closely spaced (about 1 m) and occur corresponding to slight depressions of the ondulated breccia top: multiple phases of thickening and roll-over of the beds are observed associated with these faults. The fault-planes are listric and affect the nodular limestone, flattening above the underlying breccia, and utilizing plastic marls as the detachment surface. At another spot, collapsed and folded beds (Fig. 110) apparently fill the space left by creep or extensional faulting of the substrate, in the latter case being the ductile surficial response to deeper-seated brittle deformation.

These structures are visible on two perpendicular walls of another abandoned quarry, more to the east: the growth faults are exposed on an approximately E-W oriented wall, the others are observed on a N-S oriented wall (contiguous to the former).

Substop 15.5 - The most proximal sector of the escarpment

P. Di Stefano, M. Marino, N. Mariotti, U. Nicosia & M. Santantonio

This substop is located in the eastern sector of Monte Kumeta, not far from the mount summit, an area with several vertical strike-slip faults (striking about N50°). A chaotic complex of blocks, totalling several tens of cubic metres, is observed. Eastwards this megabreccia rests through a strong angular unconformity on the Inici Fm. that forms a west facing cliff, rising up to the top of the mountain. The cliff shows Inici Fm. cut by neptunian dykes filled by RAI sediments; the presence...
of discooidal gastropods suggests a Toarcian-Aalenian age for the infilling. RAI deposits also form thin veneers draping the Inici Fm. surface. This cliff represents a very steep tract of the palaeoescarpment complex, probably originated through disintegration of a severely fractured zone, causing exposure of the older fracture-filling material through detachment of basin-facing dyke walls. Westwards, the megabreccia lies on marls of late Callovian-middle Oxfordian age, dated through belemnites and calcareous nannoplankton, belonging to the RAId.

Some blocks are made of steeply (60-70°) dipping bedded echinoid calcarenite (RB II of the RAS), representing fallen stacks of lithified material. It is interesting that these calcarenites bear themselves lithoclasts, indicating repeated phases of erosion and mass transport (Fig. 111). The original source area of these beds is unreserved. We interpret this megabreccia as a rockfall deposit that probably underwent some later plastic flow due to the presence of un lithified material. Due to absence of the MRI unit in this sector, the blocks fell directly onto the late Callovian-middle Oxfordian marls, which became locally squeezed by loading and were pervasively injected from below into the breccia.

CONCLUSIONS

The evidence of mass flow of partially to non-consolidated material, and of free-fall of the lithified peritidal substrate indicates that the present-day Monte Kumeta structure represents a tract of a Jurassic stepped escarpment partly covered by slope deposits.

RB I is mainly characterised by breccia beds, RB II by the occurrence of slumping, and RB III (as seen in the more distal western outcrops) by intraformational truncations. This indicates that this escarpment tract became a slope prograding to the west, as seen through the up-section change from a product-accumulation facies to an upper slope facies with erosional surfaces. This is also consistent with the overall downlap geometries of individual sedimentary units (Fig. 112).

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Post-Symposium Field Trip B1
(19-22 September 2002)

THE TRAPANESE DOMAIN

SCIENTIFIC COORDINATORS

LUCA MARTIRE & GIULIO PAVIA

CONTRIBUTORS

A BECCARO, CARLO BERTOK, ALESSANDRO BOVERO, FABRIZIO CECCA, CAROLINA D’ARPA, ROBERTO LANZA, FRANCESCA R, LUCA MARTIRE, GUILLERMO MELENDEZ, FEDERICO ORIZ, GIULIO PAVIA, BERENGERE SAVARY.
FOREWORD

The goal of this field trip is to illustrate the striking litho- and biostratigraphical variability of Jurassic deposits across the Trapanese Domain. The itinerary will develop along a counterclockwise circle starting with the Monte Inici area, representing the central part of a pelagic carbonate platform. Then, in the Erice area, we will observe a stratigraphic succession which is thicker and rich in reworked beds, suggesting a ramp environment connecting a shallow platform to the pelagic plateau. On the last day, we will finally move to Rocca Busambra, which should represent the tectonically controlled margin of the Trapanese Domain.

We would like to thank Dr.Ing. A. Ganci, Azienda Regionale Foreste Demaniali, Ufficio Provinciale di Trapani, for their kind logistic support.

Luca Martire & Giulio Pavia

Fig. 1 - Itinerary of the B1 Field trip across the Trapanese Domain of western Sicily. 1st day: stops 1-5. 2nd day: stops 6-8. 3rd day: stop 9.
STOPS 1-5 - MONTE INICI: LITHOFACIES, BIOSTRATIGRAPHY AND SUBUNITS OF THE ROSSO AMMONITICO FORMATION - AN INTRODUCTION

F. Cecca & L. Martire

The outcrops of Monte Inici beautifully illustrate the Jurassic evolution of the Trapanese palaeogeographic domain, which developed through two main stages: 1) the deposition of the Upper Triassic-Middle Liassic peritidal platform carbonates represented by the Inici Formation, and 2) the drowning of the platform and birth of a pelagic plateau, followed by deposition of relatively condensed pelagic limestones (Rossio Ammonitico). A cherty limestone unit is locally present in the middle part of the Rosso Ammonitico, and can be used to subdivide it into two members: the Lower Rosso Ammonitico (RAI) and the Upper Rosso Ammonitico (RAS).

The stops in this field trip (Fig. 2) illustrate two distinct types of stratigraphic successions.

The absence of siliceous levels characterizes the Monte Inici East section (Stop 1) where the Rosso Ammonitico is continuously exposed. Conversely, cherty limestones sandwiched between the RAI and the RAS are found in the Castello Inici section (Stop 2), in the southwestern sector of Monte Inici (Warman & Arkell, 1954; Christ, 1960; Wendt, 1964; Savary, 2000; Savary et alii, in press). Finally the complete three-member Rosso Ammonitico succession is best exposed in different outcrops in the vicinities of the abandoned quarry of Contrada Fornazzo (Stops 3-5).

STOP 1 - MONTE INICI EAST: THE ROSSO AMMONITICO SUCCESSION WITH NODULAR FACIES AND NO CHERTY BEDS

F. Cecca & B. Savary

The section is naturally exposed (though it was formerly quarried in some sectors) along the north and west sides of a narrow and steep valley (Fig. 3).

As not all of the succession is accessible on either side, observations are combined into a single stratigraphic log (Figs. 4, 5). A few normal faults affect the outcrop, but do not preclude the establishment of the vertical succession. Above the Inici Formation, a 34 m thick Rosso Ammonitico succession crops out: it has been subdivided into 59 intervals. Our sampling ends with interval 60, which marks the beginning of the Lattimusa Formation. Detailed sedimentological and stratigraphical descriptions of this section can be found in Cecca et alii (2001).

The visit to the section is organized in three phases aimed at examining the nodular facies of the middle Oxfordian - upper Berriasian interval, and the biostratigraphy and taphonomy of middle Oxfordian to lower Kimmeridgian and of uppermost lower Tithonian
ammonite assemblages.

Some introductory notes are nevertheless necessary.

**BASE OF THE ROSSO AMMONITICO**

The base of this succession forms a small cliff, partly inaccessible, consisting of extremely hard light coloured non-nodular micritic limestones. It has not been accurately dated as no ammonites have been recovered from intervals 1 to 5, which have been assigned to the Callovian based on data from nearby outcrops (Warman & Arkell, 1954; Christ, 1960; Wendt, 1964). The Rosso Ammonitic succession begins with a characteristic 5-10 cm thick lag deposit containing abundant glauconitic clasts, and broken mineralised stromatolites in a micritic matrix containing Bositra and crinoid remains. This lag deposit is overlain by non-nodular limestones containing stromatolitic crusts and ferro-manganese stromatolitic nodules (“snuff boxes”) about 20 cm above the base of the Rosso Ammonitico. A similar lag deposit is nicely exposed in the Contrada Fornazzo quarry, which is the object of Stop 3. The base of the Rosso Ammonitico here is younger than elsewhere in the Trapanese Domain, where the lowest pelagic sediments, usually preserved as small “pockets” resting unconformably on the Inici Formation, are Toarcian in age (Wendt, 1964; Di Stefano & Mindszenty, 2000). Considering that most probably the drowning was synchronous all over the Trapanese Domain, and that the oldest ammonite age for the post-Inici succession is Callovian, we must conclude that the Inici sector was bypassed by sedimentation for a long time.

**THE NODULAR FACES**

The lowest nodular facies are represented in Bed 6, which is dated as middle Oxfordian Gregoryceras transversarium Zone. Three major sedimentological components form the Rosso Ammonitic at Monte Inici: 1) early diagenetic nodules sensu Clari et alii (1984); 2) mineralised intraclasts; 3) matrix. Anisometric early diagenetic nodules are mm to pluri-cm sized and slightly flattened parallel to bedding planes, and show transitional contacts with the matrix. These nodules are neither mineralised nor bored. The mineralised intraclasts, which are about 1 cm in diameter, are generally sphaerical, bear a mineral coating, and are bored in some instances. The matrix is less coherent and more argillaceous than nodules and is commonly affected by dissolution seams. Three subfacies have been recognised (Savary, 2000) in this succession on the basis of the variable abundance of these major sedimentological components: 1) a nodular subfacies (Clari et alii, 1984), matrix-supported, with early diagenetic nodules but no mineralised intraclasts; 2) a pseudo-nodular subfacies (Marti, 1996), relatively matrix-poor with early diagenetic nodules and mineralised intraclasts; 3) an intraclastic nodular subfacies (Savary, 2000), matrix-supported and containing both early diagenetic nodules and mineralised intraclasts. Evidence of hydrodynamic erosion, such as erosional surfaces, truncation and taphonomic reworking of ammonite internal moulds, is recorded in both the intraclastic nodular and pseudo-nodular subfacies.

The matrix, early diagenetic nodules and intraclasts have significant textural differences. The matrix is predominantly packstone whereas the early diagenetic nodules and intraclasts are wackestones. This contrast has been explained as a result of selective early cementation of nodules, which prevents subsequent compaction (Marti, 1996). The diversity of skeletal elements contained in the nodules is higher than that in the matrix. Radiolarians are exclusively found in the nodules: early cementation has preserved the original composition of the sediments, preventing the occlusion of pores created by the dissolution of unstable siliceous tests.

**MICROFACIES**

The vertical distribution of the microfacies shows several trends (Fig. 5). Abundant Bositra and crinoid remains dominate the matrix of the lag deposit at the bottom of the Rosso Ammonitic. An abrupt change is recorded about 20 cm above, in the snuff box interval, and this marks the appearance of a diverse pelagic microfossil assemblage, including protoglobigerinids, which replace the previously dominant Bositra, belemnites, calcareous dinocysts, radiolarians and benthic foraminifera. Diversity reaches a peak in the middle of Level 6 (middle Oxfordian, G. transversarium Zone) where Saccocoma appears. In the overlying beds, the next major event is the decreased abundance of Globochaete coincident with the appearance of calpionellids at the base of Bed 42, where Saccocoma abruptly disappears.

**KEY TO SYMBOLS**

![Fig. 4 - Key to symbols used in figures 5 and 6.](image-url)
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Fig. 5 - Log o f the Monte Inici East section with vertical changes in fossil content, textures, skeletal elements, intraclasts and subfacies
distinguished in the Rosso Ammonitico. Note that Beds 1 to 5, 7 and 11 are non-nodular. Zonal and subzonal biostratigraphical subdivisions
are based on ammonites and calpionellids (A, B, C, D zones).


**AMMONITES**

The Rosso Ammoniticco is the most common ammonite-rich deposit of the Tethyan region. Despite the abundance of fossils, it is characterized by time-averaging and discontinuous deposition, that at some stratigraphic levels prevents the establishment of a detailed biozonation at the subzone level and/or the precise placing of zonal boundaries (MARQUES et alii, 1991; OLORIZ et alii, 1993, 1998). Nevertheless, closely spaced sampling in this section led to the identification of several ammonite zones between the middle Oxfordian *G. transversarium* Zone and the upper Tithonian *Paraulacosphinctes transitorius* Zone.

It was not possible to extract fossils in the interval from Bed 1 to Bed 5 because of unfavourable outcrop and extreme hardness of the rock. The same holds true for Beds 13 to 25, but in addition the rare workable beds of this interval are poorly fossiliferous. The middle Oxfordian - upper Kimmeridgian is the best characterized interval, and ammonites show interesting affinities with those described in the palaeogeographically comparable Subbetic Zone of Southern Spain (OLORIZ et alii, 1998, 1999; CARACUEL et alii, 1999, 2000). The biostratigraphically less significant Phylloceratina are the most abundant ammonites throughout the section, and this explains why most biochronological boundaries reflect a degree of uncertainty. The Oxfordian - Kimmeridgian boundary cannot be drawn precisely because neither the uppermost Oxfordian *Sutneria galar* nor the earliest Kimmeridgian *S. platynota* have been found. Ammonites of the *Sutneria platynota* Zone have been found at the top of Bed 10: *Orthospinites (Ardescia) bicus* and *Nebrodites passendorferiiformis*. There are no ammonite records that allow the Kimmeridgian-Tithonian transition to be identified. The base of the Tithonian has been tentatively placed at the base of Bed 14, based on a specimen of the genus *Haploceras*. The Tithonian-Berriasian boundary has been drawn by means of calpionellids.

**Substop 1.1 - The western side of the outcrop**

This side of the outcrop area provides good exposures of middle Oxfordian and lower to upper Kimmeridgian fossiliferous intervals. Sedimentological characteristics of the nodular facies and the taphonomy of ammonites can be observed.

The oldest ammonite assemblages found in this section come from the first nodular beds (interval 6). These contain numerous phylloceratids, with the dominant *Sowerbyceras tortisulcatum*, poorly preserved euaspidoceratids, perisphinctids and large passendorferiids (*"Perisphinctes" bocconii*, the specimen figured by GEMMELLARO, 1871, p. 55, pl. 12, fig. 2 only). *Gregoryceras fonquei*, associated with *Sequeirosia* (Gemmellarites) cf. *trichoplocus* and *Dichotomosphinctes* allows this assemblage to be assigned to the middle Oxfordian *G. transversarium* Zone. The lower part of the *P. (Dichotomoceras) bifurcatus* Zone is represented in Bed 6 based on the occurrence of *P. (Dichotomoceras) gr. bifurcatoides/stenocyclus*.

**CAUTION!** This interval crops out along a small but steep cliff which is accessible to only three persons at once.

The spectacular lower Kimmeridgian ammonite-rich Bed 12b is characterized by an extreme concentration of ammonite moulds, frequently fragmented and locally with evidences of taphonomic reworking. The base of this condensed interval contains an assemblage of the *Crussoliceras divisum* Zone: *Sowerbyceras* cf. *silenum*, Taramelliceras *gr. compsum*, *Nebrodites peltoideus*, *N. pulchellus*, *N. cf. heimi*, *Orthaspidoceras ziegleri*. This condensed interval probably correlates with the upper part of this zone, i.e. the *Orthaspidoceras ahlandi* Subzone, despite the fact that the index species has not been found so far. In fact, a condensed level of the same age extends throughout the circum-mediterranean region (MARQUES & OLORIZ, 1992). However, part of the upper Kimmeridgian is also condensed at the top of Bed 12b, where the *Mesosimoceras cavouri* Zone is represented by its index species.

**Note** at the base of Bed 12 the red chert bed. This is the sole cherty interval of this section.

**Substop 1.2 - The northern side of the outcrop**

Examination of this part of the outcrop is from younger to older beds of the succession. It begins with the observation of the lower-upper Tithonian strata, which represent the intraclastic nodular subfacies of the Rosso Ammoniticco. Ammonites are rare or represented only by the long ranging forms (phylloceratids, *Haploceras*). Bed 28 contains a rich fauna representing the "Djurdjuriceras" ponti Zone, i.e. the last biozone of the lower Tithonian, including its index species associated with both *Volanoceras volanense* and peculiar microconch morphotypes of *Haploceras carachtheis* characterized by shallow and widely spaced ventral ridges. Above Bed 28, the sole biostratigraphically significant ammonite found was in Bed 37. This is a badly preserved member of the family Himalayitidae bearing some of the typical characters of *"Pseudosimplisphinctes" jimenezi*, a species indicating the upper Tithonian *Paraulacosphinctes transitorius* Zone.

The upper Kimmeridgian - lower Tithonian massive limestones, mostly represented by the pseudo-nodular subfacies (intervals 13 to 16), are crossed in
order to reach the ammonitiferous upper Oxfordian strata of the *Epipeltoceras bimammatum* Zone. The latter is well represented by a rich and diverse assemblage from the upper half of Bed 8. The assemblage is numerically dominated by the phylloceratid *Sowerbyceras tortisulcatum* but the following species have been identified: *Calliphyllloceras benacense*, *Holcophyllloceras polyolcum*, *Lytoceras* sp., *Lissoceratoidea* sp., *Streblites frotho*, *Taramelllicerds* *cf.* *hauffianum*, *Physodoceras* *cf.* *wolffi*, *Passendorferia* (P.) *aff.* *tersiforme*, P. (Enayites) *aff.* *gygii*, *Passendorferia* (Enayites) *rozaki*, *Euaspidoceras* *sp.*, *Clambites* *sp.*, *Benetticeras* *sp.* *benetti*, *Physodoceras* *wolffi*, *Orthosphinctes* (O.) *tiziani*, O. (O.) *cf.* *mogosensis*, ? *Epipeltoceras* *sp.*, *Geyssantia* *geyssanti*. Most species occur in both the *Epipeltoceras bimammatum* and *Subnebrodites planula* Zones (Oloriz et alii, 1998, 1999a; Caracuel et alii, 1999, 2000), but assignment to the *E. bimammatum* Zone is corroborated by the appearance of a fragment resembling *Epipeltoceras* and a specimen of *Taramelllicerds* *cf.* *hauffianum* in Bed 8c. The latter indicates the homonym *T. hauffianum* Subzone, i.e. the uppermost subzone of the *E. bimammatum* Zone. Despite the lack of representatives of the genus *Subnebrodites*, Bed 9 may belong to the S. *planula* Zone based on the discovery of a single specimen of the genus *Subdiscosphinctes*.

**Substop 1.3 - The southwestern side of the outcrop**

An exceptional concentration of taphonomically reworked (reelaborated sensu Fernandeza-lopez, 1984) ammonite fragments is observed at the southern edge of the western side of the outcrop. This corresponds to the base of Bed 28 (upper lower Tithonian, "Djurdjuriceras" *ponti* Zone), marking an important lithological discontinuity with Bed 27 below. Numerous small, variably oriented, haploceratid moulds along with larger, sometimes truncated simoceratids have been collected.

Before leaving, the pseudo-nodular subfacies represented by the upper Tithonian-upper Berriasian part of the succession can be observed and sampled, particularly for calpionellids, which are remarkably well represented (Remane in Cecca et alii, 2001).

STOP 2 - MONTE INICI WEST: THE TRANSITION FROM THE NODULAR FACIES TO THE SILICEOUS MIDDLE ROSSO AMMONITICO IN THE CASTELLO INICI SECTION

F. Cecca & B. Savary

This section, located 3 km north-west of the section Monte Inici East, just North of Castello Inici, is exposed along a service road of the southern slope of the mountain (Fig. 2). The vertical changes in textures, fossil content, skeletal elements, intraclasts and subfacies distinguished in the Rosso Ammonitico are presented in Figs. 4 and 6.

The section demonstrates the existence of a lateral facies change between the middle Oxfordian cherty limestones and the coeval nodular limestones seen at the Monte Inici East section (Stop 1). Furthermore, the beds at the top of the RAI contain rich middle Oxfordian ammonite and belemnite assemblages.

The succession begins with the topmost surface of the Inici Formation. It shows neptunian dykes filled with pelagic micrites of different generations containing microfossil assemblages with radiolarians and *Bositra* remains but no age-diagnostic elements. The contact between the Inici Formation and the Rosso Ammonitico is not well exposed and probably faulted. The pelagic succession begins with a *Bositra*-rich limestone (Bed 2) characterized by non-mineralized stromatolitic structures. The textural characteristics of some deformed moulds of unidentifiable ammonites differ from those of the matrix and indicate reworking. Middle Callovian ammonites (*Reineckea* sp., *Paroxycerites* sp.) have been found at the top of Bed 3 (Fig. 6). The topmost Bed 4 contains ammonites (*Peltoceras* sp., *Orionoides* cf. *termieri*) indicating the upper Callovian *Peltoceras athleta* Zone.

The succession follows with nodular limestones where two different Rosso Ammonitico subfacies have been recognized: the pseudo-nodular subfacies characterises the intervals from Bed 3 to Bed 5 and from Beds 8 to 9, whereas the nodular subfacies occurs in beds 6 and 7. At the top surface of Bed 9 there is a condensed horizon with ammonites of the lower Oxfordian *Perisphinctes plicatilis* Zone: *Sowerbyceras* *cf.* *tortisulcatum*, *Euaspidoceras* *cf.* *douvillei*, E. cf. *lytocrideo*, *Tornquistes* (T.) *cf.* romani, *Gregoryceras* (Pseudogregoryceras) *itiyi*, *Perisphinctes* (*Dichotomosphinctes*) gr. *antecedens*. This condensed horizon marks the end of the Rosso Ammonitico, which is overlain by cherty limestones whose total thickness is unknown because the upper part of the Jurassic succession is not exposed. Furthermore, the base of this cherty succession is affected by faulting. Ammonites in intervals 10 and 11a date the lower part of the cherty limestones as middle Oxfordian *G. transversarium* Zone: *Sowerbyceras* sp. *Gregoryceras* *cf.* *riazi*, *Perisphinctes* sp. The onset of cherty limestones may be correlated with the abrupt sedimentary change to nodular facies in Level 6 of the Monte Inici East section. This corresponds to both a δ13C peak, and to the appearance of radiolitares in the adjacent sections of Monte Inici (Cecca et alii, 2001).
Fig. 6 - Log of the Castello Inici section.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Sub-stages</th>
<th>Zones</th>
<th>bed numbers</th>
<th>Subfacies</th>
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**Skeletal elements**

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<tr>
<th>Texture</th>
<th>Aptychi</th>
<th>Belemnites</th>
<th>Calcareous dinokysts</th>
<th>Radiolarians</th>
<th>Protoglobigerinids</th>
<th>Bivalves</th>
<th>Globochaete</th>
<th>Echinoderms without Saccocoma</th>
<th>Benthic foraminifera</th>
<th>Peloids</th>
<th>Mineralized intraclasts</th>
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STOP 3 - CONTRADA FORNAZZO QUARRY

L. MARTIRE, A. BOVERO, & G. PAVIA

A section of Rosso Ammonitico will be observed on the western side of Monte Inici, in the Fornazzo quarry (Fig. 7) and nearby localities. Here, differently from the eastern side of the mountain (Stop 1), three units of Rosso Ammonitico can be distinguished: the lower unit (RAI) and the upper one (RAS) are calcareous, with a more or less developed nodular structure; the middle unit (RAM) is characterized by thin and regular bedding and by a siliceous composition. The complete section (Fig. 8), however, is not exposed in a single outcrop. Four substops will be devoted to detailed examination of different parts of the succession: in the first, the top of the Inici Fm. and the lower unit of the Rosso Ammonitico; in the second, the top of the lower unit of the Rosso Ammonitico with neptunian dykes and the lower part of the middle siliceous unit of the Rosso Ammonitico; in the third, the middle siliceous unit of the Rosso Ammonitico; in the fourth, the upper unit of the Rosso Ammonitico, with a possible candidate for the Kimmeridgian-Tithonian GSSP, and the boundary with the Lattimusa Formation.

Substop 3.1 - Upper Fornazzo quarry

On the floor of this large quarry, the top of the Inici Fm. is widely exposed (Fig. 7).

It is not characterized by the typical pinnacle morphology that is almost ubiquitous in the Trapanese Domain, but corresponds to a flat surface with clear evidence of erosion. Subcircular cm-sized patches of yellow to dark red sediments are clearly recognizable on the quarry floor (Fig. 9).

When seen in vertical section these features correspond to subsphaerical, sharp-edged cavities with a short and narrow neck referable to bivalve boring.

---

Fig. 7 - The upper Fornazzo quarry. The quarry floor corresponds to the top of the Inici Fm. with scattered remnants of the lowermost beds of the Rosso Ammonitico Fm.

Fig. 8 - Lithostratigraphic log of the Rosso Ammonitico composite section cropping out in the Contrada Fornazzo area.
probably *Gastrochaenolithes orbicularis* (Kelly & Bromley, 1984). The borings are filled with grainstones or packstones with echinoderm and bivalve fragments, peloids and benthic foraminifers (*Vidalina*). Most of these borings are truncated in the upper part, and Fe-Mn oxides locally seal the infilling. Moreover, dm-deep depressions can be interpreted as scour structures. Altogether these features demonstrate that the top of the Inici Fm. suffered a phase of erosion predating the onset of the Rosso Ammonitico sedimentation.

Neptunian dykes, generally less than 10 cm across, both subhorizontal and perpendicular to bedding, and cm-sized irregular cavities interpreted as dissolution vugs occur in the last metre of the Inici Fm. They are filled with red laminated sediments ranging from mudstones to grainstones with filaments and/or echinoderm debris. A brick red mm-thick coating of the top surface of the Inici Fm. is locally observed.

Above, the RAI succession may be subdivided into several levels:

**Level 1** (10-30 cm) - The base of the Rosso Ammonitico is very condensed, discontinuous, rich in fossils and variable in thickness. It therefore deserves a detailed description (Fig. 10).

The first bed (1a) is easily recognized because it ends with an irregular knobby surface coated by a several mm-thick yellow limonite-stained crust. This effect is also seen on the walls of the abundant firm-ground burrows that cross the bed. The bed itself consists of packstone to grainstone with peloids, filaments and echinoderm fragments. Bed 1a can be traced across the whole quarry floor, but locally pinches out wherever the irregular top of the Inici Fm. rises. A maximum thickness of 20 cm has been measured.

Above the yellow limonitic hardground, a darker coloured richly ammonitiferous bed follows (Bed 1b), which is generally thinner and more discontinuous (0-15 cm). It consists of packstones with abundant protogloboigerinids and gastropod protochonchs stained black by Fe-Mn oxides, calcispheres, fine filaments, echinoderm debris and peloids. Undulated millimetric stromatolitic lamination is ubiquitous in the calcareous sediment whereas Fe-Mn-rich *Frutexites*-like crusts occur within the bed, probably marking minor discontinuities, and around intraclasts and ammonite moulds.

Also Bed 1b locally pinches out; wherever this occurs, the last bed (1c) directly overlies Bed 1a or even the Inici Fm. Bed 1c consists of a stromatolitic, *Frutexites*-like continuous layer, about 5 cm thick (Fig. 11), that is characterized by an irregular top where depressions correspond to the original lows existing among stromatiform domes.

Fig. 9 - Vertical section of a bivalve boring in the topmost Inici bed. (black-white divisions on the scale bar: 1 cm).

Fig. 10 - Sketch with details of the boundary between the Inici Fm. and the lowermost Rosso Ammonitico beds in the main Fornazzo quarry.

Fig. 11 - Polished slab of the stromatolitic, *Frutexites*-like crust with Fe-Mn oxides coating the top of Bed 1c in the main Fornazzo quarry. (black-white divisions on the scale bar: 1 cm).

Thick, black crusts of Fe-Mn oxides coat the top of Bed 1c but are present only in the depressions, indicating that erosion truncated the top of this bed following a prolonged non-sedimentation phase during which authigenic minerals grew on the stromatolitic mat. This is evidenced by the occurrence of a lag of Fe-Mn coated intraclasts and ammonite moulds in some inter-dome lows.
The basal beds of the Rosso Ammonitico Fm. at Contrada Fornazzo were made famous by Wendt (1964), who reported a long list of ammonites, some of which were also described in detail like the holotype of *Krumbeckia* (?)* nodifer*. The fossil assemblage is very rich, with more than 50 taxa recorded by Wendt and hundreds of beautiful specimens with brick-red internal moulds and iron-brown coated neomorphic shells. Actually, it is a mixed fossil assemblage with forms spanning the early Bathonian (e.g. the dimorphic couple *Morphoceras-Ebrayceras* and *Lobosphinctes metolobus*), to the early Callovian (e.g. *Macrocephalites* pl. spp. and *Homeoplanulites leptus*) and even the middle Callovian (*Putealiceras mathayense, Reineckeia reissi*, and others). In very recent times a new sampling at the Fornazzo quarry (BOVERO, 2001) confirmed the taphonomic condensation of thestromatolitic Level 1, with reeledaborated Bathonian to Callovian fossils. Carefulfield observation allows to characterize beds 1a and 1b by their different fossil assemblages. The paleontologicalcontent of Bed 1a, albeit reduced, mostly consists of ammonites indicative of the late Bathonian, such as *Oxycerites oppeli, Procercites hodsoni, P. quercinus, Choffatia cerealis* never recorded before from this locality; yet, other taxa like *Macrocephalites compressus* and *Indosphinctes peregrinus* confirm the taphonomic condensation up to the whole lower Callovian. The assemblage of Bed 1b, by contrast, mixes scarce Bathonian ammonites (e.g. *Homeoplanulites homemorphus*) with a much greater number of taxa indicative of the early to middle Callovian. Among the Callovian taxa, *perisphinctids* are especially common, with a frequency higher than that indicated by Wendt.

New findings are represented by *Homeoplanulites (H.) furculus* (Fig. 12), *Homeoplanulites (Parachoffatia) gr. subbackeriae*, *H. (P.) medani, Choffatia leptonata*, *C. recuperoi*, and *Indosphinctes cesaredensis*.

**Level 2** (280 cm) - This level starts with a cm-thick red calcareous stromatolitic layer that overlies the *Frutexites* crust capping Bed 1. Upwards, the texture changes to massive reddish packstones to grainstones with peloids, echinoderm fragments and abundant filaments, the latter increasing upsection and becoming almost exclusive. Filaments have thin rims of fibrous cement and are uncompacted. No mineralization of grains as in Level 1 is present. Stylolites and burrowing produce a faintly nodular aspect.

**Level 3** (30 cm) - Dark red, markedly nodular bed that shows gradational boundaries with both the under- and overlying beds. Cm-sized, rounded pink nodules are made of packstones-grainstones with filaments, peloids and sparse echinoderm fragments. The surrounding matrix is brick red and consists of packstones with filaments that, differently from the nodules, are flattened parallel to bedding and are crossed by clay-rich dissolution seams. The nodule-matrix boundaries may be gradational or sharp. In the first case an early diagenetic origin for the nodule is inferred whereas sharply bounded nodules may only be interpreted as intraclasts.

**Level 4** (250 cm) - Very gradually, the nodular limestones of Level 3 become more massive and lighter-coloured upwards. Microscopically this change is reflected by a gradual transition to finer grained wacke-to packstones that contain protoglobigerinids, gastropod protoconchs, calcite radiolarian moulds and relatively rare filaments. An undulose millimetric lamination of stromatolitic nature is clearly seen in the upper decimetres, where ammonites are common and burrows with diameters of 1-2 cm cross vertically the beds (Fig. 13).

Fossils are very hard to quarry from the massive stromatolitic limestones. Nevertheless an ammonite assemblage could be sampled, with wide-ranging phylloceratids (e.g. *Holoceroceras mediterraneum, Sowerbyceras tortisulcatum*) and poorly preserved *Euaspidoceras* cf. *perarmatum* and *Passendorferia* pl. spp. (G. Melendez, pers. comm.), indicating the middle Oxfordian. A slightly older age is recorded in the nearby Pizzo delle Niviere locality (WARMAN & ARKELL, 1954, p. 280; WENDT, 1964, p. 80), where the upper part of the lower Rosso Ammonitico delivered ammonites indicating the topmost lower Oxfordian with *Peltoceratoides* of the upper *Cardioceras cordatum* Zone.

An iron-stained surface locally marks the top of Level 4. It could correspond to the condensed horizon described at Stop 2 (Castello Inici), where Cecca and Savary reported a remarkable ammonite assemblage of the upper *Perisphinctes plicatilis* Zone.

The section is topped by a 10 cm-thick bed characterized by an enrichment of belemnite rostra, with complete specimens of *Hibolithes hastatus* (Fig. 14).

In the lower part of the bed ammonites are
Fig. 13 - Massive wacke- to packstones with undulose millimetric laminations of stromatolitic nature at the top of Level 4, main Fornazzo quarry. Note the frequency of ammonite internal moulds and firm ground burrows. Relatively common, though very poorly preserved. Besides the ubiquitous *S. tortisulcatum*, two resedimented, not taphonomically reworked specimens of *Gregoryceras riazi* assure reference of the topmost Lower Rosso Ammonitico to the *P. (Dichotomosphinctes) luciaeformis* Subzone, lower *G. transversarium* Zone, of the middle Oxfordian.

**Substop 3.2 - Lower Fornazzo quarry**

The top of the lower unit of the Rosso Ammonitico (RAI) and the lower part of the middle unit (RAM) are here beautifully exposed (Fig. 15), so correlation with the section described in substop 3.1 is easy.

**Level 5** (1.25 m) - Thinly bedded, chert-free limestones, yellowish in the lower 30 cm, where thin marl interbeds also occur, then changing to dark red. Microscopically they consist of wacke- to packstones with fine echinoderm debris crossed by a very dense network of clay-rich dissolution seams, indicating severe compaction of uncemented sediment. *Chondrites* burrows and poorly preserved ammonite moulds are common. The last 25 cm are mainly marls with flat calcareous nodules.

**Level 6** (2.40 m) - Red, flaser nodular marly limestones with red chert nodules. The limestones microscopically consist of wackestones with common microquartz-filled radiolarians, sparse sponge spicules and rhaxes, and fine echinoderm fragments (Fig. 16). Dissolution seams are widespread and merge around chert nodules.

**Level 7** (3.15 m) - Evenly bedded siliceous limestones consisting of wacke- to packstones with fine echinoderm debris crossed by a very dense network of clay-rich dissolution seams, indicating severe compaction of uncemented sediment. *Chondrites* burrows and poorly preserved ammonite moulds are common. The last 25 cm are mainly marls with flat calcareous nodules.
Fig. 15 - The contact between the massive lower unit of the Rosso Ammonitico Fm. and the middle thinly bedded unit in the lower Fomazzo quarry. Note the set of chert-free limestones of Level 5.

Fig. 16 - Red, flaser nodular wackestones with microquartz-filled radiolarians and sparse sponge rhaxes. Thin section, Level 6, lower Fomazzo quarry.

Fig. 17 - Subvertical neptunian dyke filled with red mudstones to filaments packstone in the lower Fomazzo quarry.

centimetres across and are partially filled with laminated, grey to red micritic sediments locally encasing cm-sized clasts of the surrounding rock. White calcite cements line the cavity walls. These features are very similar to the fissures seen in the Poggio Roccione section in the Pre-Symposium Field trip and are consequently interpreted in the same way, i.e. as cracks developed as a result of creeping of semi-lithified sediments along an unstable slope. On a small cliff a subvertical fissure about one metre large and penetrating vertically for at least two metres crosses the massive limestones of the lower Rosso Ammonitico (Fig. 17).

It is filled with a variety of red limestones ranging from mudstones to filament packstones to breccias with cm-sized clasts. The infilling is mm-laminated; angular unconformities often separate laminasets, while wrinkled and overturned laminasets and cement-filled vugs within the laminated sediments are also seen. All these features indicate that the fracture was filled by infiltration of sediments lamina by lamina from the sea floor, and that the enlargement of the fissure proceeded through different phases that caused the collapse of the just deposited internal sediments, truncation of laminasets, and the opening of voids later filled with cement.

In conclusion, this neptunian dyke can be interpreted as the evidence of a subvertical fracture produced by failure and creep along an unstable slope. Such fractures must have been part of an intercommunicating network with the cogenetical bedding-parallel creep cracks, providing connection to the sea floor. Fine-grained sediments could therefore penetrate some metres below the sea floor, possibly transported by an active flux of sea water, and reach even the fractures developed at the Inici-Rosso Ammonitico boundary.
STOP 4 - ROAD TO THE FORNAZZO QUARRY

L. MARTIRE

Leaving the Fornazzo quarry and heading southward along the road to Castello Inici, we encounter again the cherty facies of the middle unit of the Rosso Ammonitico (RAM) because of a normal fault that downthrows the northern block by some tens of metres. The siliceous unit is here observable from the base to the top (Fig. 7) even though the exposure along the road cut is not as good as in the quarry. The description of the section restarts at about 7 m above the top of the lower Rosso Ammonitico, i.e. approximately at the point where the outcrop ends at the lower Fornazzo quarry (Substop 3.2).

Level 8 (8.60 m) - Very regular alternances of marls and siliceous limestones with red chert. The thickness of the marly interbeds and the size of the cherts, that may occur in nodules or ribbons, vary vertically and produce slightly different packages of beds. The siliceous limestones, as in the underlying Level 7, consist of wacke- to packstones with abundant microquartz-filled radiolarian moulds (Fig. 17).

Level 9 (1.40 m) - Whitish flaser nodular limestones with small red chert nodules, bearing poorly preserved ammonite moulds. Microscopically the nodules consist of wacke- to packstone with radiolarians that may be preserved as spar filled moulds or as micrite moulds. The matrix ranges from fitted packstone to wackestone with dynoflagellate cysts (Stomiosphaerids), Globochaete, echinoid fragments, Saccocoma. Ammonite moulds are often finely bioclastic mudstones. Borings on the ammonite moulds provide evidence of taphonomic reworking. Very few ammonite specimens have been identified, one of these being the early Kimmeridgian genus Lessiniceras sp. (Metahaploceras strombecki Zone).

Level 10 (3.1 m) - Alternances of marls and siliceous limestones similar to Level 8, but with abundant Saccocoma, locally silicified.

Thinly bedded nodular limestones with small red chert nodules, about 2 m thick, follow through a transitional boundary representing the lowermost beds of the upper Rosso Ammonitico. Due to cover and probably minor faulting, the passage to the overlying more massive nodular limestones is not seen. The RAS is better exposed in the next substop, in the natural outcrops on the slope down the road.

**Upper Jurassic Radiolarian Assemblages from Monte Inici**

P. BECCARO

The Radiolarians in the middle siliceous member of the Rosso Ammonitico Formation have been studied as a part of a PhD Thesis project. Three sections were sampled: Castello Inici (Stop 2), lower Fornazzo quarry (Substop 3.2), road to Fornazzo quarry (Stop 4). More than fifty samples were analyzed using the normal procedures with HCl and HF; 22 samples provided useful micropaleontological residues. Though the radiolarian content is moderate, preservation is fairly good in all the examined samples (Fig. 18).

The assemblages however, unfortunately do not show a great species diversity.

Biostratigraphy was performed using Unitary Associations Zones (UAZ), i.e. units based on radiolarian assemblages (BAUMGARTNER et alii, 1995). The following list indicates the biochronology of UAZs in the upper part of the Jurassic:

- UAZ 7: late Bathonian to early Callovian
- UAZ 8: middle Callovian to early Oxfordian
- UAZ 9: middle to late Oxfordian
- UAZ 10: late Oxfordian to early Kimmeridgian
- UAZ 11: late Kimmeridgian to early Tithonian

Due to moderate preservation, the total number of diagnostic species is reduced, so only for few samples was it possible to determine the corresponding UAZ with certainty. In detail, these are the data provided by radiolarian analysis from the three sections sampled at Monte Inici:

**Road to Fornazzo quarry** (sample code IN, Fig. 7) - The base of the RAM succession (IN-1, IN-3 and IN-4) ranges from UAZ 7 to UAZ 11, whereas sample IN-8, slightly above, indicates UAZ 10 by the presence of Bernoullius dicera (UAZ 3-10), Emiluvia ultima (UAZ 10-11), Tritrabs casmaliensis (UAZ 4-10) and Xitus aff. spicularius (UAZ 10-22). Samples from the middle part of the road-section (IN-11 to IN-17) span UAZ 9 to UAZ 11, but IN-19 and IN-21 are referred to UAZ 10 due to the co-occurrence of Dicerosaturnalis angustus (UAZ 6-10), Emiluvia ultima (UAZ 10-11), Eucyrtidiellum nodosum (UAZ 3-10), Zanola cornuta (UAZ 8-10) and Xitus aff. spicularius (UAZ 10-22). Samples from the upper part of the section (IN-24 to IN-33) are less significant, and indicate UAZ 9 to UAZ 11.

**Lower Fornazzo quarry** (sample code FZC, Fig. 7) - At the base of the RAM succession (FZC-3 and FZC-7), Dicerosaturnalis angustus (UAZ 6-10), Bernoullius dicera (UAZ 3-10), Emiluvia ultima (UAZ 10-11), Tritrabs casmaliensis (UAZ 4-10) and Xitus aff.
Fig. 18 - Scanning electron micrographs of radiolarians from the siliceous member of the Rosso Ammonitico in the Fornazzo road section, northwestern side of Monte Inici. For each specimen sample (IN code), UAZone and enlargement are indicated.

1 - Tritrubs exotica (Pessagno). IN 3. UAZ 4-11. 62x.
2 - Tritrubs casamalensis (Pessagno). IN 11. UAZ 4-10. 85x.
3 - Emiluvia ultima (Baumgarten & Dumitrica). IN 19. UAZ 10-11. 77x.
4 - Emiluvia orea (Baumgarten). IN 8. UAZ 8-11. 50x.
5 - Eucyrtidellum ptyctum (Riedel & Sanfilippo). IN 21. UAZ 5-11. 171x.
6 - Eucyrtidellum nodosum Wakiya. IN 3. UAZ 3-10. 162x.
7 - Angulobracchia biordonalis Ovoldova. IN 21. UAZ 9-11. 90x.
8 - Podocapsa amphitreptera Foreman. IN 30. UAZ 9-18. 100x.
9 - Xitus sp. aff. spicularius (Aliev). IN 15. UAZ 10-22. 89x.
10 - Trichotoma blakei (Pessagno). IN 17. UAZ 4-11. 76x.
11 - Dicerosaturnalis angustus (Baumgarten). IN 4. UAZ 6-10. 78x.
12 - Hexasaturnalis minor (Baumgarten). IN 4. UAZ 3-11. 55x.
14 - Zhamoidellum? exquisita Hull. IN 3. middle Oxfordian. 182x.
15 - Zhamoidellum ovum Dumitrica. IN 11. UAZ 9-11. 149x.
17 - Transhsium brevicostatum gr. (Ovoldova). IN 8. UAZ 3-11. 122x.
18 - Archaeodictyomitra apiarium (Rust). IN 3. UAZ 8-22. 150x.
19 - Bernoullius dicera (Baumgartner). IN 8. UAZ 3-10. 12x.
20 - Ristola altissima altissima (Rust). IN 3. UAZ 7-12. 8x.
21 - Tetraclabus bulbosa Baumgartner. IN 15. UAZ 7-11. 2x.
22 - Napora kospensis Pessagno. IN 8. UAZ 8-13. 7x.
23 - Pseudoeiicvrtis reticularis Matsluka & Yao. IN 24. UAZ 8-11. 8x.
24 - Acaeniotyle umbilicata (Rust). IN 3. UAZ 10-22. 53x.
spicularius (UAZ 10-22) indicate UAZ 10. FZC-9 does not contain significant taxa, though the finding of Emiluvia ultima (UAZ 10-11) is consistent with the stratigraphic position of the sample.

Castello Inici (sample code CI: Fig. 7) - The base of the cherty limestones (CI-4) belongs to UAZs 9-10 for the presence of Mirifusus dianae minor (UAZ 9-20) and Tritrabs hayi (UAZ 3-10). Sample CI-8 represents the UAZ 10, due to the co-occurrence of Bernoullius dicera (UAZ 3-10), Emiluvia orea ultima (UAZ 10-11) and Paronaella broennimanni (UAZ 4-10). CI-10 also bears an assemblage indicating UAZ 4-10, with Angulobracchia biordinalis (UAZ 9-11), Angulobracchia purisimaensis (UAZ 3-10) and Tritrabs casmaliaensis. Upsection, samples CI 13 to 15 contain Emiluvia ora ultima (UAZ 10-11).

In conclusion, radiolarian biostratigraphy in the siliceous member of the Ammonitico Rosso Fm. gives the following results. The lower and middle parts of the RAM span the late Oxfordian to early Kimmeridgian, although the lowest samples (IN-1 to 4) can be middle Oxfordian. Samples from the upper part of the siliceous succession (road section) are Kimmeridgian. Although the ammonite record is sparse at best in these cherty deposits (their base bears G. riazi at Castello Inici, while Lessiniceras sp. occurs in the middle-upper part of the road-section), use of ammonite stratigraphy in our sections serves to better constrain the age of the siliceous succession, and of UAZs themselves. The radiolarian assemblage with Dicerosaturnalis angustus, Bernoullius dicera, Emiluvia ultima, Tritrabs casmaliaensis and Xitus aff. spicularius is therefore tentatively placed at the middle-upper Oxfordian transition. The assemblage with Dicerosaturnalis angustus, Emiluvia ultima, Eucyrtidiellum nodosum, Zanola cornuta and Xitus aff. spicularius might represent the middle part of the lower Kimmeridgian.

**STOP 5 - THE NATURAL OUTCROPS BELOW THE ROAD TO FORNAZZO QUARRY**

G. PAVIA, A. BOVERO, R. LANZA, F. LOZAR, L. MARTIRE & F. OLORIZ

**LITHOSTRATIGRAPHY**

The section is exposed on both sides of the service road leading to the quarry of Contrada Fornazzo, at the bend (700 m altitude) corresponding to the morphostructural crest that goes down from Pizzo delle Niviere to Contrada Fraginesi. Direct correlation with the previous outcrop is not possible. However, based on lithofacies analogies, the uppermost layers of the previous section should approximately correspond to the lowermost beds in this section.

The RAS succession exposed here (Fig. 8) consists of several levels which are described in detail below. The basal part of the section (Levels 1 and 2) provided rich Upper Jurassic ammonite assemblages, that will be described later on in the paragraph “The Kimmeridgian-Tithonian boundary”.

**Level 1** (3.45 m) - Nodular limestones with cherts in small nodules and thin ribbons. This interval is easily weathered because of the thin bedding, well developed nodular structure and thick marly interbeds. Two thin clay beds, 2-3 cm thick, are noteworthy, being thicker and more continuous than the marly undulose seams that separate nodular beds, and possessing the same plastic “feel” which is typical of bentonites. X-ray diffractometry indicates they are smectite clays (MONTAGNINO, pers. comm.) so their primary origin as ash layers is fairly possible.

**Level 2** (5.85 m) - Compared to the underlying interval, this one bears no chert and is more massive and less easily weathered, forming a small cliff well seen also in the distance. Beds can have different thicknesses and lithofacies, the thickest being usually the hardest. They consist of incipiently nodular to homogeneous very coarse grainstones with abundant Saccocoma debris and subordinate small peloids. Syntaxial cement rims around Saccocoma fragments are usually well developed, and can even reach a size greater than the bioclast itself except in correspondence of dissolution seams, where grains are reorganized into a fitted, poorly cemented fabric. These Saccocoma-grainstones locally grade unevenly to finer grained grainstones with scarce Saccocoma and abundant sphaerical micritic particles larger than peloids and interpreted as radiolarian moulds. These two types of sediment were likely juxtaposed because of deep bioturbation affecting layers having a contrasting texture. No “true” nodules can be positively recognized, although local merging of wavy dissolution seams can produce a “nodular effect”. These beds may be
Fig. 19 - Polished slab of nodular limestone with red marly internodular seams. Both sharp-bounded intraclasts and early diagenetic nodules with diffuse boundaries are recognizable. Level 2, section below the Fornazzo road. (black-white divisions on the scale bar: 1 cm).

referred to as the massive bioclastic facies.

Other beds, usually thinner, are less resistant to weathering and show at the outcrop the typical knobby aspect of nodular limestones (Fig. 19), where nodules and matrix are weathered differently.

Two kinds of nodules may be recognized depending on the boundaries with the surrounding matrix.

Type 1: nodules show gradational boundaries and usually a flattened ellipsoidal shape. They consist of packstones to grainstones with prevailing *Saccocoma* and subordinate peloids and *Globochaete*. The matrix is red, crossed by bundles of dissolution seams, and is composed of *Saccocoma* packstones with a fitted fabric. These nodules perfectly fit the definition of early diagenetic nodules of CLARI et alii (1984).

Type 2: nodules have more irregular, often sphaeroidal shape and sharp boundaries with the matrix. They mainly consist of fine grainstones with abundant micritic radiolarian moulds and subordinate *Saccocoma*, peloids and *Globochaete*. Some of these sharp-edged nodules have a slightly darker rim that microscopically corresponds to the mineralized filling of microborings. This proves that at least part of these nodules are pre-depositional (*sensu* CLARI et alii, 1984), i.e. they are intraclasts that experienced a period of prolonged exposure at the sea floor that resulted in colonization by endolithic organisms and coating by authigenic minerals (Fe-Mn oxides). Interpretation of Type-2 nodules that bear no borings and staining is less obvious. They could be intraclasts produced by either current erosion of semilithified sediment, or by burrowing and mixing of texturally contrasting uncemented sediments.

The contemporaneous presence of early diagenetic nodules and intraclasts indicates the intraclastic nodular
Facies by Savary (2000). The proportions of early diagenetic nodules vs. intraclasts and matrix vary from bed to bed and result in different degrees of weathering.

Level 3 (2.45 m) - Alternances of massive and nodular limestones as described in the underlying interval but with cherty intervals.

Covered tract: 0.7 m

Level 4 (1.3 m) - Nodular limestones with red chert nodules. These limestones microscopically still consist of nodules of Saccocoma packstones to grainstones and a matrix of fitted Saccocoma packstones with dissolution seams.

Covered tract: 1.8 m

Level 5 (2.0 m) - Alternances of nodular and flaser nodular limestones with sparse pink chert nodules.

Covered tract: 0.8 m

Level 6 (11.40 m) - Monotonous succession of regularly bedded flaser nodular and more massive nodular white limestones with rare grey chert nodules and ribs. Microscopically the limestones consist of wackestones with abundant calcareous dinocysts, radiolarians preserved both as micritic moulds and as spar filled moulds, Globochaete, sparse Saccocoma fragments, and Calpionellids. At the very base, in spite of poor preservation, Crassicollaria and Tintinnopsella could be identified which, in addition to the absence of Calpionella, indicate the upper Tithonian, lowermost Zone A of Remane’s biozonation. By contrast, a sample 1.5 m below the top is characterized by a rich and well preserved association of Calpionella alpina, Remaniella ferasini, R. cadischiana, Tintinnopsella carpathica referable to the lower Berriasian (upper part of Zone B).

Upsection the exposure is very poor. However the thinly bedded, white micritic limestones with conchoidal fracture can be easily attributed to the Lattimusa Fm.
THE KIMMERIDGIAN-TITHONIAN BOUNDARY

Detailed analyses of both the paleontological content and paleomagnetic signals were performed on Levels 1 to 3 of this section with the purpose of defining the Kimmeridgian/Tithonian boundary. Beds have been numbered 93 to 130 (Figs. 20, 21) with the following pertinence: Beds 93-105 to Level 1; Beds 106-123 to Level 2; Beds 124 upwards to Level 3.

FOSSIL CONTENT

The macrofossil record is represented only by cephalopod remains, among which belemnites occasionally reach 5%. More than 700 ammonites were collected bed-by-bed. Though the state of preservation is often poor, and several specimens are indeterminable, 58 taxa have been identified at the species level, the most significant being listed in Fig. 22. Phylloceratids are the dominant taxonomic group, with Sowerbyceras loryi representing more than 50% of the assemblages; other typical Mediterranean taxa are Calliphyloceras pl. spp., Holcophylloceras polyolcum and lytoceratids.

Complementary components of the ammonite assemblages are aspidoceratids, haploceratids and ataxioceratids. Hybonoticeras is especially common (Fig. 23), so biostratigraphic analysis was mostly based on this genus.

Ammonites are generally preserved as calcareous internal moulds without shell remains. They are frequently incomplete and represented by phragmocones usually with partial body-chamber or, for diameters wider than 80 mm, by fragments of the last whorl, indicating biostratinomic breakage of the shell before burial; no adult peristomes have been observed. The size of fossils is variable; in some cases, fragments indicate shell size up to 200 mm. Horizontal positions are dominant, except for small-sized fossils that can have been tilted by bioturbation and later by the combined effect of pressure solution and compaction. Most internal moulds are covered by greenish or reddish argillaceous coatings corresponding to dissolution seams on early cemented moulds. The internal moulds bear no mineralized coat, truncation facets, erosion surfaces or biogenic encrustations. The texture of the calcareous infilling is the same as that observed in surrounding nodules without any adoral discontinuity; this indicates that no removal took place from the embedding sediment, just a differential packing. The irregularities of mould shape observed in some specimens depend on plastic deformation because of differential compaction of the internal infilling, which is typically more lithified in the phragmocone than in the body-chamber.

In conclusion all these factors converge to define the great majority of ammonites in the lower RAS as resedimented elements, having experienced no taphonomical reworking (FERNANDEZ-LOPEZ, 1991; PAVIA & MARTIRE, 1997). They must therefore be considered as "coeval" to the embedding calcareous matrix. The sole ammonites in which a removal from the encasing sediment must be admitted are the moulds occurring as reworked "pebbles" in the nodular lithofacies, in particular at the base of Beds 102, 107, 117, and upper 119. Nevertheless, also in these instances, evidence of bioerosion/bioencrustation or Fe-Mn oxide coating is missing. These fossils can thus be regarded as the result of winnowing of early lithified shell infillings, with no appreciable displacement at the see bottom after the first burial episode.

AMMONITE BIOSTRATIGRAPHY

Ammonite biostratigraphy was performed following the Standard Ammonite Bio-Chronozones proposed for the Mediterranean Province by HANTZPERGUE et alii (1991) and GEYSSANT & ENAY (1991). Later data and/or reinterpretations by SARTI (1993), SCHWEIGERT et alii (1996), CARACUEL et alii (1998), CARACUEL & OLORIZ (1999), OLORIZ & VILLASEÑOR (1999), OLORIZ et alii (1999b), VILLASEÑOR et alii (2000), as well as unpublished data from research in progress by OLORIZ & SERNA-BARQUERO have also been taken into account. Index-fossils at the ammonite biozone level were only identified within the biostratigraphic range of the genus Hybonoticeras, i.e. within the Hybonoticeras beckeri and Hybonoticeras hybonotum zones. The lower and upper boundaries of this two-zone interval were placed through identification of the index-species, or allied forms, of the M. cavouri and V. albertinum Zones, respectively.

Mesosimoceras cavouri Zone - In the upper Kimmeridgian, the zone has been recognized based the joint occurrence of Mesosimoceras risgoviensis and
Pseudowaagenia acanthomphala, which is recorded from stratigraphic levels below the first occurrence (FO) of the genus Hybonoticeras. The index-species Mesosimoceras cavouri is known from equivalent horizons in other correlated sections studied in the area. In the studied profile, the M. cavouri Zone has been interpreted to range from Bed 95 to Bed 101.

Hybonoticeras beckeri Zone – This is marked here by the index-species. Although we are aware there is no general consensus on this subject, we believe the H. beckeri Zone can be subdivided into three parts, in agreement with results from the Betic Cordillera (OLRIZ and SERRA-BARQUERO unpublished data). The lower part is characterized by H. cf. pressulum and H. cf. verruciferum. The middle part is bounded by the FO of H. beckeri below and the FO of H. harpephorum and related forms above. The upper part embraces the range of the group of forms related to H. harpephorum, but its upper boundary (i.e. the Kimmeridgian/Tithonian boundary) cannot be accurately placed due to scarce ammonite content. In the studied profile, the whole H. beckeri Zone has been interpreted to span Bed 102 to Bed 108. The lower, middle and upper parts correspond to Beds 102-104, Beds 105-106, and Beds 107-108, respectively.

Hybonoticeras hybonotum Zone - In the lowermost Tithonian, the zone was established based on the range of the index-species, Hybonoticeras hybonotum and related forms (see OLORIZ, 1976-78 for descriptions and illustrations). Although definitive interpretation will only depend on improved sampling, which is currently in progress, two parts can be recognised in the H. hybonotum Zone. The upper part begins with the FO of the genus Fontannesiella (see also the Betic Cordillera; OLRIZ, 1978). In the studied profile, the H. hybonotum Zone has been interpreted to encompass Beds 110 to 114. The lower and upper parts recognised correspond, respectively, to Beds 110-113 and Bed 114. Analogous to the Betic Cordillera (OLRIZ AND SERRA-BARQUERO, pers. data), the Kimmeridgian/Tithonian boundary cannot be placed at the ammonite biohorizon level for two reasons: first, the lowermost 20 cm of Bed 110 did not provide ammonites useful for biostratigraphy; second, Bed 109 is virtually non-fossiliferous.

Virgatosimoceras albertinum Zone - The index-species is missing. However, the record of a single specimen of Virgatosimoceras cf. uniformis above the horizons with the youngest record of the genus Hybonoticeras, coupled with the record of ammonite assemblages largely dominated by haploceratids but without Haploceras verruciferum, have been used as the evidence for the V. albertinum Zone. In the studied profile, the zone has been interpreted to range from Bed 115 to Bed 120, but the boundary with the above H. verruciferum Zone could not be accurately placed.

The ammonite succession in the Fornazzo section is very similar to that discussed by CARACUEIL in the Guidaloca section (Stop 4 of the Pre-Symposium Field trip, this volume), just 5 km North of Contrada Fornazzo. As to the upper Kimmeridgian and the lower Tithonian, the biostratigraphic conclusions are essentially the same. Things differ instead for the middle part of the Kimmeridgian: ammonites are relatively frequent due to the more nodular facies, and CARACUEIL was able to document the lower Kimmeridgian C. divisum Zone and the M. cavouri Zone, the latter with a more diverse ammonite assemblage than in the Fornazzo section.

INTEGRATED STRATIGRAPHY

The section at the Kimmeridgian-Tithonian transition, in addition to the rich ammonite assemblages (Fig. 22), also bears an interesting record of calcareous nannofossil and clear palaeomagnetic signals. Such a favourable combination of stratigraphic tools has prompted us to further refine our biostratigraphic analysis, with the aim of submitting that section as the preliminary reference for the Tithonian basal boundary within the Mediterranean Province in Central Tethys, if not even as the G.S.S.P. of this Stage.

Radiolarians - They have been tested in the lower beds of the section (Level 11); several samples are under treatment following the normal procedures with HCl and HF. Radiolarian associations from Beds 95 to 100 are promising (P. BECCARO, pers. comm.). The results of radiolarian biostratigraphy using UAZs will be given in the near future, and will add to the database used for establishing the Kimmeridgian-Tithonian boundary at the Fornazzo reference section.

Nannofossils - Calcareous nannofossil assemblages were analysed from 28 samples spanning the Kimmeridgian/Tithonian boundary (Beds 93-119). The assemblages are mainly dominated by Watznaueria barnesae, W. manivitae, W. britannica, Cyclagelosphaera margerelii, Cy. wiedmannii, Cy. deflandrei, Diazomatolithus lehmannii. Despite overall poor preservation of the studied material, and generally poor biostratigraphic resolution for this time interval (DE KAENEL et alii, 1996), two calcareous nannofossil events have been recorded: the FO of Conusphaera mexicana minor and of Polycostella bekmannii, respectively in Beds 108 and 117. Two CN Zones (Vagalapilla stradneri and Conusphaera mexicana Zones, BRALOWER et alii, 1989) and two subzones (Hexapodorhabdus cuvillieri and P. bekmannii subzones) were thus identified. This is the first time these events are directly correlated to ammonite biozonation, the FO of C. mexicana minor occurring in the upper Kimmeridgian H. beckeri Zone and the FO of P. bekmannii occurring in the lower Tithonian V. albertinum Zone. Moreover, preliminary magnetostratigraphic data suggest that the FO of P. bekmannii occurs in a reversed polarity interval, which
is most useful for correlation of this interval, which is otherwise poorly constrained with calcareous nannofossil stratigraphy alone.

Magnetostratigraphy - A preliminary study was done on Beds 109 to 121 of the Fornazzo Section. Thermal and alternating field demagnetization of the remanent magnetization isolated a stable component. Its direction is consistent with literature data from Jurassic rocks of northwestern Sicily (CHANNEL et alii, 1990; SPERANZA et alii, 1999). This consistency at regional scale, along with the whole of the rock magnetic properties, suggest a primary nature of the remanence, whose polarity sequence represents the field reversal which took place at the Kimmeridgian-Tithonian boundary. The polarity is mainly reverse, with a short normal polarity interval corresponding to Beds 112 to 114. The transitional polarity found in two Beds (110 and 118) needs further investigation on a larger number of specimens.

STOP 6-8 - THE TRAPANESE SUCCESSION OF MONTE ERICE: A RAMP TO PELAGIC PLATFORM TRANSITION

L. MARTIRE

Monte Erice, formerly Monte San Giuliano, on top of which the ancient village of Erice lies, is a prominent morphological feature of the westernmost Sicily landscape. From 800 m of altitude, abrupt cliffs border this triangular ridge providing separation from the sea, to the N and W, and from the Trapani plain to the E and S. These cliffs roughly follow Cenozoic master faults and correspond to extensive outcrops of Mesozoic carbonate rocks.

This sector of the Trapanese Domain has a Jurassic stratigraphic succession that significantly differs from that of other classical Trapanese sections (Montagna Grande, Monte Kumeta, Monte Inici, Rocca Busambra). The common element is the thick sequence of peritidal Lower Jurassic limestones (Inici Fm.) followed by a Lower to Upper Jurassic succession of pelagic facies that mark the drowning of the platform. The pelagic succession, however, is much thicker and siliceous than elsewhere and has been consequently considered indicative of more basinal conditions (WENDT, 1971b; GIUNTA & LIGUORI, 1972, 1973). We will informally refer to this succession as the Erice formation.

The aims of the following stops (Fig. 24) are on one hand to visit some classical sections and fossiliferous localities, and on the other to highlight sedimentological features which strongly suggest that a new palaeogeographical reconstruction is in order.

On the southern side of Monte Erice a clear thickening of the so-called “Erice formation” is well seen from the Antica Erice to Difali sections. This is related to the drowning and block faulting of the Inici platform that took place in the Middle Jurassic and generated a stepwise escarpment dipping to the present-day west. For more detailed analyses and interpretation see stop descriptions of 5 to 7 in the Pre-Symposium Field trip (this volume).

STOP 6 - ERICE DIFALI: BATHONIAN-KIMMERIDGIAN SUCCESSION WITH AMMONITE-BEARING NODULAR LIMESTONES AND RESEDIMENTED BEDS

C. D’ARPA, L. MARTIRE & G. MELENDEZ

Observation of this section will start from the well known hardground with Bathonian ammonites (WENDT, 1971b); for more details see Stop 5 of Pre-Symposium
Field trip. This hardground occurs at about 130 m above the top of the Iniși Fm. (Fig. 25) and is underlain mainly by cherty limestone facies belonging to the Erice formation.

**LITHOSTRATIGRAPHY**

Above the hardground, massive beds of filament-rich packstones follow for 3 metres, although they are not continuously exposed. The overlying tract, 7.40 m thick, is composed by otherwise similar packstones, except for the occurrence of nodules, of occasional chert, and interbedded marls.

The upper part of the section (Fig. 26) is more interesting both for biostratigraphy and sedimentology, and will be described more in detail. A 40 cm thick bed (Level A in Fig. 29) of marly limestones with small calcareous nodules is distinctive in the weathering profile. This level is followed by three resistant beds (Level B. Beds 2-4) consisting of filament packstone. A sharp surface, probably corresponding to a discontinuity bounds the yellowish grey filament packstone, separating it from a set of nine pinkish beds (Level C. Beds 5-13) that give rise to a distinctive small cliff with a knobby weathered surface. Nodular beds are interbedded with massive strata that consist of wacke- to packstones with small peloids, protoglobigerinids, calcitized radiolarians, Globochaete, calcisphaeres, characterized by a millimetric undulose stromatolitic lamination. These beds are quite rich in ammonites that will be described in detail below.

Above this richly fossiliferous interval, Level D corresponds again to an easily weathered greenish marly limestone with calcareous nodules. The latter microscopically consist of fine-grained, densely packed peloidal grainstone or packstone with scattered echinoderm fragments, small subrounded peloids, and micritic radiolarian moulds, whereas the marly matrix is composed of fitted packstone. This lithology is found for the next 7.10 m (Level E, Beds 15 and further, Fig. 27) and is interbedded with different sediments, including siliceous wackestones with chalcedony-filled radiolarians and sponge spicules and rhaxes with red to black chert nodules. This lithology occurs in the lower part of the level. Another type of lithology is represented by clean-washed grainstones with peloids, superficial ooids and bioclasts such as echinoderm fragments and benthic foraminifera (*Siphovulvulina*, *Ophtalmidium*, miliolids). The packing is loose and consequently the intergranular pores are filled with abundant sparry cement. These grainstones occur both as thin layers (less than 10 cm thick) with a flat base and a wavy top, or as generally coarser grained and thicker (15 cm) beds with flat base and top and with parallel laminae in the lower part, which can be silicified. At 2.5 m above the base of Level E, a poorly preserved specimen of (?) *Simosphinctes*
interpretation. Above the megabed, the same nodular limestones of Level E (Levels G and H) occur, again interbedded with cm- and dm-thick peloidal grainstones. Upsection, peloids become less abundant and *Saccocoma* fragments appear. A 40 cm-thick bed is well recognizable for its silicified base and top, and is worth noting because it consists of a well washed coarse grainstone with *Saccocoma* and peloids; thick syntaxial sparry cement rims overgrow the *Saccocoma* fragments giving a sucrosic appearance to the rock (Fig. 28). The section ends with about 5 metres of whitish nodular limestones with interbedded chert lenses.

(Ceratospininctes) *rachistrophus* probably indicates the top of the lower Kimmeridgian, *C. divisum* Zone.

The most striking feature of this section, however, is a very thick single bed, 190 to 230 cm thick, made of a lithoclastic rudstone (Level F). The clasts are subrounded and range in size from few millimetres to 10 centimetres. Larger clasts, up to several decimetres, occur only rarely. Their prevailing lithology is represented by various kinds of peloidal-bioclastic-oolitic grainstones. Clasts can also be made of coral- and algae- (*Thaumatoporella*) bearing rudstone, as well as of greenish nodular limestones and cherts comparable to those underlying the megabed. Partly silicified, cm- to dm-sized fragments of thick-shelled bivalves and corals are scattered through the megabed. A slight reduction of lithoclast size takes place from base to top. The matrix is composed by a peloid and echinoderm grainstone to packstone. This megabed, already described in Stop 5 of the Pre-Symposium Field trip, and the underlying tract of succession will be the object of the next stop, where peculiar sedimentary structures will be seen, which enable a sedimentological
BIOSTRATIGRAPHY

The Oxfordian ammonite assemblages from the upper part of the Erice Difali section, in the locality named Rocce di Calderaro, probably come from the very same levels originally quarried by GEMMELLARO, which produced some key-type specimens described in his classical monographs (GEMMELLARO, 1874, 1877). These associations are particularly rich in ammonites, among which Phylloceratina are the most abundant taxa, with Holcophylloceras zignodianum and Sowerbyceras tortisulcatum. The family Perisphinctidae is mainly represented by the subfamily Passendorferiinae, including the genera Passendorferia and Sequeirosia. Aspidoceratids are represented by Euaspidoceratinae (genera Euaspidoceras and Paraspidoceras) and Peltoceratinae (genus Gregoryceras). These ammonite associations characterise the different successive biostratigraphic units of the middle and upper Oxfordian (D’ARPA & MELENDEZ, 2001). In turn, differences in ammonite content allowed the identification of different biohorizons within Level C, as shown in Fig. 29.

Beds 1-4. Lithologic analogies allow to correlate the Levels A and B with Beds 8 to 9c of the homologous section cropping out along the Sant’Anna road, which corresponds to the Callovian (Substop 7b in the Pre-Symposium Field trip, this volume). In particular, Bed 1 is of early middle Callovian age, since the equivalent Bed 8 in the S. Anna section delivered a specimen of Rehmannia (Loczycceras) reissi. This would be further supported by the finding of a specimen of Reineckeia (Reineckeia) gr. anceps in the lower part of Bed 3, indicating the lower middle Callovian. On the other hand, the boundary between Beds 3 and 4 is probably equivalent to Bed 9c, which in the Sant’Anna section delivered an oppelid (Putealiceras cf. trilineatum) indicative of the basal upper Callovian, Peltoceras athleta Zone.

Bed 5. It has yielded no ammonites.

Beds 6 to 14. This interval is referable to the middle and upper Oxfordian. The interval 106 to 114 contains rich fossil assemblages including common ammonites, preserved generally as internal moulds having the same microfacies as that of the matrix. The specimens mostly represent fragmented shells to shell fragments (scarce) and are taphonomically classified as resedimented elements. Specimens preserved as fragmented moulds, hence classified as reelaborated elements, are only occasional (see D’ARPA & MELENDEZ, 2002), and generally linked to major stratigraphic discontinuities, as at the middle-upper Oxfordian boundary.

The ammonite assemblages are characterized by the common occurrence of juvenile individuals, macro and microconchs. Namely, the representatives of subfamily Passendorferiinae do not seem to show any sign of sutural approaching or typical adult modification of their ribbing. They form homogeneous, monospecific assemblages with dominant juvenile individuals, showing unimodal, asymmetric, positive-skew frequency distribution curves, and a high ratio of recorded elements to number of species. They can, therefore, be classified as true biological, demic populations. This evidence has been recently presented by D’ARPA & MELENDEZ (2002) in this region, supporting the origin of Oxfordian Passendorferiinae from the southern margin of the Tethys around Apulia and surrounding epicontinental basins.

The results of biostratigraphic analysis can be summarised as follows:

Bed 6 - The most significant taxa are Tornquistes helveticus, T. cf. romani, Passendorferia (P.) tenius, Euaspidoceras gr. perarmatum. This association characterises the middle Oxfordian. Perisphinctes (P.) plicatilis Zone, P. (Dichotomosphinctes) antecedens Subzone.

Beds 7-8 - This interval delivered abundant ammonites such as Calliphylloceras sp., Holcophylloceras zignodianum, Sowerbyceras tortisulcatum, Taramelliceras gr. callicerum, Tornquistes aff. oxfordiense, Euaspidoceras cf. habelanium, Euaspidoceras cf. eucyphum, E. aff. fontanesi. This assemblage, due to the joint occurrence of Tornquistes and characteristic forms of Euaspidoceras, should characterise the lower part of the Gregoryceras transversarium Zone (Perisphinctes (P.) parandieri to P. (Dichotomosphinctes) luciaeformis Subzones), middle Oxfordian.

Bed 9 - The assemblage consists of Tornquistes gr. oxfordiense, Gregoryceras cf. riazi, Passendorferia (M + m) n. sp., Sequeirosia (M) brochwiezi and Euaspidoceras aff. fontanesi. This ammonite association should indicate the G. transversarium Zone (i.e. P. (D.) luciaeformis to Larcheria schilli Subzones).

Bed 10 - It delivered Phylloceras isomorphum. Gregoryceras fouquei (some specimens having intermediate features between Gregoryceras transversarium and G. fouquei), Sequeirosia sp., aff. S. brochwiezi. This association should represent a still higher interval of the G. transversarium Zone, possibly the P. (Dichotomosphinctes) rotoides Subzone.

Beds 11-12 - Gregoryceras trapezoidale. Passendorferia utionoides, and P. aff. torcalense are indicative of the P. (Dichotomoceras) bifurcatus Zone, lower upper Oxfordian.

Beds 13-14 - This interval has yielded common specimens of Holcophylloceras zignodianum and Sowerbyceras tortisulcatum. Besides this, the presence of some ammonites showing intermediate features between
**Fig. 29 - Biostratigraphic log of the Oxfordian interval of the Erice Difali section, with vertical ranges of ammonite species.**

Passendorferia and Orthospinctes gr. ariniensis in Bed 113, and the assemblage of Passendorferia gygi, Orthospinctes kirkdaleensis, Euaspidoceras hypselum in Bed 114 suggest this layer belongs to the Euaspidoceras hypselum Zone, upper Oxfordian (D’ARPA & MELENDEZ, 2001).

In general, the biostratigraphic succession is very similar to that recently described by the present authors in the Erice Difali section (D’ARPA & MELENDEZ, 2001) nearby. This similarity indicates a general homogeneity across the Apulian platform during the Oxfordian, demonstrating that biostratigraphic correlation between the Mediterranean and Submediterranean provinces across the Tethyan Realm is practicable, as remarked by
SEQUEIROS (1974) and, more recently, by D’ARPA & MELÉNDEZ (2002).

STOP 7 - ERICE CAPPELLETTA:
SEDIMENTOLOGICAL DETAILS OF UPPER JURASSIC RESEDIMENTED BEDS

L. MARTIRE

LITHOSTRATIGRAPHY

In this stop, along the main Valderice-Erice road near a liturgical chapel (“Cappelletta”), we will visit the same tract of succession of the Erice fm. seen in the upper part of the Erice Difali section (previous stop; Figs. 30, 31). A precise correlation is possible thanks to: 1) the finding of an assemblage including Tornquistes sp. in the lower part of the nodular Level 3, that may hence be referred to the lower middle Oxfordian (Perisphinctes plicatilis Zone); 2) the presence of the lithoclastic megabed. Conspicuous differences, however, occur here especially due to much greater thickness. This was produced by thickening of each individual resedimented grainstone bed. Moreover this section is worth a stop because diagnostic sedimentary structures are especially well seen.

Level 1 (5 m) - Bositra-packstones organized in dm-thick layers with flat or undulose bedding planes.

Level 2 (1.5 m) - This interval, composed of the same packstones as Level 1, is characterized by the presence of four distinct beds with a sharp base and a different texture. The first and the second beds (15 and 25 cm thick respectively) show a coarser grain size with normal grading, parallel laminae in the lower part, a higher percentage of echinoderm fragments, and remarkably greenish, micritic or micropeloidal intraclasts up to 1 cm across. The top of the beds may be silicified. The other two are thicker (30-35 cm each) and normally graded with lithoclastic rudstone at the base and bioclastic-peloidal packstone at the top. Lithoclasts are up to some centimetres across and quite variable texturally, ranging from Bositra wackestones to peloidal or ooidal grainstones, to mudstones with spar-filled shrinkage pores locally partly dolomitized. These two beds are identical to the ones occurring in the Antica Erice section, Level 8 (Stop 5 of the Pre-Symposium Field trip A).

Level 3 (2.25 m) - Nodular limestones consisting of wackestones with protoglobigerinids, gastropod...
protochonchs, calcitized radiolarians, and ammonite moulds. Stromatolitic laminae are locally recognizable.

**Level 4 (7.50 m)** - Alternances of chert beds, wackestones with radiolarians and sponge spicules, and fine-grained grainstones to packstones with peloids and echinoderm fragments. Beds are thin (10-15 cm) and tabular. At the top, two beds are clearly distinguishable. Both consist of packstone with peloids and echinoderm fragments coarser than those regularly interbedded with the underlying cherty limestones (Fig. 32). The first one is 30 cm thick, has a flat base and a slightly wavy top. The second instead shows a markedly wavy top so that the thickness varies from 7 to 18 centimetres (Fig. 33). The swells have a spacing of about 1-1.5 metres. Plane parallel laminae characterize the lower part whereas convex-up laminae occur at the top and may be referred to hummocky cross stratification.

![Fig. 33 - Hummocky cross stratification at the top of Level 4 in the Cappelletta section.](image1)

**Level 5 (17.10 m)** - Similarly to Level 4, also this interval is composed of alternances of various lithologies. Two features however are distinctive: the thickness and relative proportion of grainstone beds, and the nature of grains in the grainstones. This interval, in fact, is almost entirely composed of amalgamated grainstone layers only occasionally separated by thin beds of cherty wackestones with radiolarians or echinoderm packstones. Moreover, two different kinds of grainstones occur. The first is represented by fine-grained textures with peloids and echinoderm fragments organized in beds less than 25 cm thick. Low angle oblique laminae, again referable to hummocky cross stratification, are locally observable. The second type of grainstone is coarser and, in addition to peloids and bioclasts, is characterized by common ooids, generally > 0.5 mm in diameter. Bioclasts include benthic foraminifera (*Ophtalmidium, Nautiloculina, miliolids*), calcareous algae (*Thaumatoporella, dasyclad algae*), corals and molluscs (Fig. 34). These grainstones form beds usually thicker than 30 cm. In particular, in the lower part of this interval, two beds are worth noting because they are over 1 m thick. Moreover their thickness changes laterally from 130 cm to 160 cm and from 150 to 170, respectively, in such a way that where one is thinner the other one thickens so that the sum of the two is about 3 m everywhere. The only sedimentary structures are ill-defined normal grading and parallel laminae. Lithoclasts are lacking in both types of grainstones.

**Level 6 (about 7 m)** - Single bed showing the same features of the rudstone megabed described in Stop 6. Also a textural change takes place in this section along with thickening, as the megabed is lithoclastic only in the lower half and grades to a peloidal bioclastic grainstone toward the top.

![Fig. 34 - Grainstone with ooids and calcareous algae fragments. Cappelletta section, Level 5.](image2)

**Level 7** - The section has not been measured in detail above the megabed because of poor exposure. Peloidal grainstones follow for some metres and then are replaced by whitish cherty limestones.

**GENESIS OF THE ERICE RESEDIMENTED MEGABED**

The Jurassic succession of the Erice area has always been interpreted as the result of deposition in basinal conditions (Wendt, 1971b; Giunta & Liguori, 1972). This interpretation was mainly based on the greater thickness and ubiquity of siliceous facies compared to the most typical Trapanese Rosso Ammonitico. Strongly contrasting views, on the contrary, were proposed for the Late Jurassic megabed: Wendt (1971b) considered it as an episode of shallow water sedimentation, whereas Giunta & Liguori (1972) interpreted it as a gravity flow coming from an adjacent structural high. Our new data perhaps suggest a different interpretation. The main features displayed by the Erice fm. may be summarized as follows:

- Grain-supported textures, often well-washed, are very common if not even prevailing over mud-supported ones. Early cementation is quite common especially in echinoderm- and *Saccocoma*-rich beds, giving rise to
large syntaxial overgrowths. Both these features suggest currents were periodically active at the sea floor.

- Bioturbation (large Chondrites, Planolites, Thalassinoides) is widespread and intense, often enhanced by silicification. This infaunal activity is probably the reason for the thick bedding, and indicates the sea floor was well-oxygenated.

- Remains of benthic organisms, such as echinoderms, occur at all levels in the succession, often in the form of well-washed bioclastic sands.

- The siliceous skeletal fraction of the cherty beds is mainly represented by sponge spicules. Radiolarians are clearly recognizable only in the upper part of the section, in association with spicules. Cm-sized, rounded calcareous masses with a three-dimensional framework of spicules have been found in the Erice Difali section, and suggest that the spicule-producing communities were living in the close vicinities.

- Sharp-based, sometimes graded grainstones with peloids, oolites and skeletal grains of shallow platform biota (calcareous algae, miliolids) are clearly a product of resedimentation. The occurrence of hummocky cross stratification provides a crucial palaeobathymetric constraint, indicating that storms were responsible for sedimentation of these beds. The scarcity of hummocky cross stratified beds possibly indicates a depth close to the lower limit of storm wave base (150-200 m?), where only the most severe tempests could organize the ambient sediment into hummocks, whereas storm-induced turbidity currents periodically resulted in deposition of carbonate sands.

All these features suggest an outer ramp depositional environment, where slow background pelagic sedimentation was overprinted by typical ramp processes like the reworking and winnowing of autochthonous sediments by water currents (storm-induced?), and the active offshore export of sediments. Variations in the litho- and biofacies therefore probably reflect changes in the sedimentary dynamics of the shallower, inner parts of the ramp.

In this picture, the megabed occurring at the top of the succession must reflect a single catastrophic event taking place, however, at relatively shallow depths. Being composed of variable proportions of peloids, oolites and lithoclasts, up to cobble size, it is suggestive of a process impinging on an inner ramp where it could stir up loose sediment at the sea floor, and deeply erode early cemented shallow buried beds. The suspended material was then transported offshore. Given the huge volume of material involved, suggesting a catastrophic event rather than a storm, the hypothesis of a tsunami is here proposed to explain the deposition of the megabed. Tsunamis are rather common phenomena nowadays and even though their effects onshore are better known and studied, also the sedimentary record of the backflow in offshore environments is now being fully recognized (e.g. Shiki & Yamazaki, 1996). After inundation of the coastal zone by abnormally high waves, in fact, the water flows back forming strong return currents that, depending on local coastal morphology, may become channelized (Einsele, 1998). This results in deep localized erosion and deposition of discontinuous, rudist deposits. Such a phenomenon could explain the abrupt thickness variations of the megabed, and the variable proportions of pebbles and cobbles from place to place.

The interfingering of typical pelagic facies (ammonite-bearing nodular limestones, radiolarian cherty wackestones) with outer ramp sequences (peloidal-oolitic storm layers, crinoidal pack- to grainstones, spicule-rich cherty limestones) is a good evidence of the peculiar paleogeographic position of the Erice sector in the Jurassic. This can be envisaged as lying between pelagic plateaus (Trapanese Domain) and a shallow carbonate platform (Panormide Domain?) from which carbonate sands, litho- and bioclasts had to be derived.
Symposium Field trip, this volume). The 67 m thick section tract between the top of the Inici Fm. and the hardground therefore corresponds approximately to the Erice fm. succession described in detail in the Antica Erice section.

Striking differences instead characterize the overlying part of the succession, which will be shown through examination of several short sections.

Substop 8.1 - East side of the Miliana quarry

Along a few metre-high cliff (section MI-1, Fig. 36) the top of the filament-rich packstones (Level 1) displays the hardground in an even more spectacular fashion than in the Monte Erice area. The discontinuity is characterized by iron stained cm-large burrows penetrating into the underlying bed (Fig. 37), and is floored by a lag of lithoclasts with fragments of ammonite moulds coated by a green-brown film or sometimes by thick crusts of Fe-Mn oxides.

Ammonites are frequent; a cursory sampling yielded *Lissoceras ventriplanum* and *Choffatia* [m] sp. ind. Perhaps this is the same section described by WENDT (1971b, p. 60), who reported a long list of ammonites among which *Oxycerites nivernensis*, *Oecotraustes bradleyi*, *Prohecticoceras retrocostatum*, *Trimarginia cf. sinaitica*, *Siemiradzkia* pl. spp., *Rugiferites angulicostatus*. In a different section of the Miliana area, the hardground delivered a fine specimen of *Homeoplanulites (H.) aequalis* (Fig. 38). The sum of the biochronological information deriving from such a composite ammonite assemblage, and the state of preservation typical of taphonomically reworked fossils (e.g. truncated moulds, glauconitic and/or iron coatings), indicate the mixing of taxa spanning the middle to late Bathonian. Yellowish-grey nodular limestones follow,

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**Fig. 35** - Relationships between the two main sections exposed in the abandoned Miliana quarry. The correlation is assured by the hardground topping the filament-rich packstones of the layer located at about 67 metres above the top of the Inici Fm. (cf. Level 1 in the next Fig. 36).

seen in other sections, *i.e.* alternances of sponge-bearing cherty limestones, crinoidal packstones, and subordinate marly interbeds.

Well bedded, filament-rich packstones to grainstones then follow for about 7 m, and are topped by a hardground with Bathonian ammonites, correlated to that already seen at Monte Erice (cf. Stop 5 of the Pre-

**Fig. 36** - Scheme of chronostratigraphic correlation of the four sections measured on the eastern fronts of the Miliana quarry.
Fig. 37 - Hardground at the top of Level 1, MI-1 section, with green-brown coating on the discontinuity surface and the iron stained burrows.

Fig. 38 - Homeoplanulites aequalis (Roemer). 1.2x. upper Bathonian. Taphonomically reworked specimen. Hardground at the top of Level 1. Undescribed section of the surroundings of Miliana.

Fig. 39 - Levels 2 to 4 in the MI-2 section, eastern front of the Miliana quarry.

with filaments and echinoderm fragments (Level 2); nodules show wacke- to packstone textures and are separated by a matrix of fitted packstone.

Other clear-cut surfaces, with scarce or no oxide coatings, separate four beds at the base of the level and probably representing stratigraphic discontinuities. In the first of these thin beds, a mixed ammonite assemblage biochronologically indicates the early Callovian: Holcophylloceras zignodianum, Lytoceras polyanchomenum, Macrocephalites cannizzaroi, Homeoplanulites (Parachoffatia) funatus. In the southernmost part of the cliff these nodular limestones are overlain by other more nodular and marly limestones displaying a better defined bedding (Level 4). They consist of wackestones and fitted packstones with peloids, Saccocoma and other echinoderm debris

and are interbedded with non-nodular peloidal packstones to grainstones characterized by parallel lamination. A similar set of beds occur above (Level 6). Planed off surfaces occur both at the boundaries of Levels 4-2 and 6-4. Moving northwards along the cliff (section MI-2, Fig. 36), however, two distinct layers appear and rapidly increase in thickness (Levels 3 and 5) (Fig. 39). They consist of sharp based, parallel laminated, coarse grainstones with peloids and superficial oolites. The first one (Level 3), over a distance of about 150 m, reaches a thickness of 370 cm and its lower part is composed of a lithoclastic rudstone (section MI-3, Figs. 36, 40).

Lithoclasts are up to some decimetres across and consist of peloidal grainstones, filament and echinoderm packstones, and silicified radiolarian wackestones; coral and large mollusc fragments also occur. The upper grainstone bed (Level 5) is at most 95 cm thick and only locally contains clasts at the base. Strangely enough, the thickness increase of Levels 3 and 5 is not paralleled by a corresponding thinning of the underlying interval (i.e. Level 2) that, on the contrary, thickens toward the same direction. Above Level 5, a thick succession of dominant peloidal-bioclastic grainstones follows; they are
organized in tabular beds 25 to 40 thick with parallel laminae (Level 6). This tract of succession is well exposed in the main quarry front. Low angle cross lamination is occasionally still recognizable. These grainstone beds are mainly amalgamated and only locally separated by cm-thick interbeds of marly nodular limestones. At the very base of Level 6, in a thin nodular bed, poorly preserved serpenticone ammonites (*Mesosimoceras* gr. *cavouri*) indicate the middle upper Kimmeridgian. About 5 m above the base of Level 6 white chert beds appear. The last 7.5 m still consist mainly of grainstones but *Saccocoma* fragments become increasingly abundant and chert beds more frequent. Parallel laminae are very common and are only locally disturbed by burrows; among these, burrows which bend these laminae downward may be referred to *Fugichnia* (Fig. 41), typical of rapidly deposited beds.

About 200 m to the north the same tract of the succession is exposed again along a cliff (section MI-4, Fig. 36). In this section a few details are useful to clarify geometrical and stratigraphical relationships. At the base of Level 2, a mixed ammonite assemblage is composed by the same taxa already recorded from the section MI-1 (early Callovian). On the other hand, about 390 cm of massive red to pinkish limestone occur between the Bathonian hardground and the base of the lithoclastic megabed. This confirms the northwards thickening trend of both the nodular limestones (Level 2 of the previous sections) and the grainstone-rudstone. The bed directly below the megabed is also interesting: it is strikingly nodular, due to the presence of taphonomically reworked ammonite moulds and calcareous rounded clasts, strongly suggesting a debris flow mechanism; its base is an angular unconformity with erosional truncation of the underlying limestone beds (Fig. 42). The northernmost end of the cliff is a useful spot where a transverse cut allows three dimensional geometries to be understood. The base of the megabed erodes the underlying beds deeply (Level 2), down to the filament-rich packstones of Level 1, below the Bathonian hardground.

Ammonite moulds are quite common in Level 2, providing the following bio-chronostratigraphic data:

**Bed 2a**: Very badly preserved ammonites. Internal moulds of fragmented shells and fragmented or disarticulated moulds co-occur, indicating this is a mixed assemblage. Phylloceratids and lytoceratids are common: *Phylloceras plicatum, Holcophylloceras zignodianum,*...
Ptychophylloceras cf. euphyllum, Sowerbyceras tortisulcatum, Lytoceras gr. orsinii. Perisphinctes (Otosphinctes) sp. ind, Passendorferia [M] sp. ind., Euaspidoceras cf. douvillei, and E. cf. bacebook indicate the middle part of the Oxfordian, Perisphinctes plicatilis to Gregoryceras transversarium Zones.

**Bed 2b:** Besides frequent phylloceratids (see list of Bed 2a plus Phylloceras isotypum and Calliphylloceras cf. benacense), the following ammonites have been identified: Passendorferia [M] n.sp.ind. (= the same taxon already recorded from Bed 9 of the Erice Difali section, see Stop 5), Sequeirosia [M] gr. brochwizi. These ammonites point to the middle-upper G. transversarium Zone.

**Bed 2c:** The fossil content is scanty, although Passendorferia cf. uptonioides and Sequeirosia [M] sp.ind. seem to indicate the middle part of the P. (Dichotomoceras) bifurcatus Zone at the base of the upper Oxfordian. Nevertheless, no precise chronostratigraphic conclusion can be drawn as the fragmentation of these fossils prevents their taphonomic classification. However, the lithology of the bed strongly suggests reworking with scattered reeleraborated specimens of Gregoryceras fouquei, which is consistent with the biochronological meaning of the taxa mentioned above. In conclusion, the presence of ammonites referable to a single chron, albeit with some evidence of taphonomical reworking, supports the hypothesis that Bed 2c was sedimented in the early late Oxfordian.

**Substop 8.2 - West side of the Miliana quarry**

In this section we can see again the typical grey cherty limestones of the middle-upper part of the Erice fm., the overlying filament-rich packstones and the mineralized hardground at their top (here three hardgrounds are clearly recognizable). This set of beds (Levels 6-8 of Fig. 43) is followed by alternances of massive and nodular limestone totalling 160 cm (Levels 9-12). They are characterized by a bright red color and consist of a marly, intensely pressolved matrix in which sharply bounded nodules float. Gravitational mass flows affecting protonodular beds were perhaps responsible for the peculiar sedimentological features of these beds. Fine-grained grainstones with peloids and Saccocoma follow with a sharp basal boundary (Bed 13a). Convex-up laminae referable to hummocky cross stratification characterize the lower part of this bed where cm-sized intraclasts of mudstones also occur (Fig. 44). A 15 cm-thick bed of coarser peloidal grainstone (Bed 13b) directly overlies Bed 13a. Then a succession of nodular peloidal-Saccocoma packstones and planar bedded peloidal grainstones, again with low angle cross lamination, occurs (Levels 15-19). Similarly to the sections visited in the eastern quarry fronts, amalgamated tabular peloidal grainstones follow for several metres.

A marked westward pinch out of the beds overlying Level 12 is clearly observable on the quarry. Ammonite moulds are common in Levels 12 to 16 (Fig. 43), providing accurate ages for the lowest grainstone beds. The following assemblages are documented for the first time in the Miliana area, and are unambiguously late Kimmeridgian.

**BED 12A** - It delivered Holcophylloceras polyolcum, Sowerbyceras gr. loryi, Lytoceras orsinii, L. polycyclum, Nebrodites cf. favarenisis, N. ferrarii, N. hospes (Fig. 45), Aspidoceras acanthicum, A. longispinum, A. meridionale, Orthaspidoceras lallierianum, Pseudowaagenia micropla. The assemblage is typical of the Aspidoceras acanthicum Zone, mainly for the co-occurrence of common Nebrodites and of A. longispinum and O. lallierianum. N. favarenisis, N. ferrarii and P. micropla are known to disappear in the lower part of this biozone, so the whole ammonite
assemblage should represent the Aspidoceras longispinum Subzone (SARTI, 1993).

**Bed 12c** - The ammonite content is limited to Phylloceras consanguineum, Sowerbyceras gr. loryi, Lytoceras montanum, L. orsinii, Taramelliceras compsum, T. cf. platycyclum, T. pseudoflexuosum, Discosphinctoides (?) sp. ind., Aspidoceras gr. acanthicum. The poor taxonomic content prevents any detailed biostratigraphy. Nevertheless the absence of Nebrodites excludes the A. acanthicum Zone (SARTI, 1990), and suggests the thin layer could represent the very base of the overlying Mesosimoceras cavouri Zone. This possibility is also supported by the specimen identified as Discosphinctoides (?) sp.ind. which shows morphological characteristics comparable to those of “Perisphinctes adelus Gemmellaro” (F. OLORIZ, pers. comm.). In this case the sharp boundary at the base of Bed 12c, topping the Saccocoma-rich grainstone of Bed 12b, would reflect the gap of the upper part of the A. acanthicum Zone.

**Bed 14** - Ammonites of the upper part of this bed are rare but significant: Lytoceras polycyclum, Mesosimoceras cavouri, Aspidoceras apenninicum, A. longispinum. The presence of M. cavouri is per-se sufficient to recall the homonymous biozone, which is a Total Range Zone according to OLORIZ (1978).

**Bed 16** - The ammonite content is rich: Sowerbyceras gr. loryi, Lytoceras montanum, L. orsinii, L. polycyclum, Taramelliceras compsum, T. cf. platycyclum, T. pugile pugiloides, Mesosimoceras cavouri, M. cf. risgoviense, Aspidoceras apenninicum, A. longispinum, Pseudowaagenia acanthomphala. Reference of this bed to the M. cavouri Zone is assured by the two species of Mesosimoceras and by the appearance of P. acanthomphala, which is known to first occur in this biozone. Further indication derives from A. apenninicum, which is usually reported in the uppermost Kimmeridgian (SARTI, 1993, p. 126).

**CORRELATION AND INTERPRETATION OF THE UPPER PART OF THE ERICE FM. IN THE MILIANA AREA**

In spite of the limited distance, a precise correlation among sections is by no means trivial. This is due to extreme stratigraphic condensation (Bathonian to Kimmeridgian in 150 cm), sparse occurrence of ammonites, extreme thickness variation or even disappearance of key layers such as the resedimented beds. Here the assumption is that the first peloidal grainstones (Level 13) of Miliana West correspond to the megabed of section MI-1 to -4, for which consequently a late Kimmeridgian age must be deduced based on ammonite assemblages. Furthermore, a complex geometry results for this lithosome and for the underlying Callovian-Kimmeridgian set of beds. The thickening of the megabed, except for the axis of the channelized flow (section MI-4), is not due to increasingly deeper erosion into the older sediments. On the contrary, erosion is deeper and deeper where the megabed pinches out.

This puzzle could be explained by inferring the existence of a local slope: the highstanding parts were more effectively eroded but the lithoclastic gravel and peloidal-oolitic sands were preferentially accumulated in depressions.

In the hypothesis of a tsunami-generated catastrophic offshore flow of carbonate sands and gravels, the following picture can be proposed (Fig. 46). A burst of tectonics and related sismic activity produced normal faults with overall vertical displacements of only...
some metres and slight tilting of adjacent blocks. Partly lithified ammonite-bearing sediments became unstable on this oversteepened slope and gave rise to areally and volumetrically restricted gravity flows that were sedimented above erosional surfaces. These surfaces could be due either to a gravitational instability (slide scars) or to previous episodes of hydrodinamic erosion related to tsunami-induced backflow currents. It is speculated that a particularly violent seismic shock caused a tsunami across the shallowest part of the ramp. Huge amounts of lithified and unlithified sediment were eroded and then transported offshore. The Miliana area in this frame could have played the role of a proximal sector with a tectonically-generated sea bottom palaeotopography in which the backflow was channellized. This resulted in very rapid thickness changes of the megabed compared to its overall tabular geometry across the southern part of Monte Erice, i.e. in the outer part of the physiographic, depositional ramp.

STOP 9 - ROCCA BUSAMBRA: THE JURASSIC MARGIN OF A PELAGIC PLATFORM AND ITS CRETACEOUS EVOLUTION

L. MARTIRE & C. BERTOK

The Rocca Busambra ridge represents an outstanding feature in the landscape of this region (Fig. 47). It is characterized by abrupt cliffs, up to some hundred metres high, surrounded by intensely cultivated, gentle hills made of softer rocks which are gently incised. These correspond mostly to Miocene marls that either represent the sedimentary cover of the carbonate Mesozoic Trapanese units, or the coeval sedimentary cover of other paleogeographic-structural domains thrust over the Trapanese Units (e.g. CATALANO et alii, 1996). Pliocene high angle faults, with a probable strike slip component (GISETTI & VEZZANI, 1984), cut through the tectonic pile exposing the Mesozoic successions.

Rocca Busambra has been studied in detail in the past (e.g. WENDT, 1971a) especially for its abundant neptunian dykes. In particular WENDT discussed the presence of polygenic dyke infillings and was able to distinguish different fossil assemblages which record subsequent ages, spanning the early Toarcian to late Kimmeridgian, i.e. respectively the late Harpoceras serpentinum to Hybonoticeras beckeri chron (WENDT, 1971a, p. 153-163). Among the fossil groups represented, study of the gastropod assemblages is presently in progress by S. Conti.

The stratigraphic succession cropping out at Rocca Busambra is represented by a discontinuous carbonate succession whose main terms are:

1) - Inici Fm. (Upper Triassic-Sinemurian): Bahamian-type carbonate sediments several 100's metres thick, mainly represented by peritidal biopelsparites with fenestrae. They are topped by the typical sharp discontinuity characterized by a thick crust of Fe-Mn oxides and by a pinnacled morphology (DI STEFANO & MINDSZENTY, 2000).

2) - Rosso Ammonitico (Middle-Upper Jurassic): condensed pelagic facies represented by massive to

Fig. 46 - Tentative reconstruction of the depositional surface of the resedimented megabed exposed in the Miliana quarry.
noddular red, ammonite-bearing limestones about 10 m thick.

3) - Another discontinuity occurs at the top of the Rosso Ammonitico spanning most of the Lower Cretaceous. This interval, elsewhere in the Trapanese Domain, corresponds to white calpionellid limestones (Lattimusa Fm.) and to marl-limestone alternations (Hybla Fm.)

4) - Scaglia Fm. (Upper Cretaceous-Paleogene): pink, pelagic marly limestones with abundant planktonic foraminifers. This formation, spanning also part of the Paleogene, is more than 100 m thick. This formation has not been studied in detail yet, and so it is not possible everywhere to distinguish the Cretaceous from the Cenozoic portion.

5) - A last important discontinuity separates the Scaglia pelagic limestones from foraminifer-rich calcarenites with glauconite referable to the Middle Miocene Calcareniti di Corleone Fm.

The present structural setting of the southern flank of Rocca Busambra (Piano Pilato) displays a staircase arrangement: the Inici-Rosso Ammonitico boundary, characterized by the typical pinnacled morphology and by the thick crusts of Fe-Mn oxides, is repeated several times along the mountain slope in such a way that it could even be interpreted as the simple result of Cenozoic extension. A closer view of the presumed fault scarps, however, reveals the presence of anomalous stratigraphic relationships. The purpose of this day is to examine in detail such stratigraphical relationships in order to highlight how the present geological setting is the direct consequence of the Mesozoic tectono-sedimentary evolution.

**Substop 9.1 - Piano Pilato, road to shepherd hut: anomalous Scaglia/Inici Fm. Contact**

Climbing up the road towards the hut, on the left side the mineralized top of the Inici Fm. is observable. On the right hand side, the white Inici limestone is upthrown by a fault. A lenticular lithosome, a few tens of metres across and less than 0.5 m thick, of pink micritic limestone with globotruncanid foraminifers referable to the Scaglia directly overlies the Inici limestones of both blocks (Figs. 48, 49). The lower part of the Scaglia is a breccia with cm-sized lithoclasts of foraminifer wackestone floating in a matrix with a similar texture. Ill-defined bedding is recognizable in the upper part of this body which dips approximately 30° to the south, even though very rapid changes affect both its dip and strike. These values clearly contrast with those of the nearly horizontal beds of the Inici Fm. The boundary between these two formations is hence an angular unconformity with a very long gap corresponding to the lack of any stratigraphic record of the whole Middle Jurassic-Lower Cretaceous interval and in particular of the Rosso Ammonitico that commonly overlies the Inici Fm. in this area.

These anomalous stratigraphic relationships are an evidence of the Cretaceous pelagic draping of an escarpment incised within the Inici Fm. These discontinuous pelagic sediments moreover seal a fault of surely pre-Scaglia age.

Fig. 47 - Geographical location of the Substops 9.1 to 9.8.
Substop 9.2 - Piano Pilato, East of the shepherd hut: Jurassic and Cretaceous megabreccias and anomalous Rosso Ammonitico/Inici Fm. contact

Walking to the east of the hut for a few tens of metres, just uphill of a fig tree, the normal mineralized Inici-Rosso Ammonitico boundary is observable. Few metres to the left, dm-thick, 1-2 metres wide slabs of Rosso Ammonitico are markedly discordant with each other and with the Inici-Rosso Ammonitico normal succession (Fig. 50). Further to the left, a breccia occurs with pluridecimetric blocks of Rosso Ammonitico limestone. The matrix is texturally inhomogeneous but is basically composed by wacke- to grainstone with coarse echinoderm and Saccocoma fragments indicating the Late Jurassic. A dense network of mm- to cm-wide fissures filled with Cretaceous to Miocene sediments greatly complicates the picture and makes observation of the clast-matrix relationships difficult. Moving some metres upslope, another breccia occurs that is separated from the former by a clear-cut boundary. Clasts of both the Rosso Ammonitico and Inici limestone are smaller and much less abundant, and float in a matrix of red mudstones referable to the Scaglia. Both breccias pinch out upslope against a low cliff where the Inici Fm. and the Rosso Ammonitico are exposed. The Inici-Rosso Ammonitico boundary is represented by an abrupt, not mineralized sloping surface dipping eastwards. The Inici Fm., finally, is crossed by several neptunian dykes up to 20 cm large. They are both bedding-parallel and subvertical and are filled with a variety of sediments ranging from protoglobigerinid-wackestones to echinoderm packstones referable to the Rosso Ammonitico, and brick red mudstones with sparse planktonic foraminifers belonging to the Scaglia.

This complex situation may be interpreted mainly as the product of a Late Jurassic collapse event affecting the Rosso Ammonitico sediments (Fig. 51). This resulted in a variety of phenomena which produced an increasing degree of internal deformation, from simple sliding with minor displacement and rotation, to complete disruption of beds and formation of megabreccias. Early cemented layers gave rise to blocks, whereas uncemented deposits...
were able to flow among blocks, acting as the breccia matrix.

Moving some tens of metres eastward, leaving the low Rosso Ammonitico cliff, pink sediments still referable to the Rosso Ammonitico, but showing a facies that is nowhere found in the normal succession, overlie the normal Rosso Ammonitico. These “anomalous” beds consist of intraclastic floatstones. The intraclasts are cm-sized, and have microbored and iron stained rims. Sometimes they contain smaller intraclasts, an evidence of a polyphase process. Both the intraclasts and the matrix are composed by a wackestone with radiolarians, bivalves, echinoderm debris, ammonite nuclei, gastropod protoconchs and calpionellids (Calpionella alpina and Remaniella sp.) indicating the lower Berriasian, C. alpina Zone. These unusual sediments show geometrical similarities with the Scaglia sediments observed in Substop 7.1. Their dip, of about 20°-30°, is in fact discordant with the underlying subhorizontal Rosso Ammonitico normal succession, which they overlie through a downlap contact. Both upslope and laterally, however, they pinch out and the white limestones of the Inici Fm. crop out, whereas the mineralized crust can nowhere be detected. A fault is therefore again to be inferred, downthrowing the southern block where the Rosso Ammonitico cliff lies. The resulting escarpment is then draped by the intraclastic limestones, which therefore constrain the age of the fault as earliest Cretaceous.

Substop 9.3 - Piano Pilato: Rosso Ammonitico normal succession and anomalous deposits

The top of the Inici Fm. and a continuous section of Rosso Ammonitico crop out here on a vertical cliff. The usual mineralized pinnacled boundary is beautifully exposed. Above, one of the thickest Rosso Ammonitico sections of the area can be seen. The following levels can be distinguished (Fig. 52):

Level 1 - The lowest part of the Rosso Ammonitico is quite variable from place to place. Usually the first bed is about 20 cm thick and consists of wackestone with filaments, echinoderm fragments, calcitized radiolarians and benthic foraminifers. Locally, however, a discontinuous 10-15 cm thick bed consisting of filament- or echinoderm-rich packstone with abundant cm-sized Fe-Mn oxide oncods occurs between the Inici limestones and the thick black oxide crust that commonly directly coats the Inici pinnacles (Fig. 53). These should indeed be the beds where WENDT (1971a) found his Bathonian ammonites. A vertical neptunian dyke crosses this first level and penetrates into the Inici Fm.

Level 2 (280 cm) - Massive, light brown to reddish limestone mainly consisting of Saccocoma-rich grainstones with subordinate Saccocoma- and calcitized radiolarian- wackestones. From base to top, the boundaries between these two types of sediments become increasingly sharper suggesting a change from burrowing of texturally different layers to erosion and generation of wackestone intraclasts during higher energy episodes with winnowing and deposition of bioclastic sands. These intraclasts, however, never show microbored and/or mineralized periphery.

Level 3 (100 cm) - In spite of a still massive aspect on weathered surfaces, this interval is finer grained than the underlying one; wackestone portions are more abundant and contain small mineralized intraclasts; the Saccocoma-rich sediments are packstones displaying fitted fabrics and dissolution seams. All this produces a faintly nodular appearance.
Level 4 (260 cm) - Same features as Level 2.

Level 5 (50 cm) - Same features as Level 3 but with thinner beds with (15-20 cm), a higher ratio of wackestone vs. fitted packstone, and a higher degree of compaction of the packstone, resulting in a more evident nodular structure.

Level 6 (120 cm) - Same features as Level 5. Worth mentioning are: the abundance of microbored and mineralized intraclasts and the first occurrence of calpionellids represented only by poorly preserved *Crassicollaria* (upper Tithonian).

Level 7 (110 cm) - Bedding becomes even thinner and nodules more evident. Fragments of taphonomically reworked ammonite moulds coated by thin films of Fe-Mn oxides are common. Microscopically the first occurrence of *Calpionella alpina* still associated with *Crassicollaria* spp. is remarkable. Based on these data it is not possible to state if this bed is uppermost Tithonian (top of the *Crassicollaria* Zone) or lowermost Berriasian (base of the *C. alpina* Zone).

After climbing the steep cliff corresponding to the Rosso Ammonitico, looking at the mountain slope it is easy to recognize the same Inici and Rosso Ammonitico succession on another cliff about 50 m uphill. A normal fault is again obvious and, as in the previous stop, anomalous beds of Rosso Ammonitico with a steeper dip, approximately corresponding to the present-day slope, drape the scarp between the two cliffs (Fig. 54). These anomalous deposits overlie the top of the normal Rosso Ammonitico succession with downlap relationships and consist of intraclast-rich nodular limestones with abundant *Calpionella alpina*, probably indicating the lowermost Berriasian (Fig. 55).

Substop 9.4 - Western Piano Pilato: anomalous Rosso Ammonitico/Inici Fm. contact

The aim of this stop is to show the physical contact of the Inici Fm. with the anomalous Rosso Ammonitico deposits which was inferred in the previous stops but never directly observed. The mineralized Inici-Rosso Ammonitico contact is observable. Below this boundary, a sharp surface cuts through the white Inici limestones and locally also through small dykes filled with crinoidal grainstones, and is overlain by a peculiar kind of nodular limestone (Fig. 56). Nodules are subrounded, cm-sized and consist of pink wackestones with abundant *Calpionella alpina*. Laminated red mudstones with a fine bioclastic debris fill geopetally the internodular voids, evidencing that an open space framework existed within
a lithoclastic gravel that draped a probable fault plane along which the Inici limestone had been exhumed. Few tens of metres downslope, in spite of poor outcrop, nodular beds seem to represent the lateral continuation of these lithoclastic rudstones and, as in Substop 9.3, overlie in downlap the top of the normal succession of Rosso Ammonitico. These beds are thin and crop out discontinuously. These beds contain mixed assemblages of taphonomically reworked ammonites spanning the early late Tithonian to Berriasian: Holcophylloceras cf. silesiacum, Lytoceras liebigi, Haploceras tithonium, Corongoceras aff. leanzai, C. cf. rhodanicum, Retowskiceras andrussowi (F. CECCA, pers. comm.).

Substop 9.5 - Western Piano Pilato: anomalous Rosso Ammonitico/Rosso Ammonitico contact

A few hundred metres to the west of Subtop 9.4, an outcrop displays a unique stratigraphical situation: an angular unconformity separating bed packages all belonging to the Rosso Ammonitico. Along a low cliff, a normal succession of subhorizontal Rosso Ammonitico beds consists of the Saccocoma-rich packstone to grainstones already described in the lower and middle parts of the section visited in Substop 9.3. Other Rosso Ammonitico sediments, in thick beds, have a south-eastern dip of about 30-40°. They abut against the cliff with obvious onlap relationships on the subhorizontal Rosso Ammonitico lithosome. Actually, the steeply dipping package differs also lithologically, being markedly nodular, mainly due to the presence of cm-sized reworked ammonite moulds and intraclasts consisting of pink wackestone with rare calpionellids (Crassicollaria parvula and Calpionella alpina) separated by a matrix of Saccocoma fitted-packstones (Fig. 57). In this case, the unconformable pelagic sediments of probable late Tithonian age draped an escarpment carved within the normal Rosso Ammonitico succession.

Substop 9.6 - South-eastern side of Pizzo Nicolosi: Scaglia onlapping a fault scarp in the Rosso Ammonitico

An unconformity between the Rosso Ammonitico and the pink globotruncanid-rich wackestones of the Scaglia Fm. is extensively exposed approaching the Pizzo Nicolosi saddle. Compared to the contacts between the anomalous Rosso Ammonitico patches and the Inici Fm., this is a much more impressive angular unconformity. The sediments of the Scaglia Fm. in fact abut against the Rosso Ammonitico with a southern dip of about 70-80° (Fig. 58); the contact has a variable geometry: in some places it is smooth and flat, whereas in others it is very irregular so that, owing to the reduced thickness of the Scaglia, crags of the underlying Rosso Ammonitico crop out through the Scaglia blanket.

This beautiful example of angular unconformity represents the result of pelagic sedimentation above Late
Cretaceous high-angle normal fault scarps cutting through the whole Jurassic succession. It lies in fact along the south-eastern prolongation of the northern margin of the Pizzo Nicolosi graben, which is clearly visible in cross section from Rocca Argenteria (see Substop 10a of Pre Symposium Field trip).

Substop 9.7 - Southern side of Pizzo Nicolosi: normal succession of Rosso Ammonitico with neptunian dykes, and Rosso Ammonitico and Scaglia anomalous deposits

The pinnacled and Fe-Mn encrusted top of the Inici Fm. and a continuous section of Rosso Ammonitico are very well exposed again on a cliff several tens of metres long on the southern side of Pizzo Nicolosi. The inherited rock ground topping the Inici Fm. has the same features as those already seen in Substop 9.3. Very good exposure allows observation of a lag with several dm-sized fragments of pinnacles flooring the rock ground and encrusted by the Fe-Mn oxide crust (Fig. 59). The Rosso Ammonitico normal succession, however, is different here from that at Substop 9.3 (Fig. 60). The main difference concerns the lower part: the bioturbated Saccocoma-rich packstones or grainstones, in fact, occur at 1.80 m above the base (Level 3 in Fig. 60) and overlie a massive facies not represented in the Substop 9.3 section (Levels 1 and 2). This consists of wackestones with peloids, calcitized radiolarians, both benthic and planktonic foraminifers (protoglobigerinids), calcisphaeres, Globochaete, and rare filaments characterized by a undulose, mm-thick stromatolitic lamination. The upper half of this lower interval, moreover, contains sphaeroidal Fe-Mn oxide oncoids up to 10 cm in diameter (Level 2). The same stromatolitic facies, with mineralized intraclasts, is found again 3.5 m above the bioturbated Saccocoma-rich packstones (Level 4). The highest observable bed is again a Saccocoma-rich packstone (Level 5).

Another interesting feature of this outcrop is the presence of neptunian dykes within the Fe-oncoid-bearing bed. Subhorizontal cm-wide fissures are clearly recognizable on the cliff wall and are mainly filled with Scaglia micritic sediments and white rims of radiaxial calcite cement. In thin section, however, at the very base of the fissures, a bivalve and echinoderm grainstone belongs to the Rosso Ammonitico and suggests a Jurassic opening of the dyke, which was later reopened. Laterally, in fact, few tens of metres eastward, a subhorizontal 15 cm thick dyke appears within the same bed and may be
Substop 9.8 - Southern side of Pizzo Nicolosi: ammonite-bearing Jurassic neptunian dyke within the Inici Fm.

On the southwestern side of Pizzo Nicolosi, in a narrow creek few tens of metres above the untarred road and a water pool, the Inici-Rosso Ammonitico succession is observable again and shows features similar to Substop 9.7. In the easternmost side of the outcrop a sub horizontal neptunian dyke is easily visible thanks to the brick-red colour within the whitish Inici limestones, some decimetres below the pinnacled boundary with the Rosso Ammonitico. The micritic infilling is rich of invertebrate remains whose neomorphic tests are blackened by Mn coating. The locality was described by WENDT (1971a, p. 39), who made intensive fossil collectings. The results of his preliminary study were integrated in the general taxonomic lists reported (op. cit.) on pages 159-163. As usual, ammonites are the most frequent and significant elements (Fig. 62); they cover different chronos spanning the middle Oxfordian (e.g. Gregoryceras fouquei) to the late Oxfordian (Eripelloceras bimammatum), and to the middle-upper part of the Kimmeridgian with a mixing of species such as Simosphinctes rachistrophus, Nebrodites hospes, and Mesosimoceras cavourii. Further research is needed to confirm whether this taxonomic mixing is an artifact of difficult sampling, or is a genuine taphonomic reworking; in fact the state of fossil preservation allows to classify them as resedimented elements with no biochronological mixing.

Fig. 62 - Ammonite-bearing infilling of a neptunian dyke at the top of the Inici Fm. The study of the ammonite assemblage, dominated by phylloceratid Sowerbyceras like the specimen visible in the photo, is in progress by C. D’Arpa.

DISCUSSION

Two different kinds of stratigraphic successions are met in the Rocca Busambra area. One is the “normal” Inici-Rosso Ammonitico succession where the two
lithostratigraphic units are superposed in paraconformity through an important discontinuity marked by a thick crust of Fe-Mn oxides and characterized by a irregular pinnacled morphology, possibly due to dissolution during a prolonged subaerial exposure (DI STEFANO & MINDSZEI, 2000; see also Substop 10B of Pre Symposium Field trip). The other type of succession is an "anomalous" one where an angular unconformity exists between the Inici Fm. and the overlying pelagic sediments that, from place to place, may be the Upper Jurassic Rosso Ammonitico or the Upper Cretaceous-Paleogene Scaglia. No Fe-Mn oxide crusts occur in these instances. The normal and the anomalous successions perfectly match the facies associations A and C of SANTANTONIO (1993), that represent the product of sedimentation on the top and along the flanks of pelagic carbonate platforms, respectively. The peculiarity of these angular unconformities is that the pelagic sediments are inferred to represent the draping of originally inclined surfaces deeply cut into the approximately horizontal normal succession (mainly made of the Inici limestone).

In some cases, the surfaces have a gentle dip and connect two blocks where normal Inici-Rosso Ammonitico successions occur with a vertical displacement of a few tens of metres. The anomalous sediments that drape such escarpments onlap the highstanding block and downlap the lowstanding one. Two different mechanisms may be called upon to explain these surfaces: 1) normal faulting; 2) gravitational sliding. As proposed by WINTERER et alii (1991) and WINTERER & SARTI (1994), the latter would seem more likely because of the low angle of the surface itself. However, the lack of any significant rotation of the supposed slide blocks, and of internal disruptions coupled with vertical and horizontal components of displacements amounting to several tens of metres, lead to exclude this mechanism. Shallow low angle normal faults, possibly associated with deeper-seated higher angle master faults, may on the contrary be invoked as the main cause for the generation of a stepwise slope on the southern side of Rocca Busambra.

Other angular unconformities, by contrast, are steep (e.g. the flanks of Cretaceous depressions) and can be interpreted as normal paleo faults with a strike slip component, which gave rise to narrow graben structures (LONGHITANO et alii, 1995).

As already concluded in the Pre Symposium Field trip Stops 10 and 11 (Rocca Argenteria and Rocca Drago, representing the western prolongation of the Rocca Busambra ridge), after the drowning of the peritidal platform and a period of purely aggradational pelagic sedimentation, a history of important changes in the paleotopography of the sea floor is recorded at Rocca Busambra. In the Tithonian this sector of the Trapanese Domain was fragmented and became the margin of a pelagic carbonate platform, with escarpments along which thin lenses of pelagic sediments could be preserved only locally and often were reworked by currents or by slides. The low angle faults could be considered as minor structures associated with a master fault, now buried below Tertiary sediments, which could have marked the transition of the Trapanese pelagic platform domain to a basinal domain (Sicanian Domain?) since the Late Jurassic. In the Late Cretaceous the area was again dissected by faults and its slope was rejuvenated. All this resulted in the generation of an isolated highstanding ridge draped by thin veneers of the Scaglia Fin., a unit that attained much greater thickness in adjacent basins but is today covered under the Neogene sediments, a visible exception being in the Pizzo Nicolosi "canyon".

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Post-Symposium Field Trip B2
(19-21 September 2002)

PIANA DEGLI ALBANESI, MONTE KUMETA AND THE “SACCENSE
DOMAIN”: PELAGIC, RESEDIMENTED, AND HIGH-ENERGY SKELETAL
POST-DROWNING FACIES FROM WESTERN SICILY

SCIENTIFIC COORDINATOR

MASSIMO SANTANTONIO

CONTRIBUTORS

ANGELA BALDANZA, ANNACHIARA BARTOLINI, RAFFAELLA BUCEFALO PALLIANI, DANIELA CASSIOLI, MARCO
CHIARI, JOHN W COPE, CAROLINA D’ARPA, PIERO DI STEFANO, ANDRÁS GALÁCZ, FRANCESCA GASPARRI,
GIANNI MALLARINO, MARIA CONCETTA MARINO, MAURIZIO MARINO, NINO MARIOTTI, EMANUELA MATTIOLI,
ANDREA MINDSZENTY, CRISTINA MURARO, UMBERTO NICOSIA GIOVANNI PALLINI, GUIDO PARISI, FABIO
MASSIMO PETTI, MASSIMO SANTANTONIO & ATTILÁ VORÓS.
FOREWORD

The aim of this fieldtrip is to display the Jurassic geology of central western Sicily through three peculiar examples: the Piana degli Albanesi, the Mt. Kumeta and the Sciacca areas. These outcrops serve to represent the typical facies and primary geometries of the Imerese, Trapanese and Saccense Domains respectively (see below).

The general palaeogeography of Sicily has received different interpretations during the past decades, mainly due to the severe degree of deformation experienced during the orogenic phases that affected the Mediterranean region in the Tertiary (CATALANO et alii, 2000), and which became superimposed on earlier syndepositional structures. A general outline of the present-day geology of Sicily is given in the introductory paper by CATALANO (this volume). Interestingly, recent advances in seismic section interpretation resulted in a Permian-Early Mesozoic palaeogeography that is perhaps simpler than previously believed.

Current views envisage in the Permian-Triassic the existence of one continuous, wide carbonate shelf (Panormide, Trapanese, Saccense and Hyblean Domains) rimming the African margin, flanked by a vast basin (Imerese and Sicanian Domains) (CATALANO et alii, 1995b, 1996, 2000). The Jurassic, however, is a whole other story, and one that is relatively less well understood. In the beginning, carbonate platform environments are documented by the persistence of the Inici Fm., although coeval intraplatform basins (Marineo and Mt. Genuardo basins) existed, based on subsurface drillhole and seismic data (CATALANO & D'ARGENIO, 1982b; CATALANO et alii, 1995a, 1996; DI STEFANO et alii, 2001).

Rifting in the Early Jurassic caused the break-up of this carbonate megabank, resulting in the drowning of the Trapanese and Saccense sectors, where a complex pattern of pelagic basins and escarpment-bounded pelagic carbonate platforms developed (see also JENKYS, 1971). This produced some of the most fascinating pelagic facies in the whole Mediterranean region. These facies will be the main object of the field trip.

Massimo Santantonio
STOP 1 - PIANA DEGLI ALBANESI, IMERESE DOMAIN: DEEP-WATER SLOPE TO BASIN; RELATIONSHIPS BETWEEN CARBONATE PLATFORM AND BASIN SEDIMENTATION

A. Bartolini, R. Bucefalo Palliani, M. Chiari, P. Di Stefano, E. Mattioli & G. Parisi

INTRODUCTION AND GEOLOGICAL SETTING

The Piana degli Albanesi area is located in the southern sector of the Palermo Mountains. In this area a large thrust sheet that derives from the Tertiary deformation of the Imerese paleogeographic Domain crops out. This structural unit consists of Carnian to Eocene deep water carbonates and cherts, with repeated clastic-carbonate intercalations. Facies analysis of these clastics clearly points to a derivation from the Carnian-Eocene platform carbonates of the Panormide Domain. During the Mesozoic and Paleogene, the Imerese Domain is interpreted to document a slope to peribasinal environment adjacent to the Panormide carbonate platform (CATALANO et alii, 1996).

This stop offers a snapshot of Jurassic sedimentation in this domain through the observation of a Lower Jurassic succession belonging to the Crisanti Formation (Auct.).

This formation consists of varicoloured marls and calcilutites, siliceous limestones and bedded cherts, bearing several clastic-carbonate beds and locally also volcanic levels. The age of this formation ranges from the Early Jurassic to the Late Cretaceous. Among the clastic-carbonates, two major intercalations, several tens of metres thick, outcrop. The older is dated as Tithonian-Early Cretaceous (Ellipsactinia limestone), and the younger is Albian-Cenomanian (Orbitolina limestone) in age. The total thickness of the Crisanti Fm. ranges from about 200 up to 400 m. It overlies a thick (up to 500 m) unit of resedimented dolostones, grouped into the Fanusi Fm., containing reworked late Carnian-Rhaetian Halobia-bearing cherty limestones (Scillato Fm.). The upper boundary of the Crisanti Fm. is marked by a discontinuity surface overlain by uppermost Cretaceous-Eocene reddish calcilutites (Scaglia-type) with planktonic foraminifers (Caltavuturo Fm.).

LITHOSTRATIGRAPHY

The studied section crops out along the bypass road close to the small town of Piana degli Albanesi (Fig. 1). It belongs to the lower part of the Crisanti Fm., and is late Sinemurian-late Domerian in age, based on calcareous nanofossil and dinoflagellate cyst biostratigraphies (Fig. 2).

The outcrop, from 0 to 10 m, is characterised by grey marls alternating with laminated limestones rich in radiolarians and sponge spicules and with frequent resedimented carbonate beds. The base of the section is characterised by a thick graded calcirudite-calcarenite, 2.8 m thick, Interpreted as a turbidite. The lithoclasts consist of sponge boundstones, and peloidal-oolid-oncoid grainstones bearing a benthic foraminifer assemblage with Hirsutspirella pilosa, Cucurbita brevicollum,
Siphonophera sp., Kaeveria fluegeli and Galeanella sp. (Fig. 3). Microproblematics like Actinotubella sp., Microtubus communis and Radiomura sp. are also present. Both the microfacies types and the foraminiferal assemblages are typical of Upper Triassic reefs and are commonly found in the Norian-Rhaetian reefs bordering the Panormide Platform (SENOWBARI-DARYAN et alii, 1982; DI STEFANO, 1990). Rare wackestones with radiolarians, miliolids and Ophtalmidium are also found.

In the calcarenitic turbidites interbedded upwards (7.50 and 10.50 m) the abundance of "pelagic" elements increases and these prevail over the platform-derived elements (Fig. 4). Chert occurs here as nodules.

The lithoclasts of the two calcarenitic turbidites are the same as those of the 2.8 m thick bed described above. The bioclasts consist of echinoid and crinoid fragments and foraminifers. The upper part of both levels grades into wackestone with radiolarians and sponge spicules representing autochthonous pelagic sedimentation.

The marls and limestones have abundant radiolarians, rare hyaline foraminifers represented by elongated and flat morphotypes (Marginulina spinata, Paralingulina gr. tenera, Vaginulina sp., Frondicularia sp.), rare agglutinated foraminifers (Glomospira sp., Glomospirella sp.) and rare ostracods.

At 10.50 m a white cherty level marks the middle part of a detrital bed (60 cm thick) (Fig. 5).

Following the irregular top surface of this bed, the most siliceous facies of the Crisanti Fm. occurs. It is characterised by dark grey-black, laminated siliceous limestones interbedded with dark grey or red siliceous-marls. Lamination consists of millimetric intercalations of black organic material, radiolarians and sponge spicules. This part of the section bears evidence of gravitational instability in the form of intraformational truncation surfaces and unconformities, and slumps. Its age is still poorly constrained, but can be roughly assigned to the Toarcian-Bathonian interval.

**BIOSTRATIGRAPHY**

Dating of the lower portion of the succession is based on the integrated study of calcareous nanofossils and dinoflagellate cysts.
Microfacies of the Early Jurassic: a) Lithoclastic packstone, with aggregate grains, echinoid fragments and lithified carbonate fragments; b) Transition of fine-grained clastic limestone into radiolarian wackestone; c) Bioclastic and aggregate grains wackestone with ooids; d) Wackestone with radiolarians and sponge spicules; e) Fine-grained wackestone with benthic foraminifera, Lenticulina (1) Paralingulina (2) and bioclastic Meandrospiridae (3); f) Radiolarian wackestone with lithified carbonate fragments (lithoclasts) of shallow-marine facies.

Fig. 5 - Calcarenitic turbidite at 10.50 m level.

**Calcareous Nannofossils**

The base of the section (3 to 6 m) (Fig. 6) has given a rich and diversified nannofossil assemblage, in which Parhabdolithus liasicus, Parhabdolithus robustus, Crepidolithus crassus, Crepidolithus pliensbachensis, Mitroliithus lenticularis and Mitroliithus elegans dominate, being common to abundant.

Other significant species are Similiscutum cruciulus, which first occurs at the very base of the Carixian, and Crepidolithus timorensis, reportedly a ?Sinemurian form (small Crepidolithus of COBIANCHI, 1992; LOZAR, 1995; BOWN & COOPER, 1998). The interval from 3 m to 6 m is therefore uppermost Sinemurian or, more probably, close to the Sinemurian/Carixian boundary, NJT 4a nannofossil Subzone (MATTIOLI & ERBA, 1999).

The interval from 8 m to 9.50 m has a different nannofossil assemblage, due to the disappearance of characteristic Sinemurian-Carixian forms (P. robustus, C. pliensbachensis, C. timorensis). These are replaced by Crepidolithus cavus, Lotharingius barozii and L. frodoi. All these species first occur in the upper Domerian, NJT 5a nannofossil Subzone (MATTIOLI & ERBA, 1999) (Fig. 6).

**Dinoflagellate cysts**

The samples underwent standard palynological procedure (WOOD et alii, 1996) and yielded a variable organic residue, mainly composed of inertinite and fungal remains. This organic composition suggests a poor preservation of the organic material. The rare dinoflagellate cysts recorded in samples PCR 7, PCR 10 and PCR 15 belong to the long-ranging genera Nannoceratopsis and Mendicodinium. In the Tethyan domain Nannoceratopsis first appears in the lower Pliensbachian and it becomes widespread in the Boreal Realm (BUCEFALO PALLIANI & RIDING, 1999).
The genus exhibited a marked increase in abundance and species diversity during the late Pliensbachian (WOOLLAM & RIDING, 1983; DE VAINS, 1988; DODEKOVÁ & TCHOUMATCHENKO, 1989; RIDING & THOMAS, 1992; FEIST-BURKHARDT & WILLE, 1992; ILYINA et alii, 1994; POULSEN, 1996). Species of *Mendicodinium* have been reported from the lower Pliensbachian and lower Toarcian of different Tethyan areas (central Italy, Greece, Hungary and Portugal) (BUCEFALO PALLIANI, 1996). According to BUCEFALO PALLIANI (1996), the base of the Pliensbachian in the Tethyan Realm is marked by the first occurrence of a plexus of small species of *Mendicodinium* with varied ornamentation.

**RESULTS**

Integrated biostratigraphy yielded a continuous stratigraphical documentation ranging from the upper Sinemurian to the upper Domerian.

The Sinemurian-Pliensbachian transition, tentatively placed around metres 7-8, is mainly based on the first occurrence of a lower Pliensbachian dinoflagellate cyst assemblage.

The calcareous nannofossil and dinoflagellate cyst assemblages are remarkably similar to coeval assemblages from the Tethyan Realm (MATTIOLI & ERBA, 1999; BUCEFALO PALLIANI & RIDING, 1999).

The lowermost part of the section (uppermost Sinemurian or Sinemurian/Carixian in age) is characterised by the abundance of thick resedimented carbonate beds rich in Late Triassic reef-derived clasts. These breccias probably document an active tectonic phase that resulted in margin collapse in the adjacent Panormide carbonate platform. During the Pliensbachian detrital levels decrease in thickness, and they are mainly characterised by abundant echinoids, crinoids and dominantly open marine calcareous hyaline foraminifers. This suggests the partial drowning of part of the carbonate platform during the Pliensbachian. Upwards, the disappearance of these clastic levels could indicate the shut off of neritic carbonate production. This latter event may be linked to a more generalised palaeoenvironmental crisis of carbonate platform productivity, as documented in other Tethyan areas (PICOTTI & COBIANCHI, 1996; COBIANCHI & PICOTTI, in press; MATTIOLI et alii, in press; MORETTINI et alii, in press).

**STOPS 2 TO 4 – THE JURASSIC/CRETACEOUS SUCCESSION OF THE SACCENSE DOMAIN – AN INTRODUCTION**

M. MARINO, C. MURARO & M. SANTANTONIO

Peculiar Jurassic sequences cropping out in various sections across the Sciacca area (south-western Sicily) are ascribed to the Saccense Domain (see CATALANO et alii, this guidebook, for tectonostratigraphic setting).

The Jurassic deposits overlie several thousand metres of platform limestones and dolomites of Late Triassic age (Sciacca Fm.).


In general, an evolution can be seen from a peritidal carbonate platform (Inici Fm.) to a pelagic carbonate platform, indicating that post-drowning sedimentation occurred here on a morpho-structural high, which we call the Sciacca Plateau. As a result, the post-Inici pre-Calpionellid limestone succession is no more than about 60 m thick, often much less. The currently accepted lithostratigraphy, largely informal, comprises the following units (CATALANO & D'ARGENIO, 1990; VITALE, 1990) (bottom to top): Inici Fm. (Late Triassic p.p.-Lias p.p.), Crinoidal limestone (Pliensbachian-Toarcian?), Bostira limestone (Bathonian-Callovian?), Nodular and ammonitic limestone (Oxfordian-Kimmeridgian), Pygope limestone (Tithonian p.p.), Calpionellid mudstone (“Lattimusa”, Tithonian p.p.-Neocomian), Hybla Fm. (Early Cretaceous p.p.); Scaglia Fm. (Late Cretaceous-Late Eocene).

Our recent field investigations have highlighted a great variability of facies, thickness and geometries of the Jurassic sediments, while improved biostratigraphy produced tighter constraints for tracing time-correlation lines across the whole depositional system. Moreover, some of the facies and depositional geometries featured in this field trip are, as far as we know, novel for Tethyan post-drowning Jurassic successions.

As a general remark, the Jurassic succession of the Sciacca area is characterized by the absence of thick basinal deposits and of typical deeper-water sediments, like Middle-Upper Jurassic radiolarian cherts. The recognition in the field of angular and non-angular unconformities, and of synsedimentary faults in the Inici Fm., strongly suggests the plateau was structurally composite.

Within this Jurassic plateau distinct subenvironments can be identified if we accept the “panettone” model of SANTANTONIO et alii (1996). This
model predicts that a relationship must exist between several different parameters (facies, thickness, bed geometry, fossil content, condensation style) of PCP-top successions, and the inferred palaeolocalization (inner platform to edge) of individual sections within the PCP itself. These subenvironments are represented in the following localities: Contrada Diesi, Vallone S. Vincenzo, Contrada Monzealese.

At Contrada Diesi the Lower Jurassic carbonates are paraconformably overlain by the thinnest and most condensed (and cephalopod-rich) Bajocian-Bathonian to Tithonian succession, which suggests this represents a subenvironment closer to the plateau-edge (SANTANTONIO et alii, 1996), more subjected to winnowing and erosion.

The thickest Jurassic succession cropping out on the Sciacca Plateau (about 60m), resting paraconformably on the Inici Fm., is found at Vallone S. Vincenzo (Di STEFANO & VITALE, 1993). The open marine deposits may represent here the most internal subenvironment of the Plateau. This setting favoured the impressive accumulation and preservation of spectacular bioclastic deposits.

An intermediate palaeogeographic situation is represented at Contrada Monzealese, where only the lower portion of the pelagic succession, that overlies through an angular unconformity the Inici Fm., is observable. Although the succession is here truncated at the top by modern erosion, biostratigraphy demonstrates this was a thicker section than that at Contrada Diesi, also bearing slumped beds.

The lowest pelagic deposit above the Inici Fm. is a very thin (0-30 cm) discontinuous bed of crinoid-brachiopod-benthic foraminiferal wackestone whose age is still uncertain. A discontinuous centimetre to decimetre thick ammonite-rich polyetalitic black crust (hard-ground), with latest Toarcian/Aalenian ammonites (Di STEFANO et alii, 2002b) then follows, locally capping the Inici Fm. directly. Overlying sediments are late Bajocian in age. The minimum age of drowning of the Inici platform in the Sciacca area is therefore conservatively latest Early Jurassic, but could be somewhat older depending on the age (Pliensbachian/early Toarcian?) given to the crinoidal wackestone.

The top of the Inici platform is generally flat, locally with truncation of gently rotated beds. Erosion probably occurred under sub-aerial conditions. As mentioned above, sectors of the Inici platform were tilted during the Early Jurassic, as in the Contrada Monzealese area (Di STEFANO et alii, 2002b; see also Stop 3), suggesting the presence of a south-dipping system of listric faults few km’s south of the Quarry at Contrada Diesi. This seems consistent with the presence of deeper basins more to the south, in the present-day offshore of Sciacca (ANTONELLI et alii, 1991; CATALANO et alii, 1995b). Other minor tectonic events that occurred during the rest of the Jurassic are marked by neptunian dykes, filled either with Middle Jurassic thin-shelled bivalve and protoglobigerinid-rich mudstones, or with Late Jurassic Saccocoma mudstones.

Sedimentary features suggest a complex scenario for the Jurassic pelagites. There are localities where, in spite of its overall reduced thickness, the post-Inici succession bears “mound”-like convex-up structures, several metres across, made of well washed Bositra sands, or clinoforms made of ammonite coquina. Other localities, like the one treated in the present stop, have more typical post-drowning mud-dominated condensed successions.

While the overall modest thickness, lack of sediment gravity flows, lack of chert, and the occurrence of richly ammonitiferous condensed sections all indicate deposition over a submarine plateau, the co-existence with lateral high-energy bioclastic facies like those mentioned above suggests the sedimentary environment had features in common with those of an open shelf.

STOP 2 - CONTRADA DIESI (SCIACCA) - PARACONFORMABLE LATE EARLY JURASSIC DROWNING SURFACE; HIATUSES, TAPHONOMY AND SEDIMENTOLOGY OF UPPER JURASSIC DEPOSITS; THE JURASSIC/CRETACEOUS BOUNDARY IN THE SACCENSE DOMAIN


This stop provides a panoramic view of the “Contra Diesi” quarry (Substop 2.1), where the platform-drowning surface and a thin Jurassic pelagic succession crop out. The “Contra Diesi” quarry is located on the northern slope of Mt. Magaggiaro, along the road between Montevago and the junction of the S.S. 624 at Portella Misilbesi. Along a road nearby (Substop 2.2), the top of the Jurassic succession and a section containing the Jurassic/Cretaceous boundary will be observed.

These outcrops provide a good opportunity to calibrate biozonations, based on different fossil groups (Ammonites, Nannoplankton, Calpionellids).
Substop 2.1 - “Contrada Diesi I” (Early Jurassic-early Tithonian)


INTRODUCTION

The succession is wonderfully exposed in a very large quarry. One of the most striking features is the perfect geometrical concordance at the paraconformity between the Inici Fm. and the overlying pelagic deposits. Neptunian dykes filled with pelagites are evident across the walls of the quarry, cross-cutting the shallow water carbonates.

The total thickness of the exposed Jurassic pelagic sediments in the area is about 18 m, and these have been examined for facies analysis and biostratigraphy. The lower portion was dated through ammonite stratigraphy, while calcareous nannofossil stratigraphy was used for the upper part. The studied sections provide a good opportunity to compare different kinds of biostratigraphic subdivisions (Ammonites, Calpionellids, and Calcareous Nannofossils), even if a real integrated biostratigraphy was impossible due to the lack of age-significant ammonites in the middle portion of the section and of well preserved nannofossils in its lower portion.

LITHOSTRATIGRAPHY AND MICROFACIES ANALYSIS

The local succession (Fig. 7) can be subdivided into six informal lithostratigraphic intervals (top to bottom):

6) reddish-grey nodular marly limestone;
5) pebbly calcarenite;
4) stromatolitic calcarenitic limestone;
3) calcisiltitic limestone;
2) Bositra limestone;
1) bioclastic platform limestone (Inici Fm.).

The total thickness of units 2 to 6 is about 18 m (Fig. 7).

Bioclastic Platform limestone (Inici Fm.-Early Jurassic)

The uppermost part of the carbonate platform deposits is made by thick bedded (~60 cm) bioclastic limestone, with peloids, intraformational lithoclasts, oncolites and algae. The last metre of bioclastic limestone has fenestral lamination. The top of the carbonate platform is locally marked by a reddish surface and by a discontinuous, 1-2 cm thick black stromatolitic crust.

As mentioned above, carbonate platform sediments are paraconformably overlain by pelagites through a sharp surface corresponding to a hiatus spanning the late Early Jurassic to the early Bathonian.

Fig 7 - Panoramic view and schematic drawing of the lithostratigraphic intervals. Contrada Diesi I section.
Plate I – Microfacies of the Contrada Diesi I section.
1) Bottom to top: bioclastic platform limestone interval, crust, and Bositra limestone interval (x 23).
2) Packstone with thin-shelled bivalves (note shelter porosity). Bositra limestone interval (x 43).
3) Wackestone with protoglobigerinids. Calcsiltite limestone interval (x 43).
4) Packstone with echinoids fragments and Globochaete sp. Stromatolitic calcarenitic limestone interval (x 23).
5) Wackestone with Saccocoma sp. Pebble calcarenite interval (x 23).
6) Wackestone with Cadosina sp. Grey-reddish nodular marly limestone interval (x 100).
frequency of echinoderm fragments increases. The finer sediment portion is rich in Globochaete spp. and in large Protoglobigerina specimens; both genera are more abundant with respect to the underlying interval.

At 6.75 m a discontinuity surface is locally marked by a dark LLH stromatolite consisting of black and white alternating millimetre thick bands with strongly contrasting granulometries.

This physical discontinuity is a distinctive horizon that can be traced along the whole quarry front.

“Calcisiltitic limestone” (middle Oxfordian p.p.-upper Oxfordian)

Above the crust, a level rich in ammonites, lying flat, parallel to bedding is a useful marked bed. Many ammonites bear stromatolitic caps and some have domes on both sides, indicating reexhumation and re-elaboration phenomena. This bed records the last occurrence of thin-shelled bivalves and corresponds to a bloom of protoglobigerinids.

The uppermost 2.05 m of the interval are reddish wackestone limestone, impregnated by pervasively ferruginous minerals; upward the colour shades into light brown.

“Stromatitic” calcarenitic limestone (Kimmeridgian)

This is a 3 m thick massive interval characterized by stromatolites occurring both as isolated domes and as LLH continuous structures. Stromatolitic lamination is picked out by selective weathering, along with randomly oriented belemnites and echinoids. Ammonites frequently bear stromatolitic domes, as well as small clasts and brachiopods. The texture is a laminated packstone with abundant echinoderm fragments; coarser sediment is found in inter-dome lows. At the top of this unit, a coarse calcarenite bears plastic wackestone pebbles. Some ammonites show a double dome, so they must have been reworked.

Pebby calcarenite (early Tithonian)

This lithofacies (2 m thick) is constituted by interbedded conglomeratic levels and crinoidal sands (also with belemnites, echinoid spines and bivalves) with sparse thin stromatolites. Bed tops often display nodules floating in a calcarenite matrix.

Reddish-grey Nodular marly limestone (early Tithonian)

About 4 metres of grey-reddish nodular marly limestone thinly bedded, with internal moulds of ammonites and aptychi. Nodules of mudstone-wackestone with crinoid debris, with common stilolitic contacts, are set in a wacke- to packstone matrix with crinoid debris. Nodules probably were the \textit{in situ} result of burrowing, and apparently underwent no transport.

\textbf{BIOSTRATIGRAPHY}

\textit{Microfossil assemblage (Pl. I)}

The microfauna of the platform limestone (Inici Fm.) is represented by Siphovalvulina sp., Textularia sp., Lituosepta sp., Ammobaculites sp., Cayeuexia sp., Trocholina sp., Glomospira sp., Textulariids and Valvulinids, associated with gastropods, bivalves and echinoderm fragments.

Pelagic sediments of the Contrada Diesi I section bear a relatively uncharacteristic microfaunal assemblage throughout the Middle and Upper Jurassic interval. Microfossils include: Foraminifers (rare \textit{Radiolaria}, protoglobigerinids, Epistominidae, Nodosariidae, Textulariidae, Valvulinidae, Ophthalmididae, Lagenidae, \textit{Lenticulina} sp., \textit{Glomospira} sp., \textit{Siphovalvulina} sp., \textit{Spirillina} sp., \textit{Marginulina} sp., \textit{Turrisspirillina} sp.), Ostracoda, \textit{Stomiosphaera} sp., and \textit{Globochaete} sp. Echinoderm fragments are widespread. \textit{Globochaete} specimens are very abundant in the whole section. Peloids and intraformational lithoclasts also occur. The increase of protoglobigerinids in the upper Callovian is abrupt, and it is noteworthy that it corresponds to the sharp decrease of thin-shelled bivalves.

In the Kimmeridgian \textit{Globochaete} is common in fine-grained sediments, while echinoderm and \textit{Lamellaphythus} fragments are abundant in the coarser levels.

The FO of \textit{Saccocoma} falls at the base of the Kimmeridgian (9.50 m), while \textit{Cadosina} blooms in the upper part of the lower Tithonian.

\textbf{Nannofossils}

The first 11 m of the section have a very poor nannofossil content, because the lithology is unfavorable to their preservation.

\textit{Watznaueria barnesae} (BLACK.) first appears at 2.00 m and this is the only event that characterizes the lower part of the section (from 0 to 11 m).
The FO of *W. barnesae* (BLACK) is reported by MATTIOLI & ERBA (1999) in the early Bathonian.

Above 11 m, the calcareous nanofossil content is very abundant and the assemblages show high species diversity.

Sample 11.30 m records the FO of *Conusphaera mexicana* spp. minor BOWN & COOPER; in the 12.40 m sample *C. mexicana* spp. mexicana TREJO first appears, while *Polycostella beckmannii* THIERSTEIN first occurs in the 12.70 sample, indicating the lower Tithonian.

The first specimens of the genus *Nannoconus* appear in the 13.45 m sample, followed by the simultaneous occurrences, in the 13.95 m sample, of *Nannoconus compressus* BRALOWER & THIERSTEIN and *Hexalithus noeliae* LOEBLICH & TAPPAN, characteristic markers of the uppermost part of the lower Tithonian.

**Ammonites (Pl. II)**

The ammonite-rich deposits of the Contrada Diesi I section provide a wealth of new paleontological data on the Bathonian-Kimmeridgian interval. Further research will be necessary to better define the occurrence of hiatuses and associated omission surfaces across the succession.

Ammonite internal moulds often display evidence for taphonomical reworking, like stromatolitic caps on both sides.

From the base of the pelagic succession to 5.86 m different assemblages are characterized by forms like *Morphocers* cf. *macrescens* (BUCKMAN), *Cadomites* (Cadomites) *daubenyi* (GEMMELLARO), *Parkinsonia* (Gonolkites) *convergens* (BUCKMAN), *Cadomites* (Cadomites) *orbignyi* (DE GROSSOUVRÉ), *Bullatimorphites* (Bullatimorphites) *hannoveranus* (ROEMER), *Hecticoceras* (Hecticoceras) *posterius* ZEISS, *Reinecketa nodosa* TILL. They indicate the lower Bathonian (Zigzag Zone), upper Bathonian (Progracilis and Retrocostatum Zones), lower Callovian (Gracilis Zone) and middle Callovian (Anceps and Coronatum Zones). At 6.30 m *Neocampylites delmontanus* (OPPEL) marks the lowest occurrence of Oxfordian ammonites. In the interval from 6.30 to 9.00 m the occurrence of forms like *Perisphinctes montfalconensis* DE LORIOL, *Tornquistes* sp., *Passendorferia* (Passendorferia) *ziegleri* (BROCHWICZ-LEWINSKI), *Gregoryceras transversarium* (QUENSTEDT), *Gregoryceras fouquei* (KLIAN) and *Physodoceras atavum* (OPPEL) indicates the Oxfordian (Plicatilis, Transversarium, Bifurcatus and Bimammatum Zones). At 8.80 m *Ortosphinctes* cf. *laufenensis* (SIEMIRADZKI) marks the first occurrence of Kimmeridgian ammonites (Planula Zone, according to MATYJA & WIERZBOWSKI, 1997); from 9.00 to 10.00 m *Benacoceras* sp. and *Nebrodites cafisii* (GEMMELLARO) characterize the lower Kimmeridgian (Herbichii and Platynota Zones).

**GEODYNAMIC AND SEDIMENTARY EVOLUTION**

**Neptunian dykes**

Besides being topped by a drowning unconformity (paraconformity) overlain by the Middle-Upper Jurassic condensed succession, the upper part of the Inici Fm. exposed at Contrada Diesi displays the evidence of Jurassic extension mainly in the form of neptunian dykes.

Several mono- and polyphasic neptunian dykes in fact cross the platform limestone and, in some instances, the pelagic succession (Fig. 8).

Neptunian dykes have different ages ranging from latest Early Jurassic to Late Jurassic. Most of them are filled by thin-shelled bivalve packstone to wackestone and their age cannot better be defined than as Middle Jurassic. The oldest dykes are made of a yellowish mudstone with echinoderm fragments, bearing clasts of the Inici Fm. with abundant Textulariidae, Valvulinidae, Ostracods, *Siphovalvulina* sp. and *Thaumatoporella* cf. *parvoesculifera* (RAINERI). The youngest dykes (Late Jurassic) consist of a microbreccia in a matrix made by reddish packstone containing echinoderms, bivalves and *Lamellassphecychus* sp.; the microbreccia clasts are mudstones with radiolarians and sponge spicules, and wackestones with thin-shelled bivalves, Ophthalridiidae, *Saccocoma* sp., protoglobigerinids, *Globochaete* sp., and *Spirillina* sp.

One of the dykes is seen to correspond to a synsedimentary fault producing a small displacement (less than one metre), and is Middle Jurassic in age. It is made of a breccia with a matrix made of a light brown packstone with thin-shelled bivalves and echinoderm fragments. The breccia is made by clasts of shallow water limestone, of closely packed thin-shelled-bivalve mudstones and of mudstone, packstone and wackestone with peloids, intraclasts, *Globochaete* spp., *Stomiosphaera* sp., echinoderm fragments and foraminifers (rare protoglobigerinids, Valvulinidae and Nodosariidae).
Substop 2.2 - “Contrada Diesi II” (late Kimmeridgian-early Valanginian)


INTRODUCTION
This substop serves to observe the uppermost part of the Jurassic limestone and the marly-nodular deposits around the Jurassic/Cretaceous boundary. This succession differs slightly from that exposed in section 1 because the stromatolitic interval is here replaced by a calcarenitic/calci-siltitic level. In both sections the change from dominant limestone to marly nodular limestone is placed in the upper part of the lower Tithonian.

A 26 m thick section is well exposed above this lithologic boundary, containing the Jurassic/Cretaceous boundary within the “Calcari a Calpionelle” unit.

LITHOSTRATIGRAPHY AND MICROFACIES ANALYSIS
The section can be subdivided into three informal lithostratigraphical units:
3) “Calcari a Calpionelle” (top);
2) marly limestone;
1) calcarenitic/calci-siltitic limestone (bottom).

Calcisiltitic/Calcarenitic Limestone (late Kimmeridgian-early Tithonian)
The base of the section is represented by a light brown calcarenitic/calci-siltitic limestone. The dominant texture is a wackestone with Saccocoma, radiolarians, echinoid fragments, gastropods and protoglobigerinids.

Marly limestone (early Tithonian)
This lithofacies consists of 2 m of grey-yellowish nodular marly limestone with thin cher ribbons; the texture is a wackestone with Saccocoma, radiolarians, and echinoderm fragments. At 6.30 m Saccocoma decreases, while cadosinids increase. The last metres are made by packstone with abundant echinoderm fragments and reworked clasts.

“Calcari a Calpionelle” (late Tithonian-early Valanginian)
This unit crops out for about 18 m in this section. The lower part is a nodular limestone in very thin beds, representing a transitional lithofacies. This grades upsection into a calpionellid wackestone with very rare echinoderm fragments, radiolarians and rare foraminifers (Textulariids, Valvulinids). The first occurrence of calpionellids at 8.50 m indicates the upper Tithonian. Saccocoma disappears in the uppermost Tithonian.

At 9.50 m from the base, the FO of Remaniella durandelgai POP marks the Jurassic/Cretaceous boundary. Overlying beds represent the uppermost Berriasian (Calpionellopsis Zone, uppermost part, 15.50 m from the base) and the lower Valanginian (Calpionellites Zone, lowermost part, 16.50 m from the base). The top of the section is dated as early Valanginian.

BIOSTRATIGRAPHY
Integrated calcareous nanofossil/calpionellid biostratigraphy of the Contrada Diesi II section provides a useful cross-check of events recorded by different fossil groups.

Nanofossils
In this section the lowest significant sample is at 3.50 m; the assemblage is composed by Watznaueria manivitae BUKRY, Cyclagelosphaera deflandrei (MANIVIT), Conusphaera mexicana TREJO and the earliest small-size specimens of Nannoconus sp.

The presence of Conusphaera mexicana TREJO and of Nannoconus sp. characterizes the middle Tithonian. Conusphaera mexicana TREJO increases rapidly up to 6.0 m, where Polycostella beckmannii THIERSTEIN occurs; the first occurrence, in the sample 6.15 m, of Nannoconus compressus BRALOWER & THIERSTEIN indicates the uppermost lower Tithonian. From 14.50 to 15.50 m, a rich calcareous nanofossil assemblage [abundant N. steinmanni KAMPTNER, C. cuvillieri (MANIVIT), W. barnesae BLACK, C. margerelii NOEL, C. wiedmannii REALE & MONECHI, very rare C. mexicana TREJO and Z. cooperii BOWN] confirms an early Berriasian age, in agreement with data provided by calpionellids and ammonites. Sample 16.00 m records the FO of Calcicalathina oblongata (WORSLEY), a marker of the lower Valanginian, while Conusphaera mexicana TREJO disappears.

Calpionellids (Pl. III)
The FO of calpionellids is recorded at 8.50 m. Crassicollaria intermedia (DURAND-DELGA) and Calpionella alpina LORENZ mark the upper Tithonian (Crassicollaria Zone), according to GRUN & BLAU (1997). The Jurassic/Cretaceous boundary can be placed through the FO of Remaniella durandelgai POP at 9.50 m (base of the Calpionella Zone). The calpionellid assemblage including C. intermedia (DURAND-DELGA), C. brevis REMANE, C. massutiniana (COLOM) and C. alpina LORENZ, remains unchanged until 15.00 m.

At 15.50 m Preacalpionellites dadayi (KNAUER) is a characteristic marker of the uppermost Berriasian.

At 16.50 m the FO of Calpionellites darderi (COLOM) marks the lower Valanginian, in agreement with the calcareous nanofossils assemblage of sample 16.00 m. Calpionellites darderi (COLOM) ranges up to the top of the section. Despite careful sampling,
Calpionellid biostratigraphy indicates the base of the upper Tithonian is missing. Moreover, the reduced thickness of the Berriasian, and the lack of most of the Calpionella and Calpionellopsis Subzones and of the whole middle Berriasian strongly suggest repeated hiatuses and very low sedimentation rates.

Ammonites and Belemnites (Pl. IV)

At 8.15 m Corongoceras sp. indicates the base of the upper Tithonian. At 14.50 m “Corongoceras” sp. indicates the Boissier Subzone (lower Berriasian). At 23.5 m Tirnovella alpillensis (MAZENOT) marks the Otopeta Subzone (lower Valanginian). Toward the top of the section, at 25.00 and 25.25 m from the base, Early Cretaceous belemnites like Duvalia lata BLAINVILLE occur, and at the very end of the section (26.00 m) common specimens of Olcostephanus spp. suggest a middle Valanginian age.

RESULTS

Saccocoma occurs at the base of the Kimmeridgian (see Contrada Diesi I section) and disappears in the upper part of the Tithonian. Protogloboigerinids occur starting in the Bathonian, are abundant at the top of the Bathonian and eventually decrease in the early Tithonian, corresponding to a bloom of Saccocoma.

In the early Tithonian the bloom of Cadosina shortly predates the appearance of Calpionellids.

Based on Calpionellid stratigraphy, the lower part of the upper Tithonian is missing. This is not surprising, given the thin condensed and discontinuous nature of the succession and the reduced thickness (1.50 m) of the whole upper Tithonian. This interval is defined at the base by the FO of Corongoceras sp. (8.15 m) and some centimetres above by the FO of Calpionellids. Chitinoïdella is totally absent, while Calpionellids only indicate the last two subzones of the Crassicollaria Zone.

The occurrence of Remaniella duranddelgaii POP marks the Jurassic/Cretaceous boundary (according to GRÜN & BLAU, 1997) and the beginning of the Calpionella Zone (Alpina Subzone).

Microfossil assemblages indicate the lower Berriasian for the following 6 metres; immediately above, the FO of Praecalpionellites dayadii (KNAUER) marks the uppermost part of the upper Berriasian.

This is a good example of a stratigraphic gap that would go undetected were not for biostratigraphy.

Plate III – Microfacies of the Contrada Diesi II section.
STOP 3 - CONTRADA MONZEALESE: SYNSEDIMENTARY EXTENSION AND DROWNING OF THE INICI PLATFORM

M. MARINO

INTRODUCTION

Contrada Monzealese is located south of Mt. Magaggiaro, few kilometres east of Menfi. The outcrop is constituted by two contiguous quarries.

This stop allows for a 3D panoramic view of the stratigraphy and geometry of the Lower to Middle Jurassic deposits of the Sciacca Plateau, and of some peculiar palaeotectonic structures. These observations are important to reconstruct the sedimentary and tectonic evolution of the Saccense Domain during the Early to Middle Jurassic. Detailed descriptions of the biostratigraphy and sedimentology of this section are given in Di STEFANO et alii (2002b).

STRATIGRAPHIC SETTING

Three main lithostratigraphic subdivisions can be made in this section (base to top):

- 20-30 m of whitish massive limestone, mainly an onko-oosparitic grainstone with common Palaeodasycladus mediterraneus (PiA) (Inici Fm.). The deposits are organized into peritidal shallowing upward cycles. Reddened surfaces and intraformational breccias also occur, documenting episodes of subaerial exposure. These sediments were deposited in a peritidal carbonate platform environment during the early to (?) middle Early Jurassic. The upper 5 m of the peritidal limestone are crossed by neptunian dykes and sills, forming an in situ breccia.

- A condensed level, informally named as “Hardground” although this is a thin (0-40 cm) bed rather than a surface (see Di STEFANO et alii, 2002b), characterized by a conglomerate with red-brown biocalcarenitic matrix, a ferruginous crust and a stromatolitic cap, and by strikingly abundant fossils, mostly cephalopods. The ammonite assemblage indicates a late Toarcian-middle Aalenian age. The species found in the hardground are reported in PI. V; some specimens are figured in PI. VI (for a detailed description of the biostratigraphic, taphonomic, and sedimentologic features of this level see Di STEFANO et alii, 2002b).

This condensed level occurs in the northern side of the quarry area, and it is discontinuous in outcrop: it may either directly overlie the Inici Fm. top surface or, locally, a lensoid level of micritic limestone with brachiopods and crinoids, whose age is still poorly known.

- Up to 10 m of Bositra limestone, made of biomicritic and biopelmicritic packstone. Towards the south, two slumped intervals are seen, and can locally rest directly on the peritidal limestone. The occurrence of Parkinsonia parkinsoni (SOWERBY) indicates a late Bajocian age for the base of this unit.

Thin-shelled bivalve pelagites also occur as the infilling of sheet cracks and neptunian dykes that cut across the underlying units. Infilling of these fractures is also made of micritic pelagic limestone with protogobigerinid foraminifers.

These three intervals are all bounded by unconformities. In particular, the unconformity at the top of the Inici Fm. is a drowning-unconformity (sensu SCHLAGER, 1989), marking the sharp contact between peritidal carbonate platform limestones and the pelagic limestone. The biochronological data from the ferruginous condensed level indicate the “minimum” age of the drowning event as being late Toarcian.

It is most notable that in this area the drowning unconformity is angular: as observed on the southern side of the N-S-oriented quarry walls, a south-dipping planar surface clearly truncates the north-dipping beds of the Inici Fm. The Bositra limestone rests parallel to the truncation surface.

Pl. IV – Late Jurassic to Valanginian ammonites from the “Contrada Diesi II” section and San Vincenzo section.
1) Tithidelloceras paraskabensis (FALLOT & TERMER) L 8, x 0.5; ”Contrada Diesi II” section, m 8, upper Tithonian, P. transitorius Zone.
2) Ölcostephanus astierianus (D’ORBIGNY) L 75, x 1; ”Contrada Diesi II” section, m 24.86, upper Valanginian, S. verrucosum Zone.
3) Ölcostephanus gr. drumensis KILIAN L 61, x 0.70; ”Contrada Diesi II” section, m 24.15, upper Valanginian, S. verrucosum Zone.
4) Neocosmoceras gr. flabelliforme Le HEGARAT, Sv 33, x 1.3; San Vincenzo section, m 2, middle Berriasian, T. occitania Zone.
5) Fauriella simplicicostata (MAZENOT), L 45, x 0.7; ”Contrada Diesi II” section, m 23.15, upper Berriasian, F. boissieri Zone.
6) Micracathoceras micracanthum (OPPEL), L 84, x 0.7; ”Contrada Diesi II” section, base of the “Calcari a Calpionelle”, upper Tithonian, P. transitorius Zone.
7) Neocosmoceras sayni (SIMIONESCU), LS 77, x 1.2; ”Contrada Diesi II” section LS, siliceous bed, middle Berriasian, T. occitania Zone.
8) Spiticeras spitiensis (BLANFORD) Py 87, x 0.8; Base of the “Calcari a Calpionelle”, upper Tithonian, Durangites Zone. This species is also present with very large forms at the base of the San Vincenzo section, in a different facies.
9) Torquatisphinctes gr. latus OLORIZ, K 34, x 0.7; ”Contrada Diesi II” section, upper Kimmeridgian, H. beckeri / H. pressulum Zone.
10) Taramellliceras sp. K 32, x 0.9; ”Contrada Diesi II” section, upper Kimmeridgian, H. beckeri / H. pressulum Zone.
11) Taramellliceras pugile pugiloides (CANAVARI), K22, x 0.7; ”Contrada Diesi II” section, upper Kimmeridgian H. beckeri / H. pressulum Zone.
Fig. 9 - Panoramic view and line drawing of the palaeotectonic and stratigraphic features of Contrada Monzealese, as observed on a quarry wall.

On the northern side of the quarry area, the Inici Fm. beds and the pelagic cover are apparently conformable, but this is due to orientation of the local quarry cut being coincident with bed strike.

Slumping in the Bositra limestone is here interpreted as a local intra-plateau feature, as it occurs within a condensed succession that is not seen to grade laterally into a basinal succession.

**PALAEOTECTONICS**

Several tectonic elements can be observed on the eastern wall of the western quarry (Fig. 9). The most striking elements are two antithetic planes. The principal plane is a south-dipping listric normal fault that cuts across the visible portion of the Inici Fm. The fault plane is undulated but eventually flattens downwards, merging with a bedding surface. The hangingwall beds in the lowest portion of the section are slightly folded, forming a gentle rollover against the fault.

The other element is an antithetic north-dipping low-angle plane that terminates against the main listric fault. These two faults define a bed package that is triangular in cross-section. Beds here also are north-dipping, but they are gently folded, becoming south-dipping at the cut off with the accessory plane. This fold is interpreted as a frontal compressive feature due to minor thrusting caused by slip along a local flat of the main listric normal fault.

Noteworthy, smaller-scale south-dipping listric growth-faults occur in the lowest portion of the visible section of the Inici Fm., with associated rollover and bed thickening.

Scattered outcrops of pelagic rocks above the Inici Fm. make it possible to trace their basal contact as a flat continuous surface, confirming that the above described features affect solely the Inici Fm., and that faulting here predated the drowning of the platform.

The general angular relationships between the Inici Fm. and the overlying pelagic succession indicate a large scale tilt to the north of the entire platform in the Contrada Monzealese area. The razor-flat nature of the contact implies erosion and removal of a huge volume of sediment, that probably occurred under subaerial conditions. As a further descriptive feature of the surface, it is interesting that it locally forms some sort of a “ramp-flat” geometry, like certain “stepped unconformities” described in the literature (WINTERER & SARTI, 1994). In the Contrada Diesi area (see dedicated stops above), the pelagic deposits instead overlie Inici Fm. in perfect paraconformity, suggesting that the two areas had to be separated by a south-dipping master listric fault. This is consistent with the occurrence of intraplateau basins which is reported more to the south in the offshore of Sciacca (ANTONELLI et alii 1991; CATALANO et alii, 1995b).
Zones | Species
--- | ---
Concaum | *Eudmetoceras eudmetum*, *Pseudaptetoceras klimakomphalum*, *Pseudographoceras literatum*, "*Alocolytoceras*" *ophioneum*, *Ptychophylloceras chonomphalum*, *P. tatricum*, *Pseudaganites* sp.
Bradfordensia | *Brasilia* sp, *Pseudaganites* sp, *Ptychophylloceras chonomphalum*, *P. tatricum*, "*Alocolytoceras ophioneum*".
Aalenian | *Abbasitoides modestus*, *Abbasites abbas*, *Calliphylloceras altisulcatum*, *C. altisulcatum magnum*, *Erycites fallifax*, *Csernyeiceras verpillierense*, *Holoclyloceras ultramontanum*, *H. ultramontanum heckeri*, *Ludwigia vaceki*, *Vacekia costula*, *V. stephensi*, *Planammatoceras planinsigne*, *P. tenuinsigne*, *P. brancoi*, *P. lotharingicum*, *Pseudaganites* sp., "*Alocolytoceras ophioneum*", *Ptychophylloceras chonomphalum*, *P. tatricum*.
Aalensis | *Catulloceras* sp., *Pleydellia aalensis*, *P. aalensis ovalis*, *P. flamandi*, *P. fluitans*, *P. gr. Buckmani*, *P. macra*, *P. subcompta*, *Cotteswoldia paucicostata*, "*Alocolytoceras*" *ophioneum*, *Pseudaganites* sp., *Ptychophylloceras chonomphalum*, *P. tatricum*.
Toarcian | *Dumortieria meneghini*, *D. macra*, *D. latum bilicata*, *Polyplectus appenninicus*, *P. pluricostatus*, "*Alocolytoceras*" *ophioneum*, *Pseudaganites* sp.

Plate V - General range chart of the ammonites found in the "Hardground".

Appendix - Ammonites of the "Hardground"

F. Gasparri

This appendix serves as a general comment to the charts and specimens shown on Pl. V and Pl. VI.

On Pl.V, the zonation used is that of Ruelleau, Elmi & Venard (2001). Aalenian ammonite assemblages show the end of some Toarcian evolutionary trends (Grammoceratinae and Polyplectinae), the differentiation of new groups (Leioceratinae) and, at the end of the Aalenian, the extinction of other groups (Graphoceratinae). Hammatoceratinae start in the Serpentinus Zone (*Rarenodia* and *Praerycites*), then they begin to differentiate in the late Toarcian, are fully diversified in the early Aalenian and eventually become extinct in the late Aalenian (*Planammatoceras*, *Pseudaptetocetoceras* and *Erycites* s.l.).

Pl.VI displays a selection of ammonites found in the hardground (all specimens about natural size): 1) *Eudmetoceras eudmetum* Geczy; 2) *Leioceras comptum rieberi* Geczy; 3) *Leioceras lineatum* Buckmann; 4) *Leioceras lineatum* Buckmann; 5) *Ptychophylloceras chonomphalum* Vacek; 6) *Pseudaptetoceras klimakomphalum* Vacek; 7) *Ludwigia vaceki* Geczy.

STOP 4 – "MOUND" GEOMETRIES AND HIGH-ENERGY DEPOSITS IN A JURASSIC SUCCESSION AT VALLONE SAN VINCENZO

C. Muraro & M. Santantonio

INTRODUCTION

In the Sciacca Plateau, the Vallone S. Vincenzo section exposes the thickest post-Inici/pre-Lattimusa succession known in the area. Since no basinal deposits like radiolarian cherts occur, and since instead more high-energy and benthos-rich deposits occur here than in other correlated sections, thickening does not apparently indicate downdip transition to a basin and a deeper-water environment, but rather suggests deposition in an inner-plateau subenvironment, where the preservation potential of sediment is higher (Santantonio et alii, 1996).

In order to distinguish the east-side from the west-side of the gorge, the S.V.E and S.V.W headings will be used, respectively.

At the base of S.V.E only the uppermost levels of the Inici Fm. (few decimetres, with cryptalgal lamination and *fenestrae*, indicating an intertidal environment) crop out. The top surface represents a drowning unconformity, since it is overlain by sediments that clearly record a change of sedimentation style from peritidal to open marine.

Although we are certainly dealing with deposits sedimented in an open marine environment, these cannot be strictly termed pelagic sediments. Besides cephalopods, they are dominated by skeletons of organisms whose living habits (nekto-planktonic vs. benthonic) are strongly debated (posidoniids, Middle Jurassic, see below) or contain a significant proportion of benthic forms like echinoids, crinoids, and brachiopods, the echinoderms being often in rock-forming quantities
Plate VI - Ammonites of the "Hardground".
(Upper Jurassic). In addition, peloids can be common. These bio-sedimentological features suggest a similarity with open shelf deposits or those of a deeper-water terrace (e.g. Blake Plateau, PINET & POPENO, 1985).

Besides possessing peculiar facies associations, the Middle and Upper Jurassic deposits at S. Vincenzo display distinctive geometries never reported before with the Bositra limestone (or any other “pelagic bivalve” limestone) elsewhere in the western Tethys (CONTI & MONARI, 1992, and bibliography therein). These will constitute the main object of the substop.

LITHOSTRATIGRAPHY (JURASSIC TO LOWER CRETACEOUS)

The Jurassic succession of Vallone S. Vincenzo comprises some rather unique types of deposits, which prompted us to use a partly different informal lithostratigraphy.

From bottom to top, the following units rest above the Inici Fm.:

- “Hardground”. Dark condensed level, about 20 cm thick, with a remarkable concentration of Aalenian-Toarcian ammonites, like at Contrada Monzealese (see Stop 3). We termed this condensed and metal-encrusted interval as “Hardground”, although this term is commonly descriptive of a surface (DI STEFANO et alii, 2002b).

- Bositra limestone. Grey packstone, massive to well bedded in the medium-upper part, entirely formed by thin-shelled bivalves (CONTI & MONARI, 1992). The total thickness ranges from 13 m to 22 m, and pinch-out of individual bed sets occurs along with local downlap geometries. The age of this unit is uncertain at Vallone S. Vincenzo, due to the lack of reliable biostratigraphic indicators, with the exception of an upper Callovian Choffatia sp. (JOHN COPE, personal communication) found at the top. Having said that, correlation is obvious with other localities where ammonites occur throughout the unit. At Contrada Diesi for example, a Bathonian through Callovian section, 6.75 m thick, rests paraconformably on the Inici Fm. and is overlain by Oxfordian beds with no more posidoniids. At Contrada Monzealese, less than 2 km to the west, the base of the Bositra limestone bears late Bajocian ammonites, while the top is not exposed. This suggests a general late Bajocian to late Callovian age for this lithostratigraphic unit.

- Knobby limestone. Wackestone with ammonites, aptychi, belemnites, abundant “Globigerina oxfordiana” and assorted bioclasts in the lower part (thickness: 1.5 m at S.V.W 2, 2.8 m at S.V.E 1); packstone-wackestone, with angular lithoclasts and bioclasts, peloids, ammonites, aptychi, protoglobigerinids, radiolarians, also with echinoid-rich levels, in the upper part. Thalassinoides burrows contribute to the knobby appearance. Bed thickness ranges from 1 to 40 cm. The average thickness of the unit is about 5 m, but 10 m are attained in the southernmost section (S.V.E 1). The age is early Kimmeridgian p.p.-late Kimmeridgian. The basal decimetres did not yield useful ammonites, so we cannot theoretically exclude an Oxfordian age.

The field recognition of the Knobby limestone essentially depends on selective weathering and can be locally less obvious wherever sudden lateral changes occur from tabular beds to knobby beds, with identical lithologic composition. In these instances, placing the upper boundary of this unit can be tricky.

- Coquina limestone. This is characteristically represented by two interfingered facies: a) coarse bioclastic packstone-wackestone, with sparse whole macrofossils, and b) whole-fossil (mostly ammonites and pygopid brachiopods) coquina rudstones, the diameter of ammonites being in the 3-10 cm range (true coquina facies). In general, the lower part of the unit is solely made of facies a, while facies b hosts frequent intercalations of the former. Bed thickness typically varies from decimetric levels (facies a) to metre-thick beds (facies b). The thickness of this unit changes from 15.75 m (section S.V.W 2) to 18.5 m (section S.V.E 3). The age is early Tithonian p.p.-early late Tithonian.

In section S.V.E 1 (see Substop 4b), the coquina facies is virtually absent and is entirely replaced by bioclastic packstone (facies a, 21 m).

- Cephalopod limestone. Whitish mudstone-wackestone, in 20-40 cm thick beds, with radiolarians, aptychi, rare to common ammonites and pygopid brachiopods, benthic forams, sponge spicules, rare gastropods, calcipellids. The thickness ranges from 50-60 cm to 8 m. The age of this unit is late Tithonian p.p.-?early Berriasian p.p.

- Lattimusa Fm. In this locality only the lower informal member of this formation crops out, made of nodular whitish micritic limestone. The maximum exposed thickness is about 16 m. The age is ?early Berriasian p.p.-Valanginian.

GENERAL OUTCROP GEOMETRIES AND FACIES

The lateral thickness variations and the peculiar internal geometries of the Bositra limestone indicate the presence of a “biodetrital morphological mound” (see discussion below), probably elliptical in plane view and with its longer axis trending E-W. Several details of the “mound” will be observed in Substops 4.2 through 4.4.

The Knobby limestone drapes the “mound” conformably. It is remarkable that the change of sedimentation style, from 3D “mound” accretion to draping, corresponds to a palaeobiological event: the
extinction of posidoniids.

The Tithonian deposits partly have reverse geometries with respect to the *Bositra* “mound”, i.e., they tend to level the submarine topography. The Coquina limestone thickens to the north and south of the “mound”. An eastwards thickening, which is also observable, might on the other hand indicate a plunge of its longer axis.

Levelling of the sea bottom, however, was not fully successful due to several causes of different nature.

Firstly, differential compaction must be taken into account wherever sedimentation takes place over a strongly irregular substrate, representing a counter-acting force against the filling process. This was probably responsible for the present-day attitude of the Knobby limestone beds with respect to the palaeohorizontal, which probably exceeds the angle of repose of the original sediment.

Another line of evidence is provided by the nature of the Tithonian sediments themselves, and by their internal geometries. While the basal portion of the Coquina limestone covers the Knobby limestone conformably, the overlying beds follow through a slight angular unconformity evidenced by westwards-dipping clinoforms (Fig. 10). This not only records the progressive infilling of the accommodation space, but also the three-dimensional accretional potential of the shelly sands that make up most of the Tithonian. We infer that energy fluctuations, probably linked to repeated sea level drops, were a major control over sedimentation of this unit (see dedicated substop).

The overlying Cephalopod limestone and Lattimusa Fm. are micritic facies that indicate a change of the sedimentation style, which is a palaeoceanographic event recorded across the whole Western Tethys (Bosellini & Winterer, 1975; “Kuenen event” of Roth, 1987; Bartolini et alii, 1996; Cobianchi & Picotti, 2000).

Substop 4.1 - The Coquina Limestone

The spectacular features of facies b of the Coquina Limestone are beautifully exposed near the road, and this stands as one of the main Jurassic highlights of the whole Sciacca area.

It is made of an ammonite- and pygopid
brachiopod- shell supported and severely recrystallized coquina with a bioclastic calcarenite to lime mud matrix, alternating with levels having the same matrix but with rarer macrofossils.

At first look, it is a well-washed facies, suggesting prevalingly high-energy conditions (Figg. 11, 12). Closer inspection, however, reveals that, besides void- and inter-object filling, much of the sparite recrystallization occurred at the expense of an originally mud-rich matrix which is presently often preserved only in scattered patches, probably a result of filtering of the sediment. Cements are in the form of isopachous calcite, with no trace of gravitational vadose-zone cement, so they are fully marine in origin. The shells are generally empty or have geopetal structures, except for the body chamber, suggesting that no physical breakage occurred during or after their deposition. The ammonites generally lie with their equatorial plane parallel to bedding, but shell embrication is locally observed. Sedimentary structures suggesting gravity flow or current action, like normal grading and planar or cross-lamination, are remarkably absent. However, subtle angular unconformities associated with large scale foresets occur, which is locally also evidenced by an angle between the palaeohorizontal indicated by geopetal structures and bedding.

Sedimentation rates of the coquina limestone are relatively high (for an intrabasinal-high succession), in the order of 5-7 m per million year. We cannot therefore think of the observable, abnormal shell accumulation as the result of lowered sedimentation rates, as typically occurs on pelagic platforms. We envisage punctuated high-energy, fast-deposition episodes as the probable cause of today’s visible products. This would also be in agreement with the alternating fine/coarse rhythmic nature of the deposits (Fig. 13). On the other hand, the higher sedimentation rates of this unit are also the obvious product of the greater preservation potential that is typical of inner plateau subenvironments.

Ammonites, aptychi, pygopod brachiopods, crinoids (Saccocoma verniori), rare bivalves, gastropods and benthic forams, represent the faunal content of the unit. Identified ammonites include Simoceras aesinense (MENEGHINI), Pseudohymalaytes steinmanni (HAUPT), assorted perisphinctids, Usseliceras sp. (?), Haploceras sp., Haploceras carachtheis (ZEUSCHNER) (the most common form), Virgatosimoceras sp., Lytoceras sp., Lytogyroceras sp., Micracanthoceras sp.

According to the biozonal subdivisions established by CECCA & SANTANTONIO (1988, and bibliography therein) in the Apennines, these forms indicate the third to fifth zones of the early Tithonian, and the earliest late Tithonian. The interval corresponding to the first and second zones of the early Tithonian might easily be covered by the 4-6 m thick facies a of the Coquina limestone, which is yet undated.

The onset of the coquina facies is dated as upper early Tithonian (third biozone). This is remarkable, because two or three prominent short-term sea level
drops occur in the Tithonian, starting at exactly the same stratigraphic level (HAQ et alii, 1988). The peculiar sedimentological features described above, indicating pulses of the ambient energy, and the existence of the coquina facies itself could therefore be the products of perturbations of sea-bottom conditions triggered by falling sea-level, which might have put the area under the influence of tidal currents. CECCA et alii (1990), SANTANTONIO (1993) and SANTANTONIO et alii (1996, and bibliography therein) reported from several localities in the Umbria-Marche Apennines, in Tithonian deposits having exactly the same ammonite ages, the una tantum occurrence of distinctive (lower) photic-zone corals on pelagic platforms, and of hummocky cross-bedded and rippled echinoid/crinoidal sands at their margins, and interpreted this as the result of dropping sea-level.

Substop 4.2- Panoramic view of the Bositra “mound” geometry, and Section S.V.E 1

The whole Jurassic succession is beautifully exposed in a natural cross-section along the S. Vincenzo gorge, displaying the quite distinctive geometries of sedimentary bodies. The Bositra “mound” is incised perpendicular to its longer axis, striking E-W.

At the base of the gorge (S.V.E, Fig. 14) thin-shelled bivalve packstone in thick planar beds is observed (total thickness about 8 m).

This planar portion - geometrically concordant with the Inici Fm. - is overlain by a convex mound-shaped body (height: 14 m, width: ~50 m) made of Bositra packstone beds, planar and thick in the central part and laterally thinning with tangential downlaps. A topographic relief of about 9 m is measured between the “mound”-top and the normally bedded succession found outside the “mound”. We named this bioclastic structure a “morphological mound”.

On both sides of the gorge, the Knobby limestone drapes the “mound”, and the Tithonian deposits have an antiformal geometry, which is here clearly unrelated to tectonics.

The current mound definition involves the recognition of “lenticular or knobby bodies, which mainly consisted of dense micritic carbonate with varying amounts of bioclasts, organic bindstones and benthic metazoans” (SCHMID et alii, 2001), which can develop in relatively quiet water environments ranging from shallow-water internal lagoons to slopes and deep basins. The processes required for the inception and development of a mound are biogenous and/or purely mechanical in nature: a) physical accumulation of sediment by different types of currents; b) baffling, trapping and binding of sediment by organisms; c) organic and/or inorganic precipitation of cement. Mounds typically display internal facies changes and differ from the surrounding sediment on sedimentological, compositional and palaeobiological grounds.

The main differences separating our “mound” from typical mounds, as defined above, mainly reside in: a) the absence of a core made of sessile or encrusting organisms acting as sediment bafflers or trappers; b) absence of any kind of biogenic structure (e.g. microbial mats, thrombolites, etc.); c) absence of erosional surfaces separating bed packages of sediment that is reworked in situ (TABERNER & BOSENCE, 1995), which typically occur in mounds originated by physical processes; d) the
absence of any kind of textural or compositional contrast with the surrounding ambient sediment.

This structure can on the other hand in no way be identified as a subaqueous dune (ASHLEY, 1990) due to: a) the absence of tractive bedforms like foresets and cross-bedded sets, b) the absence of obvious internal erosional surfaces, c) the presence, on the other hand, of symmetrical lateral downlaps, indicating a growth style with coupled aggradational and lateral accretion, where bedding planes are depositional, rather than erosional, surfaces.

Points a) to c) also partly serve to remark differences with the "concave-down structures" of the Upper Cretaceous Chalk of Normandy described by QUINE & BOSENCE (1991). These structures were interpreted as interchannel ridges, with a complex internal geometry characterized by: a) erosion surfaces (due to multi-erosional phases), b) hardgrounds, c) laterally thinning strata, d) upper erosional envelope, e) coarsening upward sequence. With the exception of point c), these features obviously do not occur in the Bositra "mound". High subsidence rates, tectonic control, high ambient energy, combination of oceanic and tidal currents are the principal factors required for generation of channels and interchannel structures. The latter two agents might as well have been effective on the Sciacca Plateau, and an explanation of our structures must certainly take into account the non-biological causes (currents, etc.) of sediment accumulation. QUINE & BOSENCE (1991) stress how positive bottom features are strictly the byproduct of large scale erosion and channel formation, with associated extensive bed truncation at their flanks, and slumping. While we do recognize the occurrence of erosion in the form of local concave-up lenses, most bedding surfaces within our "mound" are accretionary in nature, and bear clear evidence of lateral growth, with associated downlaps, that are seemingly missing in the Cretaceous examples.

SECTION S.V.E 1

The succession exposed at the panoramic spot is named S.V.E 1 (Fig. 15), and documents an interesting lateral variation of the Upper Jurassic succession discussed above. The section has been measured starting from the top of the Bositra limestone.

- 2.8 m of wackestone-mudstone, locally a Protoglobigerina packstone, well bedded (bed thickness 10-20 cm), with belemnites, aptychi, ammonites, assorted bioclasts.
- 1.2 m of knobby packstone-wackestone, with angular lithoclasts and bioclasts, peloids, ammonites, aptychi, protoglobigerinids.
- 6 m of wackestone-packstone (bed thickness 10-20 cm), rich in crinoids and aptychi, also with ostracods, sponges, fragments of ammonites. Levels with whole echinoids occur from 4.4 and 5 m, and at 7 m.
- 15.6 m of bioclastic packstone, strongly recrystallized, prevalingly made of echinoderm debris, also with aptychi, ammonites, assorted bioclasts, peloids, gastropods. A coquina bed represents the 21.6 to 22 m interval, being the single intercalation of the coquina facies b. Bedding is massive to faint.
- 5.4 m of wackestone-packstone, with abundant aptychi and crinoids, also with small ammonites, gastropods, calcareous sponges, ostracods, benthic forams.
- 2 m of wackestone rich in sponge spicules and crinoids, also with small ammonites, gastropods, aptychi and calpionellids.

The lower 10 m belong to the Knobby limestone; the next 21 m interval represents the facies a of the Coquina limestone; the last 2 m are the Cephalopod limestone.

This section documents the general thickening of the extra-"mound" Upper Jurassic deposits. It is notable that the Knobby limestone here contributes to this by doubling its thickness. It is also remarkable that the coquina facies disappears laterally over a very short distance (few tens of metres), being replaced almost completely by facies a (strongly recrystallized bioclastic sand debris).

Substop 4.3 - Top of the "mound" at S.V.E, and panoramic view of the western side of the gorge

On the eastern side of the gorge, the single most complete succession in the area is visible. This has in part been measured and sampled directly (section S.V.E 3, Fig. 15; reported below), from the top of the Bositra limestone. However, due to the rugged present-day topography, direct access was impossible to part of the section, so the total thickness of the Bositra limestone could only be estimated from photographs through visual comparison with objects of known size.

This section corresponds to the core area of the "mound". At the bottom of the valley the Inici Fm. crops out with horizontal beds of fenestral limestone. This is followed by a 20 cm thick condensed level ("Hardground") with Toarcian-Aalenian ammonites. Then follow 8 m of massive tabular beds of grey thin-shelled bivalve packstones. These represent the non-mounded lower part of the Bositra limestone. They are overlain by a 14 m thick bed package, constituting the "mound" itself.

It is most interesting here the occurrence of an "accessory mound" (Fig. 16), made of protoglobigerinid wackestone, that apparently grew piggy-back on the former.
Fig. 15 - Stratigraphic logs and lithostratigraphic correlations of sections S.V.W 2, S.V.E 1 and S.V.E 3.
The "accessory mound": convex-up beds of *Protoglobigerina* wackestone (G), having at the core the topmost lens (B) of the *Bositra* "mound". See hammer for scale (arrow).

"Mound" core at S.V.W, with downlap geometries. Its maximum thickness is 1.5 m, with a width of 6 m. The core of this minor "mound" is a convex-upwards lens (up to 45 cm thick, thinning to 0 m over a distance of a mere couple of metres) of *Bositra* packstone. It rests on a thin (max 10 cm) discontinuous condensed level bearing protoglobigerinids and crinoids, also with rhyncolites, echinoid spines, benthic forams and ostracods. Bioclasts have eroded and oxidized edges, and glauconite is also present, along with fragments of inorganic laminated crusts.

The middle-upper part of this "mound" is made of protoglobigerinid wackestone-packstone in decimetric beds, with rare peloids, small ammonites, gastropods, aptychi. These beds display obvious downlap geometries against the pavement constituted by the top of the *Bositra* "mound". Again, given the nature of the sediment (dominantly a protoglobigerinid wackestone), use of the term "mound" is here on solely geometrical grounds (see discussion above). We must re-stress that the end of "mound" growth here corresponds to a change in sedimentation style from accretion to draping.

**SECTION S.V.E 3**
- 10 cm of a condensed level.
- 45 cm of *Bositra* packstone (core of the "accessory mound").
- ~1 m of *Globigerina* wackestone (the "accessory mound" - see above).
- 3.5 m of wackestone-packstone, often highly recrystallized, with abundant echinoid fragments, mostly crinoids, assorted bioclasts, small ammonites. Bed thickness 20-60 cm. This interval represents the Knobby limestone.
- 6 m of massive bioclastic packstone strongly recrystallized, with shelter structures. Bed thickness about 0.9-2 m (facies a of the Coquina limestone).
- 12.5 m of whole-fossil rudstone, with a bioclastic calcarenite matrix, alternating with levels having the same matrix but with rarer macrofossils. The faunal content is represented by: ammonites, brachiopod pygopids, aptychi, echinoid fragments, benthic forams, gastropods (coquina facies b of the Coquina limestone).
- 5.5 m of whitish wackestone-mudstone, with abundant radiolarians, calpionellids, crinoids, benthic forams, aptychi, gastropods, small ammonites. Bed thickness 20-40 cm to 1.5 m (Cephalopod limestone). The Knobby limestone is well exposed and accessible along the northern flank of the "mound". Sampling of ammonites in this unit produced specimens of *Mesosimoceras cavouri* (GEMMELLARO), *Pseudowaagenia* sp. and *Nebrodites* gr. *cafisii* (GEMMELLARO). These are all upper Kimmeridgian forms, although the latter species also occurs in the uppermost lower Kimmeridgian (CECCA & SANTANTONIO, 1988).
Observation of the cliffs at the opposite side of the gorge (S.V.W) provides additional evidence of the “mound” geometry, with beautiful examples of its inception and 3D accretion above the parallel-bedded lower part of the Bositra limestone (Fig. 17). The geometries of the Upper Jurassic units are also well displayed: the draping geometry of the Knobby limestone; the thickening of the Coquina limestone at both sides of the “mound”; the subhorizontal Coquina limestone-Cephalopod limestone contact.

Substop 4.4 – View of eastern side of Vallone S. Vincenzo, and Section S.V.W 2

This is a panoramic substop, which serves as an overview of the general geometries of Jurassic deposits. Highlights include: lenticular bedding at the “mound” core, with thinning at both sides and tangential downlaps (Fig. 18); the “accessory mound”; the antiformal geometry of the Upper Jurassic deposits at the “mound” axis.

Furthermore, complementary bed geometries to those of the “mound” are seen in the Bositra limestone to the north of the “mound” itself, in the form of concave-up lenses (Fig. 19).

On the way back to the vehicles, at the westernmost end of the Jurassic outcrop, another section has been measured (S.V.W 2, Fig. 15). This is the thinnest Upper Jurassic section of the area, corresponding to the “mound” axis. Following 5 m of Knobby limestone, the Coquina limestone is only 15.75 m thick. There are two main reasons for this: 1) the section lies on the western culmination of the east-plunging “mound” axis; 2) this is the frontal accretionary side of the Coquina limestone bed package, based on the westwards dip of clinoforms.

SECTION S.V.W 2

- 5 m of Knobby limestone. The lower 2 m are made of wackestone with protoglobigerinids and belemnites; the upper 3 m are packstones, locally peloidal, with Saccocoma sp., protoglobigerinids, aptychi, ammonites, assorted granule-sized litho- and bioclasts. Whole-echinoid beds occur at different levels.
  - 4.75 m (facies a, lower part of the Coquina limestone) of packstone with abundant echinoderm fragments, mostly crinoids (Saccocoma sp.), aptychi, ammonites, echinoid spines. Whole-echinoid beds occur at different levels.
  - 11 m of shell-supported coquina (facies b, upper part of the Coquina limestone) with a packstone/wackestone matrix bearing gastropods, crinoids, ostracods and aptychi. At 10.8 m a single bed yielded the following ammonites: Haploceras sp., Haploceras carachtheis (ZEUSCHNER), Virgatosimoceras sp., Lytoceras sp., Lytogyroceras sp. This assemblage probably indicates the fourth zone of the lower Tithonian (CECCA & SANTANTONIO, 1988).

From 19 to 20.8 m the coquina has a different mudstone-wackestone matrix, with radiolarians, calcionellids, gastropods, calcareous sponges, and benthic forams.
  - ~50 cm of Cephalopod limestone, made of a wackestone with radiolarians, calcionellids, echinoderm fragments, including echinoid spines, aptychi, benthic forams, rare small ammonites.

Appendix – Biostratigraphy of the Cephalopod limestone and the Lattimusa Fm.

A. BALDANZA, G. PALLINI & G. PARISI

The top of the Cephalopod limestone (1 m) and the lower part of the Lattimusa Fm. have been sampled for biostratigraphic analysis, based on ammonites (14 m sampled), calcareous nanofossils and calcionellids (6.8 m sampled).

These data will not be discussed in the S. Vincenzo substops, as they were treated in Substop 2.1 at Contrada Diesi, in a general discussion on the Lattimusa Fm. of the Sciacca Plateau.

Microfacies of the Lattimusa Fm.

Wackestone with frequent to abundant calcionellids. Protoglobigerina spp. occurs in the SV1-SV14 interval, while Gorbachikella sp. occurs in the next interval (SV15-SV18).

Abundant radiolarians and echinoderm fragments are also part of the faunal content. Forams are rare, but hyaline (Lenticulina sp.) and agglutinating (Textularidae and Valvulinidae) forms are ubiquitous.

Ammonite biostratigraphy

The top of the Cephalopod limestone contains a
faunal assemblage of the Durangites and Jacobi Zones, late Tithonian and early Berriasian in age, respectively. *Dalmasiceras* gr. *Kiliiani* (DJANELIDZE) and *Spiticeras* spp. (some specimens have a diameter of about 12 cm) are the most useful ammonites.

At 1.6 m a level with small unidentifiable ammonites occurs. At 1.8 m *Protacanthodiscus* sp. indicates the Jacobi Zone. At 2 m *Malbosiceras* gr. *tarini* (KILIAN) belongs to the same zone. This level also produced a small bivalve, possibly a *Pinna* sp.

At 3.5 m the occurrence of *Fauriella floquinensis* LE HEGART indicates the Boissieri Zone.

The interval ranging from this level up to 14.5 m is characterized by ammonite species occurring both in the late Berriasian and in the early Valanginian (Boissieri and Otopeta Zones).

At 11.3 m, a fragment of *Neolissoceras* sp. with very flat flanks and planar chevrons probably belonging to *N. extracornutum*, but without striae, co-occurs with *Tirnovella alpillensis* (MAZENOT).

At 12.8 m we recovered an assemblage with small-size moulds of *Tirnovella alpillensis* (MAZENOT), *Lytoceratidae* with constrictions (possibly *Protetragonites* sp.), rhyncholites, Lamellaptychi, irregular echinoids.

At 14.5 m *Olocostephanus* sp. gr. *O. drumensis* KILIAN indicates the Pertransiens Zone, and is thus the lowest positively Valanginian form.

*Calcereous Nannofossil biostratigraphy*

The basal sample (SV1) produced a very poor assemblage with rare *Conusphaera mexicana mexicana*, small specimens of *Nannoconus* sp., *Watznaueria barnesae* and *W. biporta*. The presence of *Nannoconus* sp. indicates an early Tithonian age (NJ 20 – *Conusphaera mexicana* Zone).

From sample SV2 to sample SV6 the assemblages are very rich and dominated by Nannoconids; *Nannoconus steinmanni minor* first occurs in sample SV2, marking the base of the lower Berriasian (NJK-Helenea chiastia Zone).

Both *N. steinmanni steinmanni* and *Cruciellipsis cuvillieri* first appear in sample SV3, being typical events of the lower Berriasian (NK 1 - *N. steinmanni steinmannii* Zone). The assemblages are consistently characterized by *C. mexicana mexicana*, *Z. embergerii*, *Nannoconus compressus*, *Cyclagelosphaera wiedmannii*, *C. margerelii*, *C. deflandrei* and *Watznaueria manivitae* (large specimens, over 15 μm in diameter).

Sample SV7 documents the first occurrence of *Percivalia fenestrata*: this is reported by BRALOWER et alii (1989) as a representative taxon of the upper Berriasian (NK 2 - Retecapsa angustiforata Zone).

The other samples (from SV8 to SV12) are very poor, and the assemblages are dominated by *N. steinmanni steinmanni*, *C. mexicana mexicana*, *W. barnesae* and *C. margerelii*.

Sample SV13 bears a rich nannoflora, and documents the first occurrence of *Calcicalatina oblongata*, a marker of the lower Valanginian (NK 3 – *Calcicalathina oblongata* Zone).

From sample SV14 to SV18 the assemblages are rich and the species diversity ranges from medium to high. *C. cuvillieri*, *Z. embergerii*, *N. steinmanni steinmanni*, *Diazomatholitus lehmani* and *Retecapsa surirella*, *M. pemmatoida*, *Assipetra infracretacea*, *C. margerelii*, *C. wiedmannii*, *C. deflandrei* are present, along with all the representative species of the genus.
Watznaueria. Starting from sample SV18 Calcicalathina oblongata becomes frequent.

Calpionellid biostratigraphy
The SV 1 to SV13 interval is characterized by an assemblage with Calpionellopsis, T. carpathica, R. cadischiana, L. dacica, C. simplex and (rare) C. alpina. This faunal assemblage indicates the late Berriasian (Calpionellopsis Zone). The first occurrence of C. darderi is reported from sample SV14, thus the SV14 to SV18 interval is Valanginian in age (Calpionellites Zone).

Discussion
The slight mismatch seen in the lower portion of the section between Calpionellid and Calcareous Nannofossil stratigraphy has been also observed in other sections in Sicily. This is possibly due to a still less-than-perfect correlation between the currently state-of-the-art stratigraphic range charts of the two groups.

The base of the Valanginian can be placed between samples SV13 and SV14.

STOP 5 - PORTELLA DELLE GINESTRE PARKING LOT: TECTONOOSTRATIGRAPHIC SETTING AND JURASSIC LITHOSTRATIGRAPHY OF MONTE KUMETA

P. DI STEFANO & G. MALLARINO

Among the Jurassic outcrops of the Trapanese Domain from western Sicily, Monte Kumeta offers a well-established example of the complex synsedimentary dynamics along a stepped pelagic escarpment adjacent to a structural high. A rough coincidence between the palaeoescarpment and the present-day southern slope of the mountain allows a 3D observation of the discontinuous Jurassic facies distribution on an articulate palaeotopography, which was continuously rejuvenated by tectonic and gravitational synsedimentary deformation. Stops 6 and 7 will focus on some aspects of this complex sedimentary history. Stop 6 (divided into substops) describes the main steps of the Liassic conversion from a Bahamian-type platform to a pelagic escarpment. Stop 7 (also divided into substops) focuses on the evolution of the escarpment during the Late Jurassic.

Monte Kumeta is located in the central zone of an E-W trending ridge (hence named the Kumeta Ridge) extending for about 20 km in western Sicily. This ridge belongs to a major structural unit of the Sicilian – Maghrebian chain in the southern sector of the Palermo Mountains (Fig. 20).

The stratigraphy of Monte Kumeta has been treated in several studies following CAFLISH (1966) and MASCLE (1979). WENDT (1964, 1969) provided detailed data on the stratigraphy of the Jurassic strata.

The base of the succession (Fig. 21) consists of more than 300 m of Lower Liassic peritidal to open-shelf limestones and dolostones (Inici formation Auct.) that are cut across deeply by sedimentary dykes. Three main lithofacies associations were distinguished in the Inici formation, named Inici M1, M2 and M3 (DI STEFANO et alii, 2002a). Inici M1 groups peritidal cyclothems, while Inici M2 and M3 consist of oolitic-skeletal and peloidal-skeletal grain/packstone respectively. The Inici Fm. overlies a thick, (unexposed) substrate of Upper Triassic platform dolostones and is unconformably overlain by the Calcari a Crinoidi unit which consists of white to pink encrinites, up to 15-20 m thick, of Pliensbachian age.
Pelagic sediments of Late Liassic-Tithonian \textit{p.p.} age follow upward. They are informally named as “Rosso Ammonitico” (corresponding to the Buccheri fm. from southeastern Sicily) and can be easily subdivided into three units (ABATE \textit{et alii}, 1990; DI STEFANO & MINDSZENTY, 2000).

a) A lower unit (RAI = Rosso Ammonitico inferiore) made of up to 6 m of massive, reddish condensed limestone spanning the Toarcian up to the middle Oxfordian.

b) An intermediate cherty unit (Membro Radiolaritico intermedio, MRI) characterized by 0 to 15 m thick varicoloured, bedded cherts and radiolarian marls of middle Oxfordian - early Kimmeridgian age.

c) An upper unit (RAS = Rosso Ammonitico superiore), consisting of 10 to 15 m thick reddish nodular limestones and \textit{Saccocoma}-limestones of Kimmeridgian - early Tithonian age, with megabreccia and pebbly mudstone intercalations.

Upper Tithonian - Neocomian calpionellid-bearing cherty calcilutites (“\textit{Lattimusa}” \textit{Auct.}) and Lower Cretaceous to Eocene aptychus marls and calcilutites (Hybla Formation and \textit{Scaglia} = Amerillo Fm.) follow upward. A deep disconformity at the top of the Scaglia is sealed by the Calcareniti di Corleone (RUGGIERI, 1966) of Burdigalian - Langhian age, that are followed in turn by the Mame di San Cipirrello Fm. (RUGGIERI & SPROVIERI, 1970) of Serravallian - early Tortonian age.

The Jurassic pelagic units are well exposed in a relatively small area on top of Monte Kumeta and on its southern slope (Fig. 22). In this area most of these units taper northward. Moreover, as seen in Fig. 24 A, on the very top of the mountain several units are missing and the RAS unconformably overlies a thin layer of RAI, resting in turn on the Inici M2.

In sectors adjacent to Monte Kumeta, a continuous view of the Jurassic deposits is hampered by Late Miocene thrusting (CAFLISH, 1966; CATALANO \textit{et alii}, 1978) and later (Pliocene) right-lateral transpression (GHISSETTI & VEZZANI, 1984). The Jurassic palaeotectonic heritage seems to have also played an important role in the tectonic evolution of this sector (Di
Monte Kumeta

Fig. 23 - Geological section across Monte Kumeta (mod. from Di Stefano & Mindszenty, 2000). A and B indicate the location of stratigraphic columns in Fig 24.

Stefano et alii, 2002a). At present the Kumeta Ridge appears as an E-W trending positive flower structure bounded to the north and south by wrench-fault zones (Fig. 20). Transverse geological cross-sections along this structure (Abate et alii, 1990; Di Stefano & Mindszenty, 2000) show the southern flank of a hemi-anticline that is gently arched along its E-W axis and repeatedly cut across by NW-SE and SW-NE faults (Fig. 23).

Eastward the Monte Kumeta succession is tectonically overlain by the Imerese structural units, that consist of deep-water slope-to-basin Mesozoic-Tertiary carbonates and cherts and Upper Oligocene-Lower Miocene Numidian Flysch (Caflish, 1966; Abate et alii, 1978). The thrust contact is well exposed at Monte Leardo on the eastern sector of the ridge (Fig. 20).

North of the ridge the Monte Kumeta succession is downfaulted and largely covered by the Imerese nappes. Also, to the south, the Mesozoic strata are covered by Tertiary formations. Help in the understanding of the continuation toward the south of the Jurassic sediments is provided by subsurface data from the Marineo well, drilled about 5 km ESE of Monte Kumeta. The Jurassic succession penetrated by this well has been interpreted as the filling of an infraliassic basin (Marineo basin, Catalano & D’Argenio, 1982b). It consists of about 400 m of radiolarian and sponge spicule-bearing cherty limestones that are sandwiched between the Inici Fm. and the overlying Toarcian to Upper Jurassic ammonite-rich limestones. Based on its stratigraphic position, the age of this unit could be Sinemurian to Pliensbachian. Similar deposits are well known in the subsurface of eastern Sicily (Hyblean Plateau), where they are grouped into the Modica fm. and can be compared to the Corniola Fm. of the Umbria-Marche Basin.

A recently published geological section across the Kumeta Ridge and the Marineo well, based on seismic profiles (Avellone et alii, 1998), indicates that the severe Tertiary deformation occurring between these two sectors has not altered substantially their mutual paleogeographic relationships. However, the amount of lateral displacement along the wrench-fault system, and the lateral extent of the Liassic basinal sediments in the subsurface south of the Kumeta Ridge is still poorly known.

STOP 6 - BIRTH AND DYNAMICS OF A JURASSIC SUBMARINE ESCARPMENT AT MONTE KUMETA

P. Di Stefano, A. Galácz, G. Mallarino, A. Mindszenty & A. Vörös

The reconstruction of the facies architecture in the Lower-Middle Jurassic succession of Monte Kumeta, coupled with a detailed biostratigraphy, allows a definition of the dynamic and genetic factors controlling
the conversion of a Bahamian-type carbonate platform into a pelagic escarpment (Di STEFANO et alii, 2001, 2002a).

In this sector, the Inici Fm. records a change from tidalites to oolites (from restricted, inner lagoon to a more open, sandy depositional environment), that may probably be due to the birth of a basin south of Monte Kumeta in Hettangian-Sinemurian times. The existence of such a basin has already been put forward by CATALANO & D'ARGENIO (1982b) based on borehole data. The oolitic limestones (named Inici M2) are overlain by earliest Carixian bioclastic grainstones and packstones with micritized grains and by wackestones with radiolarians and sponge spicules, organized into thin sand prisms (Inici M3). The decrease of carbonate productivity indicated by these sediments records the dissection of the platform and the subsequent isolation of a submarine topographic high in the Monte Kumeta sector.

Though based only on indirect evidence, it is suggested that a tectonically controlled escarpment must have existed between the Monte Kumeta “high” and the basin. Progressive northward retreat of this scarp resulted in the conversion of a shallow platform sector into a gradually steepening slope, along which the distribution of sediments was controlled by repeated tectonic and gravity-induced modifications of the substrate topography. The vertical and lateral changes and geometrical relationships of the recognized lithofacies suggest that they were deposited on a stepped surface which was repeatedly rejuvenated by basinward-dipping normal faults (Fig. 25).

This scenario is clearly reflected in the relationship of the “normal” platform strata with the overlying Calcari a Crinoidi of Carixian/Domerian p.p. age. The encrinite bodies also are wedge-shaped, as they thicken towards the south while filling the first generation of neptunian dykes (Fig. 26).

The top of the Calcari a Crinoidi is marked by a peculiar jagged dissolution surface with dm-scale pinnacles capped by a thick ferromanganese crust (Di STEFANO & MINDSZENTY, 2000). The formation of this peculiar surface could have been controlled by complex changes in water chemistry, probably related to the early Toarcian anoxic event and subsequent bioerosion.

The crust itself is dissected by faults with throws ranging from decimetres to metres, sometimes organized into small-scale positive flower structures. In the hollows/depressions of this highly irregular substrate, the Rosso Ammonitico inferiore (RAI) of Bajocian to middle Oxfordian age was deposited. The RAI deposits display a clearly onlapping relationship to the encrinites and to the carbonate platform beds. Their thickness rarely exceeds 4 to 5 m, and they also occur as neptunian dykes filling a dense network of fissures.

As indicated by an intense brittle deformational event that dissected the upper levels of the RAI, during late Callovian and Oxfordian times a burst of synsedimentary tectonics resulted in a steepening of the slope. This produced deformation (slumping and sliding) of the semi-lithified and un-lithified sediments along the
Monte Kumeta escarpment. Four localities, here indicated as Substops 61-4, were selected in order to demonstrate some details of the complex Early and Middle Jurassic stratigraphic evolution of this sector of the Trapanese Domain.

**Substop 6.1 - “Cava Cerniglia”**

In this quarry the extraction of Jurassic rocks has been more or less continuous during the last 20 years. The actual quarry floor is roughly NS-oriented, elongate, rectangular in plane view with three main levels. The most interesting laterally continuous wire-cut surface, offering the best dip-section, is exposed along the western wall of the lowermost level (Fig. 27). More features, like fossiliferous horizons, are well seen also at the higher levels. The most important features observed on the present-day’s quarry face and on the wire-cut blocks lying around are:

1) The RAI lithofacies, their lateral variations and the unconformable contact between the RAI and its substrate, marked by the serrate Mn-encrusted surface.


3) Fossils, mainly ammonites condensed on the discontinuity surfaces.

Warning! Because of ongoing quarrying, descriptions and photos in this guidebook may not correspond in all details to the actual state of the wire-cut surface.

**Lithofacies in the Rosso Ammonitico Inferiore**

The oldest unit exposed by recent quarry works near the bottom of the northern wall is the Inici M3. Above it, the white Calcari a Crinoidi follow through a sharp (bio) eroded contact. This unit is about 10 m thick.
Towards the top, this formation shows an intergranular porosity filled by syntaxial overgrowth cements and reddish micrite, whereas downwards the porosity is filled only by the syntaxial cement. The Calcari a Crinoidi are also cut by several generations of dm to m scale sedimentary dykes oblique or parallel to the bedding planes and filled by various sediments obviously derived from the overlying succession. Along the upper contact between the Calcari a Crinoidi and the overlying RAI, the unusually well-preserved dissolution surface with dm-scale rectangular pinnacles occurs. In pockets among these pinnacles the earliest pelagic sediments of the RAI (micritic limestone with goethite-encrusted bio/lithoclasts) are preserved. Rare ammonites recovered from the interpinnacle material indicate the lower Toarcian (*Harpoceras serpentinum* Zone). The pinnacles and Toarcian sediments are equally covered by a thick ferromanganese crust which forms a mineralized hardground up to 10 to 15 cm thick.

Above the conspicuous Mn-Fe crust follows the Bajociain to Oxfordian section of RAI, having noticeable thickness variations and onlap geometries related to the underlying palaeotopography and to synsedimentary deformation. A profile measured close to the entrance of the quarry was selected to display most of the lithofacies identified so far:

**Red pseudonodular cephalopod limestone (RAIa)**

It is a dark red to red calcilutite overlying the main Fe-Mn crust and containing abundant Mn oxide-coated ammonites. As the nodular structure is not evident in outcrops, we adopt the term “pseudonodular” rather than “nodular” (*sensu* MARTIRE, 1996). Nodules consist either of ammonite moulds or of early diagenetic nodules. The microfacies is a bioclastic packstone/wackestone with abundant fragments of thin-shelled bivalves (*Bositra*), radiolarians, few thicker mollusc fragments, and less common bentic foraminifers and peloids. Ammonites embedded in this matrix are corroded and Mn-coated, indicating redeposition. Though continuous, the thickness (0 to about 40 cm) of the RAIa was also apparently controlled by the paleotopography of the underlying main discontinuity surface. At its thickest, at least three subunits can be recognized, that are separated by thin Mn-oxide-coated bedding planes and correspond to three different ammonite zones (*Stephanoceras humphriesianum*, *Garantiana garantiana*, and *Parkinsonia parkinsoni* Zones).

**Pink wavy cross-bedded limestone (RAIb)**

It is separated from the underlying RAIa by a few cm thick discontinuous horizon of laminated goethitic marls. At places where the RAIa is absent (local relative topographic highs) the wavy cross-bedded limestone may directly overlap the thick Mn-Fe encrusted dissolution surface. The western wall of the quarry shows very clearly that the cross-bedded limestone has a lenticular geometry. Its thickness varies from a few up to 70 cm within a distance of about 40 m, reaching the maximum at about the middle of the present-day NS oriented wall, then it decreases again to a few centimetres in the NW corner of the middle quarry-level (Fig. 27). It consists of alternating laminae of coarser and finer, well-sorted, bioclastic grain/pack/wackestone with peloids, abundant *Bositra* sp. and other mollusc fragments, few bentic and planktonic foraminifers, ostracods, *Globochaete* sp., small ammonites, gastropods, echinoderm fragments and bioeroded lithoclasts. Small-scale wavy cross-lamination interpreted as current-ripple lamination is obvious at places. Sedimentary structures (current ripple lamination, grading) and lateral and vertical facies relationships suggest that the bioclastic sand was deposited episodically from swift currents on the otherwise starving sediment surface.

The uppermost few cm of this unit are a red, massive wackestone. Above, a laminated goethitic marl horizon follows, with abundant burrow fills and - in the more calcareous parts - with a rich late Bathonian [*Hecticoceras (Prohecticoceras) retrocostatum* Zone] fauna (DI STEFANO et alii, 2002a). Such laminated layers occur frequently at different stratigraphic levels of the RAI. They consist of thin, about 1 mm, often torn-apart (sheared) laminae of yellowish brown goethitic/smeectitic clay and of thin laminae of micrite, all cemented by coarse sparry calcite grown perpendicular to the walls of the interlaminar space. Lithoclasts deriving from these deposits are often embedded in neptunian dyke fillings. The interpretation of the observed textures requires more than one episode of deformation following early compaction of the clay/marls deposits. The first phase of deformation may have been downslope creep, resulting in small-scale bed-parallel displacement of the ductile clay/marl laminae, generating interlaminar cavities where diagenetic fluids could precipitate the palisade calcite.

**Red pseudonodular marly limestone (RAIc)**

It is a reddish calcilutite characterized by a pseudonodular texture due to the presence of early diagenetic nodules, ammonite moulds and bioturbation traces. The dominant microfacies is a bioclastic packstone/wackestone with radiolarians, less abundant thin-shelled bivalves, thicker, heavily bioeroded fragments of assorted molluscs, bentic forams, echinoderm fragments, peloids, rare micritic lithoclasts, embedded in a partly microsparry “matrix”. Also this unit shows considerable lateral thickness variations (from 0 to 90 cm), apparently compensating for the relief created by the lenticular geometry of the RAlb. It is subdivided by several bed-parallel goethitic marl intercalations. The number of the goethitic marl horizons varies according to
the above mentioned thickness variations. The upper part of RAIC is particularly rich in large ammonites and is characterized by a series of Mn-coated condensation horizons. The most peculiar of them, about 5 cm below the contact with the overlying red/grey nodular marls, shows widely-spaced thin (1 to 3 cm) finger-like pinnacles of a bioeroded surface, coated by a thin Mn-oxide film. The height of these pinnacles is up to 5 cm. Ammonites recovered from this unit indicate the middle Callovian (Reineckeia anceps Zone). The contact of RAIC with the overlying red/grey nodular marl (RAID) is sharp, marked by a thin discontinuous Mn-oxide crust with clear evidence of microbial activity (laminated, bulbous structures).

Red/grey nodular marls (RAID)

The basal part of it is distinctly nodular and more calcareous than the upper section, while the upper part grades into the overlying radiolaritic unit. The microfacies is a wackestone with micropeloids, shell fragments, radiolarians, sponge spicules, bioeroded echinoderm fragments, abundant planktonic and a few benthic forams. Nodules here show evidence of having been resedimented by gravity flows. Evidence for mass transport includes slump structures and concentration of early diagenetic nodules to form “pebbly mudstone” layers. As indicated by belemnite assemblages, and by calcareous nannofossil and radiolarian biostratigraphy, this unit can be assigned to the lower Callovian-middle Oxfordian (MARIOTTI, in press).

SYNSEDIMENTARY DEFORMATIONS AND ASSOCIATED FEATURES

One of the most evident features to be observed in this quarry is the response of sedimentation to repeated events of deformation.

Neptunian dykes

The earliest event of fracturing affecting the Calcari a Crinoidi clearly predates the formation of the main Fe-Mn crust. Fractures may be both vertical to subvertical or bed-parallel, and their width varies from centimetres to metres. The irregular walls of the fractures and the rounded appearance of the host rock blocks suggest that the sediment was not completely lithified when it underwent deformation. Some fissures have a polyphase filling suggesting either reopening of the same space or gradual filling by different sediments. In places, subvertical dykes are connected to swarms of thin fractures with the same filling, thus giving rise to an in situ breccia texture. The thin fractures are interpreted as injection dykes (MONTE NAT et alii, 1991). A later generation of fractures cutting across the main Fe-Mn crust has been dated as late Bajocian due to the occurrence of characteristic brachiopods [Apringia cf. alontina (DI STEFANO)].

Most subvertical dykes show an homogeneous orientation (E-W, NW-SE), suggesting a tectonic control for their opening (MALLARINO, 2002, in press).

Other deformatinal structures

A brittle deformation event affected the Calcari a Crinoidi, also displacing the Fe-Mn-encrusted pinnacled surface. The rejuvenated topography controlled the deposition of the lower part of RAIA. One of the related features was detected and documented in the late 90's as a m-scale flower-like positive structure with associated clear onlap relationship of RAIII lithofacies. In the upper two levels of the quarry it is still possible to see the effects of this articulate topography, like the direct contact between the upper part of RAIC (middle Callovian) and the underlying Fe-Mn encrusted Calcari a Crinoidi, and the merging of the goethitic marl horizons intercalated in the RAII into one level.

Another spectacular feature at “Cava Cerniglia” is a later brittle deformation event clearly postdating RAIC and resulting in ductile deformation of at least a part of the overlying upper Callovian - lower Oxfordian red/grey nodular marls (RAID). This was particularly evident along the western quarry face in 1999, so it could be described in some detail (see Fig. 27). The faults are predominantly E-W to NW-SE striking normal faults, pointing to an overall extensional regime and resulting in cm- to m-scale displacements. Minor reverse faults indicate local compression. The observed ductile deformation of the nodular marl (RAID) is clearly related to the above described tensional event. The distribution of slumps and associated gravity-driven debris flow

Fig. 28 – a) “Cava Palo” – Onlap of the RAI onto a stepped surface of oolitic bioclastic grainstones (Inici M2) which is cut across by an intense network of sedimentary dykes. The contact is displaced by small normal faults postdating the RAI deposits.

b) “Cava A” – In the lower part of the wire-cut walls the sharp contact between the Inici M3 deposits and the overlying Calcari a Crinoidi is exposed. Upwards a stepped unconformity of RAI on the Calcari a Crinoidi is evident.

c, d) “Cava A”: Close-up of the contact surface between the Inici M2 and the Calcari a Crinoidi. Arrows in Fig. 28d indicate a bioerosional cavity on the Inici M3 hardened surface filled up by crinoidal sands. Scale bar in Fig. 28c = 1 m; scale bar in Fig. 28d = 15 cm.

e) – Slope above “Cava A”: Stepped unconformity of the RAI on Inici M2/M3. The main steps (dm- to m-scale) are rectilinear and roughly E-W oriented. At places broken pinnacles consisting of Mn-Fe-coated Inici limestones are embedded in the RAI.

f, g) – “Cimitero dei pinnacoli”: Unconformity between the Inici M3 and the RAI deposits, locally characterized by a 40 cm thick debris bed.
deposits suggests that this faulting rejuvenated the local palaeotopography by steepening the palaeo-slope toward the present-day south.

**Substop 6.2 - “Cava A”**

This is a small, abandoned quarry along the road about 300 m west of “Cava Cerniglia”, formed by two nearly perpendicular wire-cut surfaces (Fig. 28b). These surfaces expose:

i) the contact between Inici M3 and the overlying Calcari a Crinoidi;

ii) the Calcari a Crinoidi top, here marked by a stepped surface without pinnacles;

iii) the stepped unconformity of the RAI deposits.

The contact between Inici M3 and the overlying Calcari a Crinoidi is characterized by a sharp surface (Fig. 28c-d) along which small-scale bioerosional cavities can be observed in places. Rare, cm-scale subvertical dykes filled with crinoidal sands can also be seen on the wire-cut surface. Otherwise the contact surface is criss-crossed by several generations of cm-sized neptunian dykes filled either by a yellowish calcilutite with angular lithoclasts, or by calcite cements and varicoloured silt. The surface is also cut by several subvertical faults, producing cm-scale displacements that postdate the deposition of the Calcari a Crinoidi. The thickness of the Calcari a Crinoidi ranges from about 1.5 up to 4 m. The upper boundary of this unit is a sharp, stepped unconformity sealed by RAI deposits.

In the lower part of the eastern side of the quarry, the RAI deposits onlap a m-scale palaeorelief of Calcari a Crinoidi. Here the RAI covers a thick Fe-Mn crust. Higher up, on the wire-cut wall a step of about 40 cm is observable (Fig. 28b). It is interpreted as the result of local downslope collapse of the topmost beds of the Calcari a Crinoidi, during the deposition of the RAI. The downslope collapse phenomena seem to have been favoured by bed-parallel neptunian dykes in the upper part of the unit, which served as detachment surfaces. The mechanical removal of joint-bound blocks gave rise to a stepped surface sealed by the RAI limestones (stepped unconformity, sensu Winterer & Sarti, 1994). The overlying RAI contains dm-scale lithoclasts either of Mn-Fe-coated pinnacles or fragments of the Fe-Mn crust. These lithoclasts are obviously derived from adjacent upslope areas which were exposed and eroded at those times. Sections of ammonites observed in the lower RAI indicate a Bajocian age for the sediment filling the stepped unconformity.

The general relations and depositional geometries as observed at “Cava A” and in adjacent areas clearly points to the lateral (northward) pinch out and onlap of the Inici M3 and of the Calcari a Crinoidi on a stepped surface of Inici M2. The resulting palaeotopography was repeatedly rejuvenated also in this case during the deposition of the RAI, producing multiple unconformities.

**Substop 6.3 – “Cimitero dei pinnacoli”**

This is a small (about 6x6 m) outcrop on the gently sloping hillside. Features to be observed are:

i) contact between Inici M3 and the overlying RAI (the Calcari a Crinoidi are missing);

ii) downslope transport of Mn-encrusted broken pinnacles by submarine debris-flows along the exposed surface of the Inici M3.

The base of the section exposes an about 1 m thick section of the topmost zone of the Inici M3, consisting of a radiolarian and sponge spicule-bearing wackestone with scattered oncoids and small benthic forams. The Inici M3 top is a sharp surface draped by the RAI deposits. Along the surface a step of about 1 dm is filled up by a reddish pelagic calcilutite with some cm-sized Fe-Mn nodules concentrated at the base. Both the Inici M3 and the step-filling calcilutite are abruptly overlain by a 40 cm thick debrite consisting of a red calcilutite matrix which supports dm-sized broken pinnacles of Calcari a Crinoidi that are coated by Fe-Mn crusts (Fig. 28f-g). Ammonites occurring in the matrix indicate an upper Bajocian age for this debrite bed. A few cm thick Bositra lumachella overlies this bed, also filling fractures in the underlying
beds. Well preserved ammonites in these fracture-filling sediments indicate a late Bathonian [\textit{Hecticoceras} (\textit{Prohecticoceras}) retrocostatum Zone] age.

A 40 cm thick bed of goethitic sheared clays with abundant trace fossils follow upward. It is overlain by a centimetric alternation of reddish \textit{Bositra} bioclastic grain/packstone to thinly-laminated bioclastic wacke/mudstone, showing at places structures related to soft sediment deformation. This bed also bears a large block of Fe-Mn encrusted Calcare a Crinoidi (Fig. 29).

The last exposed unit upward is the varicoloured marly calcilutite (RAId). As in “Cava Cerniglia”, this unit is slumped, bearing pebbles of red calcilutites and abundant belemnites and aptichi. The observed features indicate continued downslope mass transport of RAI deposits embedding also lithoclasts mainly derived from the pinnacled surface of the Calcare a Crinoidi.

It is suggested that the upslope morphology was a stepped surface exposing in places the Fe-Mn-encrusted pinnacled discontinuity. The pinnacled debrites point to an intense mechanical erosion of the Calcare a Crinoidi in the upslope area, also postdating the formation of the dissolution surface.

Substop 6.4 - “Cava Palo”

“Cava Palo” is a small, abandoned quarry along the southern slopes of Monte Kumeta. Along the south-facing E-W trending quarry wall a sharp unconformity between Inici M2 and the RAI can be observed in detail (Fig. 28a).

Features to be observed include:

i) The oolitic limestone of Inici M2 cut across by vertical/subvertical and subhorizontal, sometimes polyphase neptunian dykes filled by several generations of varicoloured calcilutites.

ii) The uneven stepped, at places Mn-encrusted contact between Inici and RAI without intervening Inici M3 and/or Calcare a Crinoidi.

iii) The draping of the basal layers of RAI above the stepped surface.

iv) A palaeotopographic depression filled by alternating layers of a \textit{Bositra}-rich calcilutites and laminated goethitic-marly/clayey horizons.

Inici M2 consists of well-sorted bioclastic/oolitic grainstones with \textit{Paleodasycladus} and \textit{Thaumatoporella}. Reddish calcilutites from the overlying RAI penetrate a dense network of fractures and infiltrate in places an intergranular porosity in the grainstone. Between Inici M2 and the RAId deposits neither Inici M3 sediments, nor the Calcare a Crinoidi occur in this section. This is a common relationship observed on the upper slope of Monte Kumeta.

The Inici surface is characterized by dm-scale fault steps predating the RAI deposition. Additionally, later small faults displace the unconformity surface and the overlying RAI. On the Inici surface a discontinuous Fe-Mn crust occurs, from which middle and upper Toarcian ammonites were collected (F. MACCHIONI, pers. comm., 2000). Upwards, a bed about 20-40 cm thick rests on this stepped morphology. It contains scattered fragments derived from the main Fe-Mn crust, and in places, angular fragments of Inici.

The articulate palaeotopography in the eastern part of the quarry shows a m-scale depression filled up with alternating \textit{Bositra}-rich limestone and laminated goethitic-marly/clayey horizons which laterally pinch out completely. The \textit{Bositra} limestone is normally graded, with a concentration of randomly oriented shells at the base, passing upwards into a very fine bioclastic pack/mudstone with small oriented fragments of thin-shelled bivalves. They are interpreted as channel-filling microturbidites.

The local section is topped by a bed of reddish \textit{Bositra} limestone, about 80 cm thick. Higher up, along the present-day slope, thinly-laminated \textit{Bositra} limestones and the varicoloured marly limestone of the RAId can be also observed. E-W trending subvertical neptunian dykes with a polyphase filling cut across the Inici limestone both in the western and eastern termination of this quarry.

APPENDIX - NEPTUNIAN DYKES AT MONTE KUMETA

G. MALLARINO

Neptunian dykes are among the most common and peculiar features of carbonate successions deposited in the Tethyan region. In western Sicily, Jurassic neptunian dykes in Liassic platform limestones were described in detail by WENDT (1965, 1971). He identified vertical or oblique fissures (Q type) and horizontal fissures (S type) filled up by condensed pelagic limestone of Liassic-Malm ages as a result of extensional tectonics. At Rocca Busambra the author described polyphase dykes with Jurassic to Miocene fillings. At the same locality LONGHITANO \textit{et alii}, (1995) considered tectonic extension, partly coupled with dissolution, as the main opening mechanisms of polyphase dykes. At Rocca che Parla (another locality studied by WENDT), MARTIRE \textit{et alii} (2000) corroborate a tectonic origin for the subvertical fractures in the Liassic platform limestone. In eastern Sicily, SARTI \textit{et alii} (2000) studied some Jurassic-Cretaceous fissures and interpreted them as the result of gravity related fracturing followed by filling by episodic microturbidites.

Along the Jurassic escarpment of Monte Kumeta the opening of fractures was related either to extensional tectonics or to dilation due to down-slope creeping.
data indicate that at least three generations of fractures formed from Early to Middle Jurassic times. Orientation of dykes similar to the strike of coeval faults (Fig. 30a,b), and the occurrence of fitted breccia are all considered to be the evidence of coeval tectonics, whereas box-shaped cavities are indicative of gravitational down-slope sliding of blocks. During Late Jurassic times anastomosed cracks indicating surficial extension due to incipient sliding of semilithified deposits suggest gravity as the main controlling factor at that time.

**LOWER TO MIDDLE JURASSIC DYKES**

They penetrate the Inici Fm, the Calcari a Crinoidi and partially the RAI. The first generation of dykes is filled up by the Calcari a Crinoidi, the second and third generations are filled by RAI sediments and they predate and cut across the main Fe-Mn crust, respectively.

**FIRST GENERATION**

The oldest fractures, as mentioned above, cut across the Inici Fm. and are filled by crinoidal packstone-grainstone with bioclasts and peloids. They are relatively rare and their orientation is both subvertical and bedding-parallel. A group of fractures are filled only by crinoidal limestone, suggesting quick filling soon after their opening. In other cases the crinoidal limestone occurs as the first filling of polyphase dykes (Fig. 31a). The subvertical fractures have strikes ranging from E-W to

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**Fig. 31** - Rose diagram of Lower-Middle Jurassic dykes (a) paralleled to stereographic representation of Lower-Middle Jurassic fault planes (b).
NW-SE (fig. 30a). Straight and smooth walls suggest brittle fracturing of a well lithified host rock. Some fissures show multiple filling patterns with sediments alternating with phosphatic and Fe-Mn crusts and cements.

SECOND GENERATION

On top of Monte Kumeta, the Calcari a Crinoidi is penetrated by several dykes filled by RAI deposits (wackestone with benthic foraminifers, ammonite fragments and bivalve shells). Three major typologies of fractures are related to this episode:

- **Bed-crossing fractures**
- **Bedding-parallel fractures**
- **Swarms of thin fractures**

**Bed-crossing fractures**

Fractures up to 1 m in width, with a penetration depth of some metres, have a preferential orientation ranging from E-W to NW-SE. Often, a matrix-supported breccia with host rock elements represents the main filling, clearly indicating that fractures were filled up as soon as they opened by forced injection of loose sediment (Fig. 31b). The sudden opening of the fracture itself probably produced a “vacuum effect”, leading to sucking in of the overlying soft sediment (CASTELLARIN, 1966). Quick infilling is also suggested by the lack of cement on the walls. At places walls show a fitted breccia texture affecting some decimetres of the host rock.

Other mechanisms for sediment injection can be excluded. Sediment pressure cannot be invoked owing to reduced thickness of the RAI, neither can hydrostatic pressure. Hydrostatic pressure within the host rock and the overlying sediment was most likely the same due to reduced thickness of the RAI, neither can hydrostatic pressure. Hydrostatic pressure within the host rock and the overlying sediment was most likely the same due to reduced thickness of the RAI, neither can hydrostatic pressure. Hydrostatic pressure within the host rock and the overlying sediment was most likely the same due to reduced thickness of the RAI, neither can hydrostatic pressure. Hydrostatic pressure within the host rock and the overlying sediment was most likely the same due to reduced thickness of the RAI. Quick infilling is also suggested by the lack of cement on the walls. At places walls show a fitted breccia texture affecting some decimetres of the host rock.

**Bedding-parallel fractures**

These fractures form a network occurring on top of the Calcari a Crinoidi. Their width is up to 50 cm and they penetrate the host rock no deeper than 5 m. At places they form parallel sets cutting decimetric beds of host rock. The host bounding the fractures is reddish stained. Often wall fractures show uneven morphologies and in situ breccia textures. Breccia elements consist of both rounded clasts of pinkish crinoidal limestone, and angular clasts of whitish crinoidal limestone (Fig. 31c). Moreover, at places the whitish angular clasts are embedded within the pinkish crinoidal limestone. Fractures cutting across the pinkish host contain a filling consisting of RAI sediments with floating ossicles of crinoids clearly derived from the host. Transmitted light microscopy observations show that in the whitish crinoidal limestone only syntaxial overgrowth cements fill up the intergranular pore spaces, whereas in the pinkish one a reddish matrix (related to the RAI deposition) is the last sediment occluding the porosity. All the above mentioned features strongly support fracturing of host areas with different degree of lithification. Brittle fracturing occurring in whitish harder parts produced angular clasts whereas the pinkish, relatively less lithified areas formed both the matrix and the rounded clasts. The pinkish encrinite occurs only in the upper part of the Calcari a Crinoidi and it gradually disappears downward. This might be the consequence of RAI infiltration from the top. The floating crinoid ossicles within the filling could be due to mechanical disaggregation by fracturing and associated mechanical abrasion during forced filling. However, dissolution by corrosive undersaturated fluids enhancing uneven wall morphologies and enlarging fissures cannot be excluded.

**Swarms of thin fractures**

A different network of veinlets (up to 10 cm in width) with a random distribution cuts across the Calcari a Crinoidi. They originate fitted breccia textures (Fig. 31d) and are usually associated with larger bed-crossing dykes. In Fig. 31d an example of these fractures is shown, from “Cava Cerniglia”. Thin sinuous veinlets develop from a “master dyke” and penetrate the crinoidal limestone for up to some metres (Fig. 31d). They bound angular host clasts ranging from few centimetres up to 50 cm. Veinlets are seen to die out in the host rock, suggesting the latter was unevenly lithified. Veinlets are filled up by the same reddish calcilutite filling the “master dyke”. At places the veinlet filling contains micritic clasts showing the same texture of the surrounding sediment. These fractures were described by MONTEMAT et alii, (1991) and were interpreted as the result of forced injection of sediments by overpressured fluids (injection dykes).

**THIRD GENERATION**

This is the most prominent generation of fractures all over Monte Kumeta, reaching up to 2 m in width and tens of metres of penetration depth. The filling is RAI sediment (wackestone/packstone with thin-shelled bivalves). These dykes cut across both the Inici Fm. and the Calcari a Crinoidi. Based on the wall morphology, three major types of fractures can be identified:

**Dykes with straight walls**

These fractures are characterised by smooth and straight walls. Often they form polyphase dykes that reopened and filled up fissures formerly filled by the Calcari a Crinoidi (Fig. 31a). Some dykes contain angular clasts of host embedded in the filling, but walls do not show any fitted breccia texture. Moreover, fillings near the walls of the fractures may show bands parallel to the walls themselves, thus indicating a forceful injection of
sediment from above (Fig. 31a; CASTELLARIN, 1966).
Orientation of these dykes ranges between E-W and NW-SE.

**Dykes with uneven walls**

At “Cava A” bedding-parallel dykes with irregular walls cut across both the Inici limestone and the Calcare a Crinoidi. Width is up to 30 cm. Oblique dykes also occur locally, resulting in a variably oriented network of fractures. Crosscutting relationships show that other fillings occur besides the main thin-shelled bivalve calcilutites. Veins of fibrous calcite (cm width) cut across the dykes, although in some cases they seem to occur as the last filling occluding the cavity. Within few veins centripetal growth of calcite crystals is terminated by infiltration of red-brownish sediment. Cathodoluminescence microscopy shows that the cements are non-luminescent. The top of the Calcare a Crinoidi is offset by faults that do not displace the overlying RAI. Associated with these faults are shear zones consisting of decimetre-wide bands of fitted breccia with infiltrated RAI.

**Box-shaped cavities**

Cavities with a “box” morphology occur on top both of the Inici Fm and of the Calcare a Crinoidi. They consist of a wide depression (width is up to 10 m) with a flat, often bedding-parallel, bottom. Laterally the depression is bounded by nearly vertical walls (steps) whose height ranges from decimetres up to some metres. These cavities are mostly filled by bedded Bajojician Rosso Ammonitico. A good example in the Calcare a Crinoidi can be observed at “Cava A”. Steps in this structure are about 50 cm in height. At the bottom of the cavity a bedding parallel dyke is cut by the box-shaped surface itself. No faults occur along the steps.

**Upper Jurassic dykes**

Two main sets of fractures clearly postdate the previously described ones. Based on crosscutting relationships and filling sediments, they can be attributed to the Upper Jurassic. The first set is a network of small and anastomosed cracks penetrating a thick massive bed of RAS on top of Monte Kumeta. The second set consists of few cm-size and randomly oriented fractures in the Inici host.

**Dykes in RAS host**

This generation of fractures (cm width) mainly occurs within a 3 m thick massive bed of RAS cropping out in an abandoned quarry wall near the summit of Monte Kumeta (Fig. 32a). The host rock consists of reddish wackestone with abundant echinoderm fragments, rare radiolarians, benthic foraminifers (*Lenticulina sp.* and *Spirillina sp.*) and randomly embedded angular fragments of Inici limestone (dm across).

The cracks are interconnected and randomly oriented thus forming an intricate network. However, sub-horizontal orientation is locally prevailing and fractures dip about 10°-30° southward. The base of the fractures shows an irregular morphology and in some cases mm-size rounded fragments of host rock are present. The randomly oriented cracks are not connected to any bigger subvertical dyke.

Fillings show the following succession: i) greenish crystalline sediment; ii) isopachous coarse fibrous calcite; iii) reddish mudstone (Fig. 32b).

i) Greenish crystalline sediment. It consists of a mosaic of silt to fine sand sized calcite crystals (20-150 μm) with floating clay minerals. Rare patches of micrite are preserved. FL observations show few “ghosts” of acicular crystals as relict structures. They originally might have been sponge spicules. Crystal boundaries show either triple junctions or not. Based on these observations and following BATHURST’s criteria (1975),
the first filling is interpreted as a mosaic of micro and pseudospar due to early recrystallisation of a marine carbonate mud. Microprobe semi-quantitative analysis of clay minerals suggests possible smectite. Moreover, clay minerals are preferential sites for calcium phosphate crystal accumulation. The origin and age of the greenish crystalline sediment are poorly constrained yet, owing to the intense recrystallisation. In the overlying RAS succession no such sediment occurs.

ii) Isopachous coarse fibrous calcite. It is formed by elongated centripetally growing crystals. CL petrography show that fibrous cements are non luminescent except the distal zone which is bright orange. This reflects a change in Mn/Fe ratio of fluids during crystal growth. These cements pre-date the last marine filling, thus indicating an early cement precipitation near the water-sediment interface. Veins of bright yellow luminescent calcite cutting the fibrous cement likely suggest later phenomena of hydraulic fracturing.

iii) Reddish mudstone. This filling, which occludes the cavities, consists of partially recrystallised mudstone with ragged fragments of echinoids and rare benthic foraminifers (spirillinids).

Often the first filling is overlain by the fibrous cement thus forming geopetal structures. Veins of fibrous calcite cutting across the above infillings suggest a later fracturing event.

The fractured bed overlies a thin layer (20 cm at least) of polychrome marls, which are not cut across by the fractures. Up-section also a thick bed of slump-nodular limestone overlaying the massive bed is clearly not cut by the cracks. DI STEFANO & MINDSZENTY (2000), interpreted these cracks as the result of dilation due to downslope creeping of the massive bed along a décollement surface.

**Upper Jurassic dykes in Inici limestone host rock**

Few fractures (cm width) cutting across the Inici limestone host and the lower Bajocian dykes crop out around the summit of Monte Kumeta. They are filled by greenish sediment and fibrous calcite. Transmitted light microscopy observations show close similarity to fillings i) and ii) of the previously described Upper Jurassic anastomosed cracks. Smooth and sharp walls are indicative of brittle fracturing.

**STOP 7 - LATE JURASSIC EVOLUTION OF THE SUBMARINE ESCARPMENT AT MONTE KUMETA – AN INTRODUCTION**

M. MARINO, U. NICOSIA & M. SANTANTONIO

As anticipated in the previous stop, Monte Kumeta represents an escarpment tract marginal to a Jurassic intrabasinal high – a product of Early Jurassic extensional tectonics (MARIOTTI et alii, 2001). This stop is aimed at analysing the facies, sedimentary features and geometries of the upper Callovian-Tithonian deposits, and their bearing on the reconstruction of the geodynamic evolution of this structure during the Late Jurassic. Reference to an “escarpment” is here due to the fact that the post-drowning deposits rest unconformably on an erosional surface that truncates bedding of the peritidal substrate.

The upper Callovian-Tithonian succession is characterised by carbonate and siliceous deposits and by mixed pelagic condensed/resedimented deposits that rest unconformably both on the shallow water limestones of the Inici Fm. and on the Rosso Ammonitico Inferiore (RAI). Resedimented deposits also bear lithoclasts that are made up of carbonate platform limestone (Inici Fm.) and of pelagic carbonate. The lack of a condensed pelagic succession conformably lying on the Inici Fm. (“pelagic condensed facies association” of SANTANTONIO, 1993), and the volumes of resedimented material imply that much of the original depositional system, most noticeably the top of the palaeostructure representing the source area of clastics, is un.preserved.

The palaeoescarpment is now NE-SW dipping, as shown by the NE-SW thickening of the different units (see also the previous stop). The carbonate and siliceous pelagic deposits pinch out towards the top of Monte Kumeta, where only the Inici Fm. crops out (Fig. 33).

Besides possessing a wedge geometry, the Upper Jurassic post-radialarite succession (Rosso Ammonitico Superiore – see below) characteristically bears spectacular evidence of mass transport and sediment instability in the form of slumps, intraformational truncations, and shallow growth faults. This demonstrates that following partial sealing of the Early-Middle Liassic escarpment topography by the Rosso Ammonitico Inferiore, the area became a slope that was locally oversteepened. The Rosso Ammonitico Superiore apparently behaved here as a detached body with respect to the substrate. Its “thin-skinned” deformation might either have been the product of sea-bottom instability (slow creep to sliding) triggered by gravity alone, or the surficial response to faulting in the substrate. No Late Jurassic faults, however, can positively be documented at Monte Kumeta. These geometries indicate that the present-day western area corresponds to the distal sector of the Jurassic structure, while the present-day eastern area corresponds to its proximal sector.

The presence of clasts of Inici Fm. in the succession requires sourcing from submarine outcrops of the pre-drowning carbonates. This demonstrates that, along this relatively low-angle escarpment, draping by pelagic deposits was discontinuous due to the occurrence of non-depositional spurs of peritidal bedrock.
Fig. 33 – Schematic representation of the stratigraphic setting of the Jurassic deposits of Monte Kumeta, as reconstructed along an E-W transect.

**LITHOSTRATIGRAPHY**

The local post-Inici Fm. Jurassic succession consists of four lithostratigraphic units (from bottom to top):

- **Rosso Ammonitico Inferiore (RAI)**: only the uppermost lithofacies of this unit [upper Callovian-middle Oxfordian red/grey nodular marls (RAId)] is here considered (see Stop 6). An analysis of this lithofacies is included with this stop because it is indispensable for the interpretation of the Late Jurassic stratigraphy and geodynamic evolution of the Monte Kumeta structure. It is composed of nodular limestones and brown to yellow-greenish marls, with an impressive amount of belemnites, aptchi, corals, crinoids, rhyncholites, echinoderm fragments and shark teeth. The RAId crops out discontinuously and its best exposure is in the “Cava Cerniglia” (see Substop 6.1). There it overlies the uppermost hardground of the RAI, assigned to the Callovian (Anceps Zone). Slumps may occur at the base of the RAId, and at the top resedimented levels embed clasts of the Inici Fm. and soft clasts derived from the RAI itself (see previous stop). At the top, some levels are silicified, probably due to a diagenetic underbed effect of the overlying cherty sediments.

In the eastern area, where the Membro Radiolaritico Intermedio (MRI) wedges out, this lithofacies is directly overlain by the resedimented deposits of the Rosso Ammonitico Superiore (see below). In the very proximal sector, it is “squeezed” among large resedimented blocks of a local breccia (see Substop 7.4). The belemnite assemblage, calcareous nannoplankton and radiolarians indicate a late Callovian-middle Oxfordian age (MARIOTTI, in press).

- **Membro Radiolaritico Intermedio (MRI)**; middle Oxfordian-lower Kimmeridgian): cherts and cherty limestone, greenish-grey at the base and reddish at the top. This unit is clearly wedge-shaped, reaching its maximum thickness (about 15-20 m) in the SW sector of Monte Kumeta; the unit pinches out north-eastwards, and disappears 200 m from the top of the mountain, abutting a local escarpment tract. No evidence of resedimentation
is observable. Biostratigraphic data will be discussed in the Substop 7.1.

- Rosso Ammonitico Superiore (RAS; ?lower Kimmeridgian - lower Tithonian): this unit exhibits the greatest lithofacies variability. It consists of an heterogeneous complex of breccias, very fine to coarse calcarenites, nodular limestones, and sand-sized echinoid skeletal debris. Along the palaeoescarpment these rock types are organised into different sedimentary bodies. Resedimented deposits (mainly megabreccias) predominate in the proximal sector, where they unconformably overlie the RAI sediments, these latter lying in turn unconformably on the Inici Fm. The megabreccias terminate eastwards against the carbonate platform limestone which here forms a west facing cliff, rising for about 30 m to constitute the top of the mountain (for a more detailed description see Substop 7.4). At the very base, a polygenic breccia with decimetre to metre-sized clasts rests on the radiolarian cherts through an erosional contact. This breccia crops out in several places, and it is well seen in the eastern sector of the mountain (Substop 7.1).

The lowest sedimentary body (RBI) consists of a massive matrix-supported breccia (about 5 m thick). The clasts are decimetre to metre across, and they are referable both to the Inici Fm. (very angular) and to its pelagic cover (angular to rounded). The breccia thins out westwards within a distance of few tens of metres. The massive breccia is covered by a nodular pebbly mud-to siltstone also wedging out to the west (see Substop 7.3).

A second rock body (RBII), up to 6 m thick, is composed of echinoid calcarenite. Some of these calcarenite beds have downlap terminations towards the west.

The third rock-body (RBIII), which will not be examined in detail in this field-trip, is composed mainly of bedded calcarenite; more distally, several pebbly mudstone levels occur. Calcarenites bear assemblages with regular and irregular echinoids, whereas aptychi, rhychnolites and crinoids are found in pebbly-mudstone levels, in the lower beds. Towards the top, this unit is mostly made of Saccocoma-rich calcarenites. In the lower portion of the RBIII, intraformational truncations and cut-and-fill erosional contacts among beds are visible; however, the upper part of the section has beds with a regular tabular geometry. Up-section, and distally, evidence for sediment gravity flow decreases, and nodular limestone is dominant, thickening westwards.

Ammonites provide biochronological constraints for the base of the RAS; the basal breccia bears upper Kimmeridgian ammonites (Pseudowaagenia acanthomphala), but these may easily be reworked and the age of this deposit be somewhat younger.

- Lattimusa Fm. (upper Tithonian-Berriasian): Calpionellid-rich mudstone and wackestone; at the base sediments are nodular and ill-bedded, and they seem to onlap the underlying deposits; up section, beds are tabular. This unit crops out only in the western and southwestern sectors, about 500 m from the top of Monte Kumeta. Only the lower part of the formation was sampled.

**SUBSTOPS 7.1 – 7.5**

These substops lie along a W-E transect, corresponding to a distal to proximal transect of the Jurassic structure.

**Substop 7.1 - The MRI**

**A. BALDANZA, M. CHIARI & G. PARISI**

This substop illustrates the MRI unit. In this stop the unit is about 1 m thick. The radiolarian and nannoplankton biostratigraphy of the whole unit will be summarised here.

As mentioned above, the thickness of the unit is generally variable, as do the lithology, the state of preservation, and the frequency of radiolarians. In virtually all the examined sections, the radiolarian assemblages are badly preserved, with the exception of few scattered samples. Our results from collections across the whole area indicate a middle Oxfordian-early Tithonian age for the MRI. Unitary Associations alone are sometimes too low-resolution, so we needed to take into consideration biochronological data from the underlying units. In fact the radiolarian-rich samples belong either to the UAZ 8-11 (Emiluvia orea ultima and Tetratabs bulbosa), or to the UAZ 9 (Suna echinoids and Palinandromeda podbielensis) and to the UAZ 10-11 (Acanthocircus suboblongus and Emiluvia ora ultima). This interval ranges through the middle Callovian-Tithonian, but the occurrence of upper Kimmeridgian ammonites (Pseudowaagenia acanthomphala) at the base of the RAS, and of a late Callovian-middle Oxfordian belemnite assemblage at the top of the RAI (RAId) serve to better constrain its age.

The nannoplankton assemblages found in samples from this unit are characterised by *Lotharingius crucicentralis*, *L. hauffii*, *Retecapsa incompta*, *Cyclagelosphaera margerelii*, *C. deflandrei*, *C. wiedmannii*, *Watznaueria ovata*, *W. britannica*, *W. barnesae*, *W. manivitae*. *Schizosphaerella* is missing in the assemblage, which could be referred to the Oxfordian-lower Kimmeridgian, before the last occurrences of *Lotharingius crucicentralis* and *L. hauffii*. 
Substop 7.2 - The base of the RAS

M. Marino, N. Mariotti & U. Nicosia

The substop is located on the northern side of Monte Kumeta, near the forestry observation tower.

In this substop it is possible to observe a megabreccia resting directly on the uppermost beds of the MRI, here made of reddish radiolarian cherts, with alternating calcisiltite levels, about 1 cm thick. This breccia represents the base of the RAS unit, and contains a megaclast, about 1 m across, of peritidal limestone (Inici Fm.).

The breccia represents the first evidence of the restart of resedimentation processes after the quiet interval in which undisturbed cherty sediments were deposited. This indicates rejuvenation of the local sea-bottom topography, possibly linked to a tectonic phase.

Substop 7.3 - Geometries of resedimented beds

P. Di Stefano, M. Marino, N. Mariotti, U. Nicosia & M. Santantonio

A few tens of metres westwards along the northern side of the mount, abandoned quarry works allow observation of the 5 m thick lateral equivalent of the breccia seen in the previous stop. This is the lower part of lobe RBI (see above; Fig. 34). It is an heterometric and polygenic breccia, bearing clasts of the Inici Fm. (very angular) and of the RAI. The clasts are scattered and the deposit is mud rich and matrix-supported. This might indicate either a) collapse and disruption of an Inici + RAI + RAS escarpment-tract succession, followed by downslope mass flow with still unconsolidated RAS acting as a cohesive matrix, or b) freefall of clasts of Inici and of RAI from a submarine outcrop into the RAS, followed by slow creep, or c) freefall of clasts of Inici from a submarine outcrop into the RAS, followed by sliding along a detachment surface cutting a RAI + RAS succession. Interpretation c) implies conversion into a mud-supported debris flow of an originally clast-supported rockfall deposit.

Moving toward the southern side of Monte Kumeta, the second sedimentary body (RBII) of the RAS is beautifully exposed. It is a regularly bedded echinoid calcarenite. In this stop the westward downlap of these beds is clearly visible (Fig. 35).

The downlap geometry suggests lateral accretion of the echinoid-calcarenite that prograded over RBI. More to the west, slumping is observed in more mud-rich beds. Their snout and dip of the axial planes indicate transport towards western quadrants.
Substop 7.4 – Syn- and early post-depositional deformation structures

P. Di Stefano, M. Marino, N. Mariotti, U. Nicosia & M. Santantonio

A bedded nodular limestone rests on the massive breccia of RBI, showing synsedimentary or early post-sedimentary deformation, growth faults and collapse structures.

The growth faults (Fig. 36) are closely spaced (about 1 m) and occur corresponding to slight depressions of the ondulated breccia top: multiple phases of thickening and roll-over of the beds are observed associated with these faults. The fault-planes are listric and affect the nodular limestone, flattening above the underlying breccia, and utilizing plastic marls as the detachment surface. At another spot, collapsed and folded beds (Fig. 37) apparently fill the space left by creep or extensional faulting of the substrate, in the latter case being the ductile surficial response to deeper-seated brittle deformation.

Substop 7.5 - The most proximal sector of the escarpment

P. Di Stefano, M. Marino, N. Mariotti, U. Nicosia & M. Santantonio

This substop is located in the eastern sector of Monte Kumeta, not far from the mount summit, an area with several vertical strike-slip faults (striking about N50°). A chaotic complex of blocks, totalling several tens of cubic metres, is observed. Eastwards this megabreccia rests through a strong angular unconformity on the Inici Fm. that forms a west facing cliff, rising up to the top of the mountain. The cliff shows the Inici Fm. cut by neptunian dykes filled by RAI sediments, containing discohelicid gastropods suggesting a Toarcian-Aalenian age. RAI deposits also form thin veneers draping the Inici Fm. surface. This cliff represents a very steep tract of the palaeoescarpment complex, probably originated through disintegration of a severely fractured zone, causing exposure of the older fracture-filling material through detachment of basin-facing dyke walls. Westwards, the megabreccia lies on marls of late Callovian-middle Oxfordian age, dated through belemnites and calcareous nannoplankton, belonging to the RAlc.

Some blocks are made of steeply (60-70°) dipping bedded echinoid calcarenite (RBII of the RAS), representing fallen stacks of lithified material. It is interesting that these calcarenites bear themselves lithoclasts, indicating repeated phases of erosion and
mass transport (Fig. 38). The original source area of these beds is unpreserved. We interpret this megabreccia as a rockfall deposit that probably underwent some later plastic flow due to the presence of unlithified material. Due to absence of the MRI unit in this sector, the blocks fell directly onto the late Callovian-middle Oxfordian marls, which became locally squeezed by loading and were pervasively injected from below into the breccia.

**CONCLUSIONS**

The evidence of mass flow of partially to non-consolidated material, and of free-fall of the lithified peritidal substrate indicates that the present-day Monte Kumeta structure represents a tract of a Jurassic stepped escarpment partly covered by slope deposits.

RBI is mainly characterised by breccia beds, RBII by the occurrence of slumping, and RBIII (as seen in the more distal western outcrops) by intraformational truncations. This indicates that this escarpment tract became a slope prograding to the west, as seen through the up-section change from a product-accumulation facies to an upper slope facies with erosional surfaces. This is also consistent with the overall downlap geometries of individual sedimentary units (Fig. 39).

**Appendix - Kimmeridgian crinoids at Monte Kumeta**

D. CASSIOLI & R. MANNI

In the Italian geo-palaeontological literature, papers on the Mesozoic crinoids of Sicily are rare (Tommasi, 1908; Gemmellaro, 1919; Serra, 1938). These articles describe single crinoid species, so a whole crinoid association has never been described before from the Jurassic of Sicily.

The crinoids studied were collected from a level of red marls, few centimetres thick, Kimmeridgian in age, and belonging to the RAS of the Mt. Kumeta succession. This level also bears common aptychi, rhyncholites and few fragmentary belemnites.

The crinoids are very abundant, and several hundreds of columnals, brachials and cups have been collected; several species were identified, some of which new.

The species, grouped into families, are:
- Sclerocrinidae: *Gammarocrinites* sp.
- Eugeniocrinidae: *Eugeniacrinites* n. sp., *Eugeniacrinites* sp., *Lonchocrinus* spp.
- family uncertain: *Ninocrinus* n. sp.

Besides, a number of columnals of undetermined isocrinids and a centro-dorsal of a comatulid (probably of the family Solanocrinidae) were collected. Only Articulata were studied in detail.

*Phyllocrinus* and *Eugeniacrinites* are the most common genera, respectively represented by three and two species; phyllocrinids are represented by more specimens (*i.e.* *Phyllocrinus sabaudianus* is the most abundant species with over 200 cups).

All the identified genera (*Gammarocrinites, Apsidocrinus, Phyllocrinus, Eugeniacrinites* and *Lonchocrinus*) are ubiquitarian; *Ninocrinus* had previously been reported only from Central Italy.

Our association is a typical Late Jurassic cyrtocrinid Tethyan association, representing the sub-association B2 of Manni & Nicosia (1994), which is here Kimmeridgian in age. This association differs from the coeval European associations in that it includes *Ninocrinus*, but also differs from those of central Italy as...
Hoyacrinus (a genus so far reported only from the Kimmeridgian of Central Italy) is missing, while Gammarocrinites and comatulids occur instead.

As far as the palaeoecology of those forms is concerned, this association is overall characterized by rheophobic species. Some specimens of Eugeniocrinites sp. and Lonchocrinus sp. have a sloped cup axis, suggesting they were more rheophilic forms, probably indicating an environment with persisting weak currents.

Echinoids

R. Manni

Certain levels in the local Kimmeridgian-Tithonian succession bear common echinoid tests. These tests, generally deformed and crushed, are about 3-5 centimetres across. In some echinoids, test and inner cavity constitute an unicium of calcite. Rare clavate spines also occur (length 2.5 cm; width 1.1 cm), probably belonging to cidaroids.

Due to poor preservation, it is difficult to classify these echinoids. Tubercles and pores are not seen. The ambulacra, thin and curvilinear, consist of two columns of small simple plates. Probably the ambulacrum tree is depressed. The posterior ambulacra are frontally convex, while the anterior ones are frontally concave. The wide interambulacra consist of two columns of plates. The apical system is disjunct. The periproct is probably marginal, while the peristome is central.

Owing to these characters, it is possible to ascribe these echinoids to the family Disasteridae A. Gras, 1848 (order Holasteroida Durhan & Melville, 1957). The genus is probably Disaster Agassiz, 1836.

Appendix – The Early Kimmeridgian belemnite assemblage at Monte Kumeta

N. Mariotti

Many hundreds of belemnite rostra, often well preserved, were collected from a true belemnite "nest", a lens-shaped thinly laminated shale, nearly 80 cm thick, belonging to the RAId ("Red/grey nodular marls").

The belemnite assemblage is composed by the following taxa: Hibolithes hastatus Montfort, 1808, Hibolites sp. aff. H. beyrichi Oppel, 1857, Belemnopsis latesulcatus (Voltz) in Thurmann, 1832, Belemnopsis sp. 1, Duvalia monsalvensis (Gillieron, 1873), D. neyrvensis (Favre, 1876), D. didayana (D’Orbigny, 1842), D. dumortieri (Oppel, 1865), Rhopaloteuthis sauvanausa (D’Orbigny, 1842), R. argoviana (Mayer, 1863), Pseudobelus coquandus (D’Orbigny, 1842), Rhopaloteuthis sp. 1.

The assemblage is virtually the same in every level of the shale so it may have undergone some kind of in situ reworking.

The most significant forms are Belemnopsis latesulcatus, Rhopaloteuthis sauvanausa and R. argoviana, indicating a late Callovian-middle Oxfordian age.

The belemnite-bearing levels rest above a reddish calcilutite whose top is particularly rich in ammonites occurring in stacked Mn-coated condensation horizons. The ammonites collected from the topmost level indicate the middle Callovian (Anceps Zone) (see Stop 6). Data provided by radiolarian and calcareous nannoplankton stratigraphy in the belemnite beds and in the overlying
“Membro Intermedio Radiolaritico” unit produced the same chronostratigraphic results (MARIOTTI et alii, 2001). The resulting data fit well with biostratigraphical data related to the belemnites that range from the late Callovian to middle Oxfordian.

All the belemnite rostra are parallel to bedding and frequently iso-oriented, sometimes forming exceptionally rich levels. The fauna also includes a diverse assemblage with foraminifers, rhyololites (many forms of the genera Hadrocheilus, Leptocheilus and Gonatocheilus), aptychi (Lamellaaptyschi and Laevaptyschi), crinoids (roots, columnar plates and Phyloecriniditid calycyes), fragmentary irregular echinoids (large plates) and shark teeth.

It is possible that the exceptionally rich fossiliferous nature of the belemnite bed was a product of object sorting that occurred with some kind of gravity flow. Most of the belemnites are fragmentary but it is often possible to assemble the fragmented rostra, even those very long and slender. This suggests en masse transport, probably over a fairly short distance.

Several rostra were colonised by corals, and three (and in few cases four) corals are often found attached to a single rostrum, demonstrating the presence of an environment suitable for these organisms. The coral assemblage is probably oligotypic, as it consists of several specimens belonging only to two taxa. Their morphology falls into two categories: cone-shaped and discoidal.

Settling behaviour can be evaluated considering that frequently larger corals grew beyond the belemnite diameter and that corals on the same rostrum show different growth stages with the same orientation. We believe that belemnites were lying flat on a muddy surface along the non-depositional escarpment. These were very probably the only hard surfaces emerging from the mud and thus were obvious sites for colonization by coral larvae that must have been present in a large number in the sea water. These rostra must have remained stable for quite a while, and the period of starved sedimentation must also have lasted a time long enough to allow the growth of the corals.

It is worth mentioning that solitary and colonial corals have been recorded in Central Apennines (NICOSIA & PALLINI, 1977; MARIOTTI et alii, 1979; SANTANTONIO et alii, 1996), from deposits sedimented on and along the flanks of intra basinal highs.

It is also worth noting that a comparable palaeoecologic interpretation was offered for rostra, heavily bored by Acrotoracic cirripedes, from structural high successions in Central Apennines (MARIOTTI & MATTEUCCI, 1989; MARIOTTI, in press). In our material from Sicily, however, the rostra are never bioeroded.

Several rostra are coated by a black film, similar to the Mn-coated horizons of the underlying calcareous unit. Whenever these “black” rostra are colonized by corals, the corals themselves are not coated. This indicates that when the rostra were colonized, they had already experienced a history of burial, early lithification, coating and reexhumation.

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Post-Symposium Field Trip B3
(19-21 September 2002)

THE PALEONTOLOGICAL MONUMENT OF MONTE NERONE
(UMBRIA MARCHE APENNINES)

Scientific Coordinator

Stefano Cresta

Contributors

FOREWORD

Monte Nerone area has, since its first geological description, been studied by many geologists from all part of the world. The rich geological heritage of Monte Nerone, has made the area one of the most important areas in Central Apennines for geological teaching and research. This famous marine Mesozoic locality is also a scenic area in the central Apennines. Although the scenery of Monte Nerone is a result of geologic processes, the geology along the road and trails was until few years ago an enigma to most visitors, namely the non-researcher ones, and to the in-habitants. The Piobbico Civic Museum started in 1997, under the writer direction, a geoconservation programme “Neroniade” both to remedied the situation as to manage the area under the institution of a Regional Geological Monument.

The present guide and the excursion would not have been possible without the joint effort and the enthusiastic work of several young researchers and the generous support of the Piobbico Municipality.

Stefano Cresta
INTRODUCTION

S. Cresta

The Umbria Marche arcuate fold belt is located in the Northern Apennines in between the front of the Trasimeno-Falterona-Cervarola nappe and the Pliocene Adriatic foredeep. From a lithostratigraphic point of view, it is usually described in terms of three superimposed lithotectonic groups. From bottom to top they include: the basement, the Triassic evaporites, the Mesozoic-Tertiary sedimentary cover. The basement has been drilled in boreholes located at the internal boundary of the Umbria Marche fold belt, but does not outcrop anywhere in the fold belt. The Triassic evaporites do not outcrop either; they were drilled by boreholes, showing that the average thickness in the core of the anticlines is about 2000 metres. The pre-deformation thickness is smaller and it has been estimated as about 1000 metres (Lavecchia & Palli, 1980). Usually the Triassic evaporites are considered as the major decollement level between the cover and the basement. The sedimentary cover consists in its lower part of neritic and pelagic limestones of Early Jurassic to Palaeogene age (1300-2000 metres) and in its upper part of terrigenous siliciclastic flysch-type deposits of Neogene age (1500-2000 metres). From a structural point of view, the Mesozoic-Palaeogene sedimentary sequence can be regarded as a 1st order litho-structural unit embedded between two incompetent less viscous levels, the floor being the Triassic evaporites and the roof being the Miocene flysch-like deposits. During the Late Miocene-Early Pliocene this sequence underwent an intensive shortening, that gave rise to the Umbria-Marche fold and thrust belt. This belt consists of an alternance of large anticlines, with average wavelengths of 4-5 km, overturned eastward on adjacent tight asymmetric synclines, with average wavelengths of 1-2 km. The geometry of the Umbria-marche fold belt is the result of a two-stage deformation. During a first stage (Late Miocene), the Mesozoic-Palaeogene sedimentary sequence, embedded between the Triassic evaporites and the Miocene flysch-like deposits, became largely detached from the basement, was shortened progressively by a combination of buckling and more or less homogeneous strain. During the Early Pliocene the area underwent further shortening and the pre-existing features were transported eastward by the low-angle compressional and transpressional shear planes.

The Jurassic deposits of the Monte Nerone area (Fig 1) record the rifting and the drowning of a part of the vast, Mediterranean Late triassic peritidal carbonate-evaporitic platform (Dercourt et alii, 1993). The post-drowning submarine rift topography comprised basins and fault-bounded swells, i.e. the Pelagic Carbonate Platforms (= PCPs). The PCPs are defined as “intrabasinal highs on continental crust, bordered by synsedimentary faults and [...] sites of condensed and discontinuous pelagic carbonate sedimentation over drowned fragments of a former peritidal carbonate platform” (Santantonio, 1994, p. 122). Across the whole Umbria-Marche area a remarkable hiatus, lasting from the early Bajocian to the late early Kimmeridgian, is recorded on the top of PCPs within pelagic cephalopod-rich, nodular limestones of the Bugarone formation. The time-duration of this hiatus spans from about 22 Ma (Odin, 1994) to about 19 Ma (Gradstein et alii, 1994). In the basins, where the sedimentation was continuous, it is possible to observe a drop in the biotic diversity beginning in the early Bajocian and lasting the entire time span of the hiatus (Bartolini & Cecca, 1999).

![Fig. 1 – Location map of M. Nerone Paleontological Monument.](image)

LITHOSTRATIGRAPHIC SETTING

S. Cresta

In order to prepare the reader for the sketches and figures contained in the descriptions of the field trips, we present here the descriptions, summarized from the literature, of all the units that make up the Umbria-Marche Jurassic succession. Only the bio and chronostratigraphic features of the sections chosen as examples will be discussed in the field trip notes, while the general characteristics of the lithostratigraphic units will not.

Calcare Massiccio (Hettangian-Sinemurian) - In the Hettangian a carbonate platform with oolitic bar, lagoonal and tidal flat facies developed, above which the poorly stratified, massive carbonate sediments of this unit, consisting of alternating laminated intervals, paleosoils, stromatolitic mats, and oolite bars, were deposited. The
Fig. 2 - Itinerary of the field-trip on representative sections for Jurassic-Lower Cretaceous Ammonite biostratigraphy.

Stop 1 - Bajocian and Kimmeridgian cephalopod limestones (F. Pisciarello section)
Stop 2 - Dogger Malm nodular limestones (Bugarone quarry section)
Stop 3 - Jurassic ammoniferous beds (Infernaccio section)
Stop 4 - Aalenian ammonite biostratigraphy (G. Cerbara section)
Stop 5 - Lotharingian cephalopod limestones (Candigliano section)
Stop 6 - Barremian-Aptian boundary proposed GSSP (Gorgo a Cerbara section)
Stop 7 - Hauterivian-Barremian boundary and ammonites (M. te Petrov sections)
Stop 8 - Toarcian ammonites and biostratigraphy (Lecceti section)
Stop 9 - Lotharingian-Carixian boundary and ammonite biostratigraphy (Bosso River section)
average thickness of this unit is 500-700 m.

_Corniola_ (Sinemurian-earliest Toarcian) -- It typically consists of regularly bedded grey to nutty brown micritic limestones; bed thickness ranges from centimeters to decimeters. Texturally it is generally a mudstone, more rarely a wackestone. Chert is common, and the upper part bears argillaceous interbeds. Since these sediments were deposited in a basin that was still evolving morphologically, turbidites, slumps and slides are common, most notably in the lower part, which can also host megabreccias near basin-margins. The thickness of the unit varies considerably, ranging from ~300 m in basins to 10-20 metres on PCP-tops.

_Rosso Ammonitico_ (early Toarcian p.p. – late Toarcian p.p.) -- It consists of nodular limestones and calcareous marls. The nodules are irregularly shaped, often elongate parallel to the bedding, with dimensions ranging from one to several centimeters, and encased in a clayey-marly matrix. The sediments are greyish-yellowish to red and generally contain rich ammonite assemblages. Graded and laminated turbidites, slumps and pebbly mudstones (often made up of resedimented early diagenetic nodules) can be common in the thicker sections. The thickness of the unit varies from ~50 m to ~7 m on PCP-tops.

_Calcari e Marne a Posidonia_ (late Toarcian p.p. - ?Bathonian) -- This unit is made of “filaments” rich calcareous mudstones and, more rarely, wackestones. Its lower part is nodular, with interbedded resedimented deposits and slumps. The base has been set just below the point where predominately calcareous sedimentation resumed, following the period of dominantly clayey-marly deposition, while upsection sediments become increasingly chert-rich, gradually changing into the next unit. The thickness of this formation amounts to several tens of metres.

_Calcari Diasprigni_ (?Callovian – late Kimmeridgian) -- They consist of radiolarian rich sediments; their skeletons, dissolved during diagenesis, supplied the silica for cherts in lenses, nodules and continuous layers. In the upper part of the unit chert is of the characteristic pinch and swell type, and the calcareous component is virtually null. It is at most some tens of metres thick. This unit sometimes forms intercalations in the Bugarone Formation, in wedges up to 6 m thick. Upsection this unit grades into cherty limestone in thin beds with abundant remains of the crinoid _Saccocoma_ and of aptychi, locally forming graded and/or laminated beds, which can be mapped separately (up to ~20 m).

_Bugarone_ (late Toarcian p.p. – Tithonian) – This is a typical condensed pelagic platform unit. It consists of bioturbated, more or less dolomitized and locally nodular limestones and marly limestones. It is 16 metres thick in the type section at the Bugarone quarry (Monte Nerone). Based on ammonites, a major stratigraphic gap was identified, rendering its subdivision into two units necessary. The lower one, named _inferiore_, (average thickness 12 meters), falls between the _Dumortieria meneghinii_ (late Toarcian) and _Stephanoceras humphriesianum_ (early Bajocian) Zones. The upper one, named _superiore_ (average thickness 3 metres), falls between the _Cruscolliceras divisum_ (early Kimmeridgian) and _Simoceras volanense_ (early Tithonian) Zones. On pelagic carbonate platforms the _Calcari diasprigni_ Fm. can locally occur intercalated between the two units (see above). A _Micritic Cephalopod-rich_ lithofacies has been distinguished at Fosso Pisciarello (stop 1.1.) and Gorgo a Cerbara (stop 2.4). The rocks belonging to it are neither nodular nor dolomitized, and contain abundant ammonites, aptychi, belemnites and fossil corals. This lithofacies is generally very thin, because of extreme sedimentary condensation.

**BIOSTRATIGRAPHIC SETTING**

_S. Cresta_

The nearly ideal outcrop of the Jurassic sequence in the Monte Nerone area has over the last twenty years encouraged the biostratigraphic study of ammonite associations. The richly diverse associations favour their correlation on a regional to Tethyan scale, a circle in which Monte Nerone can be considered a Jurassic key-point. The biostratigraphic units identified here define the lower Sinemurian-Bajocian and lower Kimmeridgian _p.p._-Tithonian interval. Upper Bajocian-lower Kimmeridgian _p.p._ assemblages have never been recorded at Monte Nerone, as well as across the whole Umbria-Marche area.

While detailed studies on ammonite biostratigraphy have been carried out in many Jurassic outcrops in the Umbria-Marche region, the Monte Nerone area is the only one where all the ammonite zones recognisable in the Sinemurian-Tithonian interval occur over an area less than ten square km’s wide. This is the reason why it has been suggested as a key locality for biostratigraphy within the Mediterranean Province.

The paleogeographic framework arranges the Jurassic sections to be examined into pelagic carbonate platform (PCP) and basin sequences; the ammonite biostratigraphy of the middle Pliensbachian-Aalenian interval, represented in both paleoenvironments, shows the same bioevent sequence. The Sinemurian of the PCP sequences is in a shallow water facies (Calcare Massiccio) generally with no ammonites, with the notable exceptions of the Pieia and Gorgo a Cerbara outcrops (Cecca et alii, 1987), in which, however, the Liassic depositional geometry is peculiar. The upper Aalenian-lower Bajocian and Kimmeridgian-Tithonian sequence bears ammonites only in the PCP areas.
Fig. 3 – Schematic representation of the Toarcian - Kimmeridgian interval in the Fosso Pisciarello section. The following biostratigraphic interpretation is given:
Bed 1, Geczyceras speciosum Zone;
Bed 2, Dumortieria meneghinii Zone;
Bed 3, Leioceras opalinum Zone;
Beds 4-6, barren;
Beds 7-8, Otoites sauzei Zone;
Bed 9a, Otoites sauzei Zone;
Bed 9b, Stephanoceras humphriesianum Zone with reworked ammonites from O. sauzei Zone (E. greppinii MAUBEG, E. contrahens BUCKMAN, Skirroceras sp.);
Bed 10, reworking level with O. sauzei and S. humphriesianum Zone ammonites reeclaborated shells (Emileia spp., Lokuticeras tenuicostatum (Hochstetter), Stephanoceras pyritosum (QUENSTEDT), Skirroceras n. sp. aff. Dolichoechus BUCKMAN, Stemmatoceras frechi RENZ);
Bed 11, Kimmeridgian condensed cephalopod limestone (for details see text).

Fig. 4 – Kimmeridgian ammonites from Bed 11 of Fosso Pisciarello section: A, Taramelliceras (Metahaploceras) strombecki (OPPEL), x 0,8; B, Taramelliceras trachinotum (OPPEL), x 0,8.
The biostratigraphic study is based upon the sections sampled in the Bosso zone (basin), Picia-quarry (slope), Bugarone quarry (PCP), Pian del Sasso (PCP), Ranchetti quarry (PCP), Collungo (PCP), Pisciarello stream (PCP-margin), Campo al Bello (PCP), Ranchi (PCP-upper slope), Infernaccio (PCP-upper slope), Presale-stream (PCP), Gorgo a Cerbara (basin). The reference area for the lower and middle-upper Lias (Ariettites bucklandi - Hildaites levisoni Zones) is the basin sequence exposed in the Bosso River valley (River, Stirpeto, Eremita, Lecceti); for the upper Lias and lower Dogger (Hildoceras bifrons - Stephanoceras humphriestianum Zones) it is the upper slope sequence between Monte Nerone (PCP) and Gorgo a Cerbara (basin); for the Malm (Crussoliceras divisum - Durangites Zones) it is the Monte Nerone PCP sequence. The biostratigraphic considerations will however take into account all the outcrops of the intervals considered, mentioned in the text as auxiliary sections.

The Standard Ammonite Zonation adopted as reference is the one proposed by the Groupe Français d'étude du Jurassique (1997) because it updates the Tethyan framework and at the same time also gives an account of the surveyed peculiarities in the different paleogeographic dominions.

STOP 1 - BAJOCIAN AND KIMMERIDGIAN CEPHALOPOD MICRITIC LIMESTONES (FOSSO PISCIARELLO SECTION)
(see also CECCA et alii, 1990, p.106)

D. DI PIETRO & D. MARINUCCI

In this section the sampled levels show the smallest thicknesses caused by the high sedimentary and stratigraphic condensation.

Above the lower Bajocian limestones (Fig. 3) we find a first layer (30-40 cm thick), divided in two by a discontinuity surface.

In the lower part the following species have been recognized: Taramellliceras (T.) trachinotum (OPPEL), T. (Metahaploceras) gr. strombecki (OPPEL), Orthaspidoceras gr. uhlandi (OPPEL), O. Garibaldi (GEMMELLARO), Lithacosphinctes aff. evolutum (QUENSTEDT), Nebrodites (Mesosimoceras) beniamus (CATULLO in CANAVARI). This assemblage can be referred to the Divisum Zone for the presence of O. uhlandi and T. trachinotum, even if the presence of numerous T. (M.) strombecki specimens (Fig. 4), hardly ever so plentiful in the Apennines, could mean that in the first level there is a condensation of the Taramelllicerasc (Metahaploceras) strombecki and Crussoliceras divisum Zones.

In the upper part the following species have been recognized: Taramellliceras (T.) gr. compsum (OPPEL), T. (T.) pugioiodes (CANAVARI), Hemihaploceras (Zittellicerasc) piccinini (ZITTEL), Aspidoceras acanthicum (OPPEL), Aspidoceras longispinum (SOWERBY), Orthaspidoceras ziegleri CHECA, Pseudowaagenia acanthophala (ZITTEL), Nebrodites (N.) peltoideus (GEMMELLARO), Hybonoticeras beckeri (NEUMAYR), and H. pressulum (NEUMAYR).

The assemblage as a whole is ascribable to the upper Kimmeridgian, Hybonoticeras beckeri Zone, even if the presence of N. peltoideus suggests that the Taramelllicerasc compsum Zone is condensed in this layer.

The second layer (from 30 to 50 cm), in which a remarkable sedimentary and stratigraphic condensation is detected, contains ammonites belonging to the lower Tithonian, Hybonoticeras hybonotum, Semiformiceras darwini, Semiformiceras semifoma and Semiformiceras fallauxi Zones. We point out the presence of Glochicerasc (Paralingulaticeras) lithographicum (OPPEL), Taramelllicerasc (Fontannesielia) valentinum (FONTANNES), Semiformiceras darwini (NEUMAYR), S. semifoma (OPPEL) Pseudolissoceras rasile (ZITTEL), P. bavaricum BARTHEL, Aspidoceras rafaeli (OPPEL), Virgatosimoceras gr. albertinum (CATULLO), V. gr. micrum OLRIZ, Simoceras aesinense MENEGHINI, S. biruncinatum (QUENSTEDT), S. admirandum ZITTEL, Pseudodiscosphinctes geron (ZITTEL), P. rhodaniforme OLRIZ, P. aff. chalmasi (KILIAN).

The next bed is characterized by an extremely irregular thickness (20-40 cm) and by many discontinuity surfaces, crossing each other and thus isolating lenses differing in fossiliferous content and degree of dolomitization. The ammonites are abundant, sometimes forming “lumachella” deposits, and indicate the upper Tithonian and the lowermost Berriasian. Because of severe condensation, the chronostratigraphic signal had to be cross-checked through the study of Calpionellids assemblages. At 10 cm from the base of the layer, assemblages referable to Calpionella Zone (sensu ALLEMMANN et alii, 1971), Calpionella alpina Subzone (sensu REMANE et alii, 1986) were found, indicating the lowermost Berriasian.

Afterwards, the stratification becomes ill-defined, while the dolomitization is more and more intense. From this point, the sampling went only one metre on. The boundary between the Remaniella and Calpionella elliptica Subzones can be placed at about 50 cm from the base of this last part of the section, while the boundary between the Calpionella and Calpionellopsis Zones is at about 80 cm from the base. In correspondence of this boundary we found the following ammonites species:
**Jabronella aff. paquieri** (SIMIONESCU), *Jabronella* sp., *Spiticeras* sp.

**STOP 2 – LIAS-DOGGER NODULAR LIMESTONES (BUGARONE QUARRY SECTION)**

S. CRESTA, D. DI PIETRO & A. GRIPOPO

**LITHOLOGY**

The Bugarone Formation is a condensed, ammonite-bearing sequence which is found on pelagic platforms throughout the Umbria-Marche Apennines. In the field, it shows a striking rhythmicity, with evident hierarchical bedding patterns in the namesake quarry walls of Monte Nerone (Fig. 5).

The limestones in this sequence are biomicrites of pinkish-brownish color, separated by planar partitions of bluish-gray clay, but more massive and more brownish strata peppered with dolomite rhombs also occur. The stratigraphic sketch given here bears only limited resemblance to the rhythmic patterns exposed on the quarry wall. Sawed surfaces on quarried slabs stacked in the quarry show an incipient nodularity, with creamy, more calcareous nodules in a matrix slightly more marly, greenish to buff, and seemingly bioturbated. The faunal content includes “filaments” representing cross-sections of bivalves of the *Bositra* and *Lentilla* types, early globigerinacean foraminifera and ammonites.

**AMMONITE BIOSTRATIGRAPHY**

Through the analysis of the identified species in the sampled sections it has been possible to recognise, mainly among the Hammatoceratids, some bioevents that allowed the definition of local biozones correlated to the standard scale (*P. planinsigne, E. sutneri, E. fallifax, E. intermedius, P. klimakomphalum, R. longalvum, E. amplectens* Biozones, CRESTA, 1996). We must add that it has not been possible, up to now, to define with certainty to which extent the Standard Zones, including their subzones and biohorizons, are actually represented in the Apenninic Aalenian. Due to these uncertainties we conservatively chose to make use of the classical Stage subdivisions (*Leioceras opalinum, Ludwigia murchisonae, Graphoceras concavum* Zones).

**Dumortieria meneghinii** Zone - To this Unit we refer 9 beds, 57 cm thick, with 2 fossiliferous levels (beds...
3 and 7). In this Unit the ammonite fauna is characterized by the presence of *Dumortieria meneghinii* (Haug in Zittel) and *D. taramelli* Fischer; among the Hammatoceratids, besides the persistence of *Geczyceras personatum* (Merla), *Neronia elaphus* (Merla), the first representative of Erycites, appears.

**Pleydellia aalensis Zone** - To this Unit we refer 14 beds, 133 cm thick, with 4 fossiliferous levels (beds 10, 11, 14, 19). The ammonite fauna is dominated by platycones belonging to the genera *Pleydellia* and *Cottewoldia*, in the lower and middle parts of the unit (Pleydellia macra and Pleydellia aalensis Subzones). In the upper part (*Pleydellia buckmani* Subzone) the fauna is generally very scarce and is dominated by serpenticones of the genus *Catulloceras* Gemmellaro along with Phylloceratina.

**Leioceras opalinum Zone** - To this Unit we refer 26 beds, 217 cm thick, with 5 fossiliferous levels (beds 24, 28, 33, 41, 44). In the association, whose characteristic element is *Tmetoceras scissum* (Benecke), we identified *Leioceras* (Cypholioceras) *lineatum* (Buckman), *Leioceras opalinum* (Reinecke), *Leioceras comptum* (Reinecke), Planammatoceras gr. planinsigne (Vacek), *Erycites sutleri* Gemmellaro, and *E. fallifax* Arkell.

**Ludwigia murchisonae Zone** - To this Unit we refer 35 beds, 337 cm thick, with 9 fossiliferous levels (beds 48, 50, 51, 55, 61, 62b, 62c, 62e, 63). The levels indicated by the old Authors under the name of *Erycites fallax* beds were referred to this Unit. The Zone in its lower part (*Ludwigia haugi* and Ludwigia murchisonae Subzones) is characterized by *Erycites intermedius* (Hantken in Prinz), Abbasioides modestus (Vacek), *T. scissum* (Benecke), *T. regleyi* (Dumortier), Planammatoceras tenuinsigne (Vacek), Csernyeiceras subaspoidoides (Vacek), Alocyloceras opineum (Benecke), Ancilioceras opalinoides (Mayer), Ludwigia haugi Douville, and the bloom of *E. fallifax* Arkell. In the upper part (*Bradfordia bradfordensis Subzone*) the association becomes poor and its definition is based upon the presence of *Pseudaptetoceras klimakomphalum* (Vacek) and of the earliest Haplocerataceae (*Praestrigites* sp.).

**Graphoceras concavum Zone** - To this Unit we refer 11 beds, 213 cm thick, with 3 fossiliferous levels (beds 73, 82, 83). The Zone is recognizable through the appearance of *Riccardiceras longualvim* (Vacek) and Abbasites sp. to which, in the upper levels, Euaptetoceras ampectens Buckman, *E. amaltheiforme* (Vacek), *Riccardiceras telegdirothi* (Geczy), *Haplopleuroceras subspinatum* Buckman, Euhopllocerases modestum Buckman, Graphoceras limitatum (Buckman), G. gr. decorum Buckman, Bradfordia inclusa Buckman, Praestrigites deltetus Buckman are associated. The same association characterises, in the Bajocian GSSP of Cabo Mondego, the terminal part of the *Graphoceras concavum* Zone (*Graphoceras limitatum* Subzone; *Euaptetoceras ampectens* Horizon).

**BEDDING**

Our attention was attracted by the hierarchical bedding patterns in the sequence (Fig. 6). Major beds, 24-35 cm thick, are generally separated by one or two beds a few cm thick. We have numbered these “major bedding units” up to number 26. The top of unit 25 lies 7.1 m above the base; above the top of unit 26 the bedding patterns become less regular, and were not included in our study.

A number of units deviate from this pattern: Unit 9, 10 and 11 show no thin interbeds and are separated only by faint bedding planes; Unit 12 is an “ugly duckling” thicker than most interbeds yet only half as thick as the other major bedding units, and bounded by clayey layers in which traces of very thin interbeds are visible. Units 18 and 19 were assigned to a completely homogenized unit of twice average thickness. Units 20 and 21 lack a central major bed, each consisting of 4-5 “interbeds”. Complete amalgamations of various units have prevented us from carrying our analysis beyond unit 26.

Such bedding patterns are not uncommon in the deep-water marls of the Cretaceous, where they occur in stratigraphic segments showing Milankovitch rhythmicity. There one can follow gradations: low-carbonate/high-carbonate precession couplets are generally grouped in sets of five into eccentricity bundles, in which the lowest and highest are thinnest and the middle ones thicker.

In the more calcareous Barremian Maiolica Limestone and the Cenomanian Scaglia Bianca limestone the shaly parts become reduced to bedding planes, and the middle beds in the bundle commonly become amalgamated by bioturbation. By analogy, it would seem: that units 20 and 21 of this section represent such eccentricity bundles of precessional couplets; that in most units the central couplets have been lost by bioturbation; that in units 9-10 all precessional traces have been lost and the eccentricity cycles have become nearly amalgamated; and that in units 18-19 such amalgamation has occurred at the eccentricity level as well.

A first analysis of these rhythms allowed to estimate the duration of the section in ~3.3 million years for a time span that extends from the late Toarcian to the late Aalenian.

A second, more complete image analysis study (Grillo et al., in prep.) allowed a cyclostratigraphic reconstruction of the lower part of the section, thus bracketing the lower and middle Aalenian.

Computer-processed scans of outcrop photographs (for the methodology, see Grillo and Fischer, in prep.) quantified the rhythms, and frequency analysis of the treated data provided consistent power spectra, showing
Fig. 6 – Upper Toarcian-Aalenian schematic log of Bugarone Quarry wall.
the full hierarchy of Milankovitch frequencies.

In particular, a tentative identification of the main bedding cycle with the ca. 100 ka eccentricity period yielded spectra in which all of the consistent peaks correspond to orbital periods as expected for the Jurassic, i.e. with obliquity and precession shorter than present values.

Owing to the scarcity of radiometrically datable strata, the Jurassic stages have long been assigned pragmatic values that assumed essentially equal zonal duration. With this approach, it is possible to estimate the mean accumulation rate of this sequence in 2.9 Bubnoff, a reasonable figure for such a condensed section. Counting eccentricity cycles, it is possible to obtain a zonal duration of about 2,200 ka for the lower and middle Aalenian, while planned further analysis would eventually make it possible to estimate the duration of the whole Aalenian stage.

STOP 3 – JURASSIC AMMONITIFEROUS BEDS IN THE INFERNACCIO SECTION

S. Cresta, D. Di Pietro & D. Marinucci

The section is exposed on the right side of the Infernaccio valley, on the northern slope of Monte Nerone, at an altitude of 1148 m, and can be reached by car along the road taking to the mount top from the north.

The Jurassic sequence is about 30 metres thick; for a detailed description see CECCA et alii (1990); figure 7 shows the sampled lower Bajocian beds, 5 metres thick, also sketched in figure 8. In order to compare the description by Cresta et alii (1995), the progressive numbering of the levels given by the Authors was maintained; our new excavation, on the other hand, stressed further subdivisions to be made within some of these levels, making an integration of the numbering necessary.

Early Bajocian

The sequence has rather uniform lithology, ranging from limestone to severely bioturbated dolomitized limestone. Dolomitization mainly affects the matrix, more rarely the filling of the fossils and burrows, and its intensity generally decreases from the top to the bottom of the sequence.

The ammonites are preserved again as inner moulds (Fig. 9); in some layers (53a-g) they are sometimes deformed by sliding along their horizontal axes and their position is always parallel or subparallel to the bedding. The collected specimens have variable size (4 to 30 cm) and the association in each individual layer does not show any evident signs of re-elaboration (inverse geopetal structures, moulds with eroded or striped-by-dragging surfaces). Most of the specimens have a body chamber and in many of them the peristome is preserved (Stephanoceratidae and Otoitidae).

The faunal content of each level is summarized as follows:

Level 38 (10 cm) - Docidoceras sp. (2), Eudmetoceras cf. eudimetum BUCKMAN (1), Euapetoceras amaltheiforme (VACEK) (2).
Level 39 (15 cm) - Euapetoceras amaltheiforme (VACEK) (1), Phylloceras sp (1).
Level 40 (20 cm) - Docidoceras gr. limatum POMPECKJ (3), Docidoceras teleidirothi (GECZY)(1), Euapetoceras amaltheiforme (VACEK) (8), Haplopleuroceras subspinatum BUCKMAN (1), (?) Hyperlioceras sp. (1), Praestrigites deltoitus BUCKMAN (3), Eudmetoceras acanthodes BUCKMAN (1), Holcophylloceras sp. (2), Phylloceras sp. (1), Lytoceras sp. (1).
Level 41 (a10, b15, c10 cm) - From bed b: Docidoceras zemistephanoides GECZY (1), Strigoceras sp. (1).
Level 42 (a5, b20 cm) - From bed b: Bradfordia inclusa BUCKMAN (1), Docidoceras gr. limatum POMPECKJ (1), Holcophylloceras sp (1).
Level 43 (a10, b10, c10, d10, e15 cm) - From bed c: Shirbuirnia stephani BUCKMAN (1), Shirbuirnia sp. (1), Strigoceras sp. (1); from bed e: Fissilobiceras sp. (2).
Level 44 (a30, b15, c10 cm) - From bed b: Fissilobiceras fissilobatum (WAAGEN) (1), Mollistephanus sp. (1).
Level 45 (a10, b5, c15 cm) - From bed a: Papilliceras arenatum BUCKMAN (2), Phylloceras sp. (1), Calliphylloceras sp.(1), Holcophylloceras sp.(1).
Level 46 (a10, b5 cm) – No ammonites found.
Level 47 (20 cm) - Kumatostephanus paucicostae FALLOT et BLANCHET (1), Kumastephanus sp. (2), Skirroceras baylei (OPPEL) (1), Skirroceras sp. (1), Strigoceras sp. (1), Hebetoxytes incongruens BUCKMAN (1), Emileia gr. contrahens BUCKMAN (3), Emileia bulligera BUCKMAN (1), Emileia sp. (2), Otoites delicatus BUCKMAN (1), Otoites contractus (SOWERBY) (4), Sonninidae gen. ind. sp. ind. (2), Phylloceras sp. (3), Holcophylloceras sp. (6), Partschiceras sp. (1), Megalytoceras sp. (2).
Level 48 (a15, b5, c10 cm) - From bed a: Skirroceras baylei (OPPEL) (11), Kumastephanus sp. (1), Emileia contrahens BUCKMAN (2), Otoites sp. (1), (?) Witchellia sp. (1), Phylloceras sp. (6), Calliphylloceras sp. (1), Holcophylloceras sp. (12), Lytoceras sp. (3), Nautiloida ind. (1).
Level 49 (a10, b10, c10 cm) - No ammonites found.
Level 50 (a5, b5, c10, d5 cm) - No ammonites found.
Fig. 7 - Jurassic beds of the Infermaccio section: A) Calcare massiccio Fm.; B) Corniola Fm.; C) Lower Bugarone Fm. (Upper Toarcian-Aalenian beds); D) Lower Bugarone Fm. (Lower Bajocian beds); E) Calcari diasprigni Fm.; F) Upper Bugarone Fm. (Kimmeridgian-Lower Tithonian beds).

Level 51 (15 cm) - Labyrinthoceras meniscum (WAAGEN) (2).

Level 52 (a10, b15 cm) - No ammonites found.

Level 53 (a5, b5, c8, d8, e5, f10, g5, h5 cm) - From bed c: Stephanoceras tenuicoastatum HOCHSTETTER (3), Skirroceras macrum (QUENSTEDT) (1), Skirroceras dolichoecus (BUCKMAN) (1), Phylloceras sp. (1). From bed d: Stephanoceras scalare WEISERT (1), Stephanoceras tenuicoastatum HOCHSTETTER (1), Stephanoceras pyritosum (QUENSTEDT) (1), S. tenuicoastatum sp. (9), Skirroceras sp. (4); From bed h: Stephanoceras sp. (3), Stemmatoceras frechi RENZ (4), Lytoceras sp (1), Phylloceras sp. (2), Holcophylloceras sp. (2).

Level 54 (a15, b10, c5 cm) - From bed b: Phylloceras sp. (3).

Level 55 (a15, b5 cm) - From bed a: Phylloceras sp. (1).

Kimmeridgian-lower Tithonian

Above a level about 4 metres thick of radiolarian-rich limestones rests a non-fossiliferous calcareous bed (20 cm), followed in turn by a 1 m thick bed referred to the upper Kimmeridgian, Hybonoticeras beckeri Zone, for the presence of Pseudowaagenia acanthomphala (ZITTEL) and Lithacoceras (Virgalithacoceras) aff. 'fruticans' (SCHNEID). The lower Tithonian is represented by 8 beds (fig. 10) in which the following species were sampled (CECCA et alii, 1990, p. 110) (Fig. 11):

Bed 3 (30 cm, Hybonoticeras hybonotum Zone) – Protetragonites quadrirsulcatus (D'ORBIGNY), Hybonoticeras hybonotum (OPPEL), Glochiceras (Paralingulaticeras) lithographicum (OPPEL).

Bed 4 (20 cm, Semiformiceras darwini Zone) – Protetragonites quadrirsulcatus (D'ORBIGNY), Phylloceras serum (OPPEL), Ptychophylloceras ptychoicum (QUENSTEDT), Lytoceras sulie (OPPEL), Haploceras (H.) carachteis s.l. (M/m)(ZEUSCHNER), Pseudolissoeeras rasile (ZITTEL), Semiformiceras darwini (NEUMAYR), S. darwini morf. beticum OLORIZ, Scheireria neoburgensis (OPPEL), Virgatosimoceras gr. albertinum (CATULLO), V. micrum OLORIZ, Simoceras praeecursor SANTANTONIO, Lithacoceras gr. lemenci (PILLET & FROMENTEL), "Subplanitoides" pseudocontiguus DONZE & ENAY, Dorsoplanitoides sp.

Bed 8 (30 cm, *Semiformiceras fallauxi* Zone) – *Semiformiceras fallauxi* (OPPEL).

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**STOP 4 – AALENIAN AMMONITE BIOSTRATIGRAPHY IN THE GORGO A CERBARA SECTION**

S. CRESTA & S. URETA

The biostratigraphic study of the Toarcian-Aalenian boundary in the Gorgo a Cerbara section started in the eighties (KALIN & URETA, 1987; CRESTA, 1988) and has been continuous through the years (CECCA et alii, 1990; CRESTA et alii, 1995).

The ammonite assemblages of the Lias-Dogger boundary, sampled in the Gorgo a Cerbara section, are typical of the Apenninic region, within the Mediterranean province. Moreover, unlike coeval Mediterranean outcrops (San Vigilio and Monte Erice), built up by few decimetreally highly condensed levels, this 8 m thick succession provides a somewhat “expanded” picture of lower-middle Aalenian biostratigraphy. For systematic study, 336 specimens typical of the *Dumortieria meneghinii* (upper Toarcian)-*Ludwigia murchisonae* (middle Aalenian) interval were identified. 167 of them belong to the suborder Ammonitina, 116 to Phylloceratina, and 53 to Lytoceratina. For palaeontological and biostratigraphical details, see KALIN & URETA (1988), CRESTA et alii, (1995). To summarize, the association is made up by 336 specimens distributed in 30 fossiliferous levels, within a 58-layer succession (Fig. 12), subdivided as follows:

- **layers 1-13** (1,35 m) upper Toarcian, *Dumortieria meneghinii* Zone, 3 fossiliferous levels, 8 collected specimens (Phylloceratina 2, Grammoceratinae 6);
- **layers 14-19** (1,30 m) upper Toarcian, *Pleydellia aalenis* Zone, 4 fossiliferous levels, 24 collected specimens (Phylloceratina 9, Lytoceratina 4, Grammoceratinae 11, Erycitidae 1);
- **layers 20-33** (2,50 m), lower Aalenian, *Leioceras opalinum* Zone, 11 fossiliferous levels, 118 collected specimens (Phylloceratina 46, Lytoceratina 8, Grammoceratinae 3, Tmetoceratinae 19, Graphoceratidae 6, Erycitinae 34, Hammatoceratinae 2);
- **layers 34-46** (2,10 m), middle Aalenian, *Ludwigia murchisonae* Zone, 12 fossiliferous levels, 186 collected specimens (Phylloceratina 60, Lytoceratina 41,
Fig. 9 – Lower Bajocian ammonite from the Infernaccio section: 1) *Stephanoceras pyritosum* (QUENSTEDT), x 0.7, bed 53; 2) *Stemmatooceras frechi* RENZ, x 0.9, bed 53; 3) *Fissilobiceras fissionalbatum* (WAAGEN), x 0.8, bed 44b; 4) *Otoites contractus* (SOWERBY), x 1, bed 47.
Fig. 10 – Lower Tithonian fossiliferous beds of Infernaccio section.

Tmetoceratinae 20, Graphoceratidae 14, Eryctinae 36, Hammatoceratinae 15;

layers 47-58 (2 m), non fossiliferous. From the middle Aalenian onwards, the remains of organisms with aragonitic shell disappear from the stratigraphic record, probably as a consequence of the increased effects of dissolution in the depositional and diagenetical environments. This could be related to subsidence and regional bathymetric evolution (KALIN & URETA, 1988).

BIOSTRATIGRAPHY

The recorded ammonioidea sequence (Fig. 13), from the base to the top, is the following:

bed 4.- Calliphylloceras sp.
bed 5.- Dumortieria taramelli FUCINI (4)
Phylloceras sp.

bed 11.- Dumortieria moorei (LYCETT) (2)
bed 14.- Pleydellia macra (DUMORTIER) (3)
Cotteswoldia cf. costulata (ZIETEN)
bed 15.- Catullocers dumortieri (THIOLLIÈRE) (2)
Pleydellia aalensis (ZIETEN), Phylloceras sp. (2), Calliphylloceras sp., Alocolytoceras sp.

bed 16.- Pleydellia aalensis (ZIETEN), Catullocers dumortieri (THIOLLIÈRE), Erycites sp., Calliphylloceras cf. altisulcatum (PRINZ), Calliphylloceras cf. nillsoni (HEBERT), Phylloceras sp. (2), Lytoceras sp. (2)
bed 17.- Catullocers dumortieri (THIOLLIÈRE) (2), Phylloceras sp., Alocolytoceras sp.
bed 18.- Catullocers dumortieri (THIOLLIÈRE), Phylloceras sp.

bed 20.- Leioceras opalinum (REINECKE), Tmetoceras scissum (BENECKE) (2), Calliphylloceras altisulcatum (PRINZ), Calliphylloceras sp. (2), Holcophylloceras ultramontanum (ZITTEL) (2)
bed 21.- Leioceras opalinum (REINECKE), Holcophylloceras ultramontanum (ZITTEL), Phylloceras sp.
bed 22.- Tmetoceras scissum (BENECKE), Phylloceras sp. (2), Lytoceras sp.
bed 23.- Catullocers dumortieri (THIOLLIÈRE), Calliphylloceras sp., Phylloceras sp.

bed 24.- Leioceras opalinum (REINECKE), Catullocers dumortieri (THIOLLIÈRE) (2), Planammatoceras planinsigne (VACEK), Planammatoceras sp. (2), Tmetoceras scissum (BENECKE), Alocolytoceras sp., Phylloceras sp. (3), Calliphylloceras sp.
bed 26.- Erycites fallifax ARKELL (2), Tmetoceras scissum (BENECKE), Lytoceras sp.
bed 27.- Leioceras sp., Tmetoceras scissum (BENECKE) (4)
bed 29.- Tmetoceras scissum (BENECKE) (5), Alocolytoceras cf. ophioneum (BENECKE), Phylloceras cf. perplanum PRINZ
bed 30.- Leioceras sp., Erycites fallifax ARKELL (6), Planammatoceras sp., Phylloceras sp. (4), Calliphylloceras sp. (4)

bed 32.- Erycites fallifax ARKELL (11), Tmetoceras scissum (BENECKE), Calliphylloceras nillsoni (HEBERT), Calliphylloceras cf. nillsoni (HEBERT), Phylloceras sp. (4), Lytoceras sp.

bed 33.- Leioceras sp., Erycites fallifax ARKELL (10), Erycites sp. (3), Tmetoceras scissum (BENECKE) (5), Holcophylloceras ultramontanum (ZITTEL) (3); H. cf. ultramontanum (ZITTEL), Holcophylloceras sp. (2) Calliphylloceras cf. altisulcatum (PRINZ), Holcophylloceras sp. (2), Phylloceras sp. (8), Lytoceras sp. (2)

bed 34.- Ludwigia haugi DOUVILLE, Ancolioceras opalinoides (MAYER) (2), Erycites fallifax ARKELL (5), Erycites intermedius HANTKEN in PRINZ, Tmetoceras scissum (BENECKE) (2), Spinammatoceras pugnax (VACEK), Planammatoceras sp., Abbasitoides modestus (VACEK) (2), Alocolytoceras cf. ophioneum (BENECKE), Phylloceras sp., Calliphylloceras sp., Lytoceras sp., Holcophylloceras sp. (3)
bed 35.- Tmetoceras scissum (BENECKE) (5), Tmetoceras regleyi (DUMORTIER) (2), Phylloceras sp.
Fig. 11 - Lower Tithonian ammonites from the Infernaccio section: 1) *Hybonoticeras* *hybonotum* (OPPEL), x 0.8, bed 3; 2) *Simoceras* *aesinense* MENEGHINI, x 0.8, bed 6; 3) *Semiformiceras* *semiforme* (OPPEL), x 0.9, bed 5; 4) *Haploceras* *verruciferum* (OPPEL), x 0.9, bed 5; 5) *Ptychophylloceras* *ptychoicum* (QUENSTEDT), x 0.9, bed 4; 6) *Semiformiceras* *darwinii* (NEUMAYR), x 0.9, bed 4.

bed 36.- Ancolioceras opalinoides (Mayer) (2), Erycites intermedius HANTKEN in PRINZ, Planammatoceras planissigne (VACEK) (3), Tmetoceras scissum (Benecke) (3), Tmetoceras regleyi (Dumortier) (3), Tmetoceras sp., Calliphylloceras nilsonni (HEBERT), Lytoceras cf. rasile (VACEK), Holcophylloceras sp. (2), Phylloceras sp.

bed 37.- Calliphylloceras nilsonni (HEBERT), Phylloceras sp. (2)

bed 38.- Accardia cf. procerinsigne (VACEK), Planammatoceras sp., Ancolioceras opalinoides (MAYER)

bed 40.- Ancolioceras opalinoides (MAYER), Abbasitoides modestus (VACEK) (6), Tmetoceras scissum (Benecke) (2), Erycites sp. (3), Phylloceras sp. (2), Lytoceras vaceki GECZY (2), Erycites intermedius HANKEN in PRINZ (2), Alocolytoceras ophioneum (Benecke) (3), Calliphylloceras sp. (2), Holcophylloceras sp.

bed 41.- Abbasitoides modestus (VACEK), Erycites cf. intermedius HANKEN in PRINZ (3), Holcophylloceras ultramontanum (ZITTEL), Alocolytoceras ophioneum (Benecke) (2), Alocolytoceras cf. ophioneum (Benecke), Alocolytoceras sp. (3), Lytoceras sp. (4), Phylloceras sp. (7), Holcophylloceras sp. (2), Ancolioceras sp. (2), Lytoceras amplum (OPPEL), Lytoceras vaceki GECZY, Calliphylloceras sp., Planammatoceras sp., Tmetoceras sp., Erycites cf. fallifax ARKELL (2)

bed 42.- Ancolioceras opalinoides (MAYER), Erycites cf. fallifax ARKELL, Accardia cf. lorteti (DUMORTIER), Pseudaptetoceras cf. klimakomphalum (VACEK), Ancolioceras sp., Planammatoceras sp. (2), Holcophylloceras cf. ultramontanum (ZITTEL), Calliphylloceras cf. connectens (ZITTEL), Alocolytoceras cf. ophioneum (Benecke), Lytoceras cf. rasile VACEK, Lytoceras sp. (2), Holcophylloceras sp., Phylloceras sp. (2)

bed 43.- Ludwiga murchisonae (SOWERBY), Eudmetoceras sp., Calliphylloceras cf. nilsonni (HEBERT), Phylloceras cf. perplanum PRINZ, Lytoceras cf. vaceki GECZY, Lytoceras sp., (3), Calliphylloceras sp. (2)

bed 45.- Erycites fallifax ARKELL, Phylloceras sp., Lytoceras sp.

Fig. 12 – Upper Toarcian – Lower Aalenian schematic log of the Gorgo a Cerbara section.
Fig. 13 – Aalenian Erycoids from the Gorgo a Cerbara section (all specimens x 0.9): a) Erycites fallifax ARKELL, bed 36, mature specimen with peristome, Ludwigia haugi Subzone; b) E. fallifax ARKELL, bed 32, mature specimen with peristome, upper part of the Leioceras opalinum Zone; c) E. fallifax ARKELL, bed 32, phragmocone, upper part of the L. opalinum Zone; d) E. fallifax ARKELL, bed 32, mature specimen, upper part of the L. opalinum Zone: d1) lateral view; d2) ventral view, showing a rudimental keel; e) E. fallifax ARKELL, bed 32, mature specimen, upper part of the L. opalinum Zone; f) Abbasitoides modestus (Vacek), bed 40, immature specimen, upper part of the L. opalinum Zone; g) A. modestus (VACEK), bed 41, mature specimen, Ludwigia haugi Subzone; h) A. modestus (VACEK), mature specimen, L. haugi Subzone.
STOP 5 - THE PROPOSED GLOBAL BOUNDARY STRATOTYPE SECTION AND POINT (GSSP) FOR THE BARREMIAN-APTIAN BOUNDARY AT GORGO A CERBARA

R. COCCIONI

The studied section is located 4 km east of the town of Piobbico in the bed of the Candigliano River and east of Monte Nerone. The lithological boundary between the Marne a Fucoidi and the Maiolica Formations is gradational and it has been placed above the uppermost occurrence of black chert in the Maiolica limestones according to COCCIONI et alii (1987).

Following the discussions at and after the Second International Symposium on Cretaceous Stage Boundaries (Brussels, 1995), the majority of the Aptian Working Group (AWG) selected the base of magnetic chron M0 as the event for defining the base of the Aptian stage (figure 14). After accepting the base of magnetic chron M0 as the base of the Aptian stage, the AWG identified the Gorgo a 'Cerbara section (Umbria-Marche Basin, Central Italy) as possible GSSP for the base of the Aptian Stage (ERBA et alii, 1996). This section represents an excellent exposure of uppermost Valanginian to lower Aptian pelagic carbonates (Fig. 15), and offers a wide range of available stratigraphies including litho-chronostratigraphy (Bralower, 1987; COCCIONI et alii, 1992; JUD, 1994; Cecca et alii, 1994), magnetostratigraphy (LOWRIE & ALVAREZ, 1984; CHANNELL et alii, 1995, 2000), calcareous nannofossil (Bralower, 1987; COCCIONI et alii, 1992; ERBA, 1994; CHannell et alii, 1995, 2000) and planktonic foraminiferal biostratigraphy (COCCIONI et alii, 1992; Cecca et alii, 1994), radiolarian biostratigraphy (JUD, 1994; DUMITRICA and DUMITRICA, 1994; ERBACHER, 1994; ERBacher et alii, 1996; ERBACHER & THUROW, 1997), dinoflagellate biostratigraphy (COCCIONI et alii, 1993), chemostratigraphy ($\delta^{13}$C, $\delta^{18}$O) (HADJII, 1991; ERBACHER, 1994; ERBacher et alii, 1996; ERBacher & THurow, 1997) and cyclostratigraphy (HERBERT, 1992; FIET, 2000; FIET & GORIN, 2000).

Moreover, the Oceanic Anoxic Event la (OAE1a) is represented by the black shales of the Selli Level (COCCIONI et alii, 1989, 1997). The uppermost Hauterivian Faroani Level also occurs.

Magnetostatigraphy was originally performed by LOWRIE & ALVAREZ (1984), but the section was resampled in great detail across magnetic chron M0 to increase the stratigraphic resolution of the boundaries (ERBA et alii, 1996; CHannell et alii, 2000). The Barremian-Aptian boundary has been designated to coincide with the base of polarity chron M0 at 893.20 m of LOWRIE & ALVAREZ (1984) which originally documented the magnetic stratigraphy at Gorgo a Cerbara (see also, ERBA et alii, 1996; CHannell et alii, 2000). However, a detailed field survey across the Barremian-Aptian transition has revealed that the original meter levels painted by LOWRIE & ALVAREZ (1984) on the rocks, and still preserved there, are largely irregularly spaced and do not correspond to the meter unit measure. Following ERBA et alii, (1996) and further, more accurate field investigations (COCCIONI & GALEOTTI with collaborators, in press), the irregularly spaced meter levels of LOWRIE & ALVAREZ (1984) have been re-arranged by calibrating them to the lithological log of COCCIONI et alii (1992). The relative position of the events included in the interval surveyed by COCCIONI et alii (1992) was modified accordingly. The base of magnetic chron M0 results, therefore, to fall at 35.40 m of COCCIONI et alii (1992).

Formal ratification of the proposed Barremian-Aptian boundary stratotype section at Gorgo at Cerbara should take place in the near future.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{Fig_14.png}
\caption{Fig. 14 - Meter levels 892, 893 and 894 of LOWRIE & ALVAREZ (1984) and meter level 35 of COCCIONI et alii (1992) are here recognizable. The base of magnetic chron M0 which has been selected as the event for the definition of the Barremian-Aptian boundary falls at 893.20 m of LOWRIE & ALVAREZ (1984) that is at 35.40 m of COCCIONI et alii (1992).}
\end{figure}
Fig. 15 – Uppermost Valanginian-lower Aptian integrated stratigraphy at Gorgo a Cerbara (after COCCIONI, GALEOTTI et alii, in prep.). Abbreviation: F=Faraoni Level; S=Selli Level. The Nannoconid crisis (see Erba, 1994) was identified by CHANEL et alii (2000) at meter level 896 of LOWRIE & ALVAREZ (1984) that is at 37.52 m of COCCIONI et alii (1992). Polarity chronozones and time scale after HARDENBOL et alii (1998).
AMMONITE BIOSTRATIGRAPHY (from CECCA et alii, 1995a, p. 192)

The record of ammonites from the uppermost Hauterivian-Barremian is not continuous; however, a few diagnostic layers have been detected and described as follows.

Hauterivian-Barremian boundary – The oldest ammonite was found in bed 277: it has been identified as Subsaynella sp. In the beds 264-266 at 817.5 m, Crioceratites sp. gr. duwalli LÉVEILLÉ / villiersianus (D’ORBIGNY) and Plesiospitidiscus sp. indicate a late Hauterivian age, earlier than the P. angulicostata Auct. Zone and this level can be ascribed to the B. balearis or to the P. ligatus Zones. The P. angulicostata Zone, and particularly the P. catulloi Subzone, is very well represented in bed 246 which corresponds to the guide-bed of the Faraoni Level (CECCA et alii, 1994a). The Hauterivian-Barremian boundary falls surely above bed 246, which contains latest Hauterivian faunas, and below beds 198-200 where we collected a typical Barremian Spitidiscus, i.e. an interval between meters 822 and 833 of LOWRIE & ALVAREZ (1984). In the absence of faunas in the latter interval, the boundary is drawn between metres 824 and 828 on the basis of data from other sections (Mount Petrano). Then this Stage boundary falls in chron CM4.

Lower Barremian – Typical Barremian Spitidiscus occur between beds 200-178 but this does not correspond to the actual FO of Spitidiscus. This interval is assigned to the S. hugii Zone, although no other significant Ammonitina have been found. At beds 151-153 specimens of the genus Holcodiscus occur, including the zonal index H. caillaudi (D’ORBIGNY). The fauna of beds 142-143 is also placed in the H. caillaudi Zone because of the presence of Subpulchella cf. changarnieri (SAYN), which is limited to the early Barremian (VERMEULEN, 1980). No significant faunas have been found in the interval between beds 177 and 154. The sediments between could belong partly to the S. hugi and H. caillaudi Zones and partly to the S. nicklesi Zone. The lower Barremian sediments of the Gorgo a Cerbara section are included in chron CM3.

Upper Barremian – The lower/upper Barremian boundary has been tentatively drawn around bed 130. Above the faunas of the H. caillaudi Zone no ammonites unambiguously typical of the A. vandenheckii Zone have been found. Typical late Barremian ammonites occur in beds 121-119: Heinzia gr. provincialis (D’ORBIGNY), H. aff. lindigi (KARSTEN in UHLIG) and Costidiscus sp. cf. recticiostatus (D’ORBIGNY). Coronites aff. coronatooides (SAYN) occurs in beds 84-85, and in bed 81 we have found Barremites (Cassidoiceras) cf. cassidooides (UHLIG), H. gr. provincialis, C. aff. hoplitiformis (SAYN). The faunas of the beds between beds 130 and 81 are then included in the A. vandenheckei Zone. The occurrence of H. sartousi (D’ORBIGNY) in bed 48 clearly indicates the H. sartousi zone; this species is rather abundant in bed 43 where it is associated with H. cf. ouachensis (SAYN). Above bed 43, ammonites become extremely rare and mainly represented by the Silesites serannonis (D’ORBIGNY) group, which is poorly significant for biostratigraphic purposes. Above bed 28, i.e. above metre 882, the beds are barren or do not contain biostratigraphically significant fossils. A single specimen, identified as ?Prodesquesites sp. was found in bed 5, indicating the lower Aptian.

STOP 6 – AMMONITE BIOSTRATIGRAPHY OF THE HAUTERIVIAN-BARREMIAN BOUNDARY IN THE MONTE PETRANO SECTIONS

(see also CECCA et alii, 1995, p. 199)

A. MARINI

The sections are exposed along the road which leads from the town of Cagli up to the top of Monte Petrano. Numerous outcrops of the Maiolica formation are found along road-cuts. They are isolated from each other because of faulting. The complete succession is exposed on the northern flank of the mountain (outcrops M and N). Outcrop A exposes some beds with Holcodiscus caillaudi (D’ORBIGNY) and Nicklesia pulchella (D’ORBIGNY) sensu KILIAN (1888) [probably belonging to Subpulchellia compressissima (D’ORBIGNY)]. This has been confirmed by COMPANY et alii (1993), and this level can be ascribed to the caillaudi horizon of their S. compressissima Zone, which corresponds to the lower part of the H. caillaudi Zone sensu HOEDEMAKER & COMPANY.

One of the best sections of the Faraoni Level as well as the Hauterivian-Barremian boundary is exposed at outcrop B (Fig. 16) where this boundary can be traced based on the FO of a characteristic heteromorph ammonite [“Parspinoceras” evolutum (FALLOT & TERMIER)]. Several specimens were collected in this bed, allowing to define its intraspecific variability. Two morphotypes are distinguished: one is characterized by simple ribs, while the other has buckled ribs in the young stage and simple ribs in the adult.

The bed B32 is the Guide bed of the Faraoni Level. Specimens of Pseudothurmannia have been found also in the overlying calcareous beds 33 and 34, along with some gastropod specimens. These gastropods, which are characterised by very long, fine, hook-shaped spines, show some morphologic affinities with the genus Harpagodes. They are quite common in the studied outcrops from Gorgo a Cerbara (stop 2.9) to Monte Tenetra.
In bed 49 we have found a fauna only composed by specimens belonging to "Paraspinoceras" evolutum (FALLOT & TTERMIER). They occur above the Pseudothurmannia beds and according to VERMEULEN (1972) this species indicates the base of the Barremian.

STOP 7 - DOMERIAN-TOARCIAN BOUNDARY IN THE LECCETI SECTION (see also FARAONI et alii, 1994)

A. DILIGENTI & F. DURONIO

The reference window for the lower Toarcian outcrops along the left side of the Bosso River, locality "L Lecceti", and it can be reached by a suspended gangway some hundreds of metres SW of Secchiano. FARAONI et alii (1994) sampled an interval 6.5 metres thick in which they recognised 13 fossiliferous levels (Fig. 17).

Polimorphum Zone – This is a 5-layer unit, 1.5 metres thick, with 5 fossiliferous levels. The zone is characterised in its lower part by Dactylioceras (Eodactylites), and by the persistence of the species association of Domerian affinity (Hildoceratids and Phylloceratids). It includes two associations, the lower of which is characterised by D. (Eodactylites) mirabile (FUCINI), D. (E.) polimorphum (FUCINI), D. (E.) simplex (FUCINI), D. (E.) pseudocommune (FUCINI) (faunula 1 by CRESTA et alii, 1995), and the upper one by Dactylioceratids close to Orthodactylites (Secchianoceras VENTURI), by the last differentiation of Neolioceratoides (incl. Petranoceras VENTURI) and by a Toarcian acme of Protoogrammoceras bassanii (FUCINI). This association has not yet been found in the PCP areas, where the zone is probably condensed in a hard-ground level. As previously mentioned, several species of Domerian affinity, belonging to Fontanelliceras, Distefania, Canavaria, Geyeroceras, Meneghiniceras, Calaiceras and Harpophylliloceras, are present in association here and in the other outcrops.

A similar association was described by KALIN & URETA (1988) at Gorgo a Cerbara, including the following species: D. (Eodactylites) mirabile (FUCINI), D. (E.) cf. polimorphum (FUCINI), D. (E.) pseudocommune (FUCINI), Neolioceratoides schopeni (FUCINI) and N. hoffmani (GEMMELLARO).

Levisoni Zone – In this unit, 5 metres thick, recognised within a marly sequence with isolated nodular episodes only in the Bosso-Lecceti section, 8 fossiliferous levels were identified. The Zone is characterised in the lower part by Rakusites tuberculatus Guex, Taffertia taffertensis Guex, Nodicoeloceras gr. merlai (PINNA) and by small forms with harpoceratoid morphology belonging to the genus Hildaites (H. exilis, H. striatus GUEX). For this association, coinciding with the faunula 2 by CRESTA et alii (1995, Presale section), FARAONI et alii (1994) propose the use of the Hildaites striatus Subzone.

In the upper part of the unit the striated morphologies are replaced by species with strong, sinuous, occasional ribs, separated by intercostal spaces as large as the ribs themselves (H. eremitensis VENTURI, H. pseudolevisoni VENTURI, H. undicosta MERLA).
STOP 8 – CARIXIAN
AMMONITE BIOSTRATIGRAPHY
IN THE BOSSO RIVER VALLEY
(from FARAONI et alii, 1996, p.81)

Jamesoni Zone - The reference window for this interval outcrops along the Bosso River below the Cagli-Pianello road, about 1.5 km SW of the village of Secchiano. Recent studies by FARAONI et alii (1994, 1996) added to the original biostratigraphic framework established by FERRERI (1975) and DOMMERGUES et alii (1983). The window opens onto 39 metres of sequence, divided into 89 layers, 21 of which are fossiliferous. The recognised species are summarised in fig. 18; for further details, see FARAONI et alii (1996). For the biostratigraphic description of the interval, these authors proposed the adoption of the following biozones:

Tetraspidoceras quadrarmatum biozone (layers 39-81, thickness 19 metres, 9 fossiliferous levels). This unit, proposed as an Oppel-zone, is characterised by the presence of Tetraspidoceras quadrarmatum (DUMORTIER); its lower limit does not coincide with the appearance of the marker, which is restricted to the upper part of the biozone, but with a Galaticeras sp. and Radstockiceras gemmellaroi biohorizon overlain by an assemblage with Radstockiceras aff. numismale (OPPEL), Catriceras catriense VENTURI, “Catriceras” sp., Aegolytoceras varicosum VENTURI, Partschiceras striatocostatum (MENEGHINI) and Polymorphites calensis FARAONI et alii.

Miltoceras sellae biozone (layers 82-125, 20 metres thick, 12 fossiliferous levels). This unit, proposed as a taxon range zone, is characterised by the replacement of the deroceratid species with two rows of spines (T. quadrarmatum (DUMORTIER), “Epideroceras” gr. ancyrense BREMER) by others with one row of spines like Miltoceras sellae (GEMMELLARO). Three bioevents [(Farinaccites clavatus FARAONI et alii, Polymorphites apenninicus FARAONI et alii, Tropidoceras gr. flandrini (DUMORTIER)] are recognisable in this biozone.

Ibex and Davoei Zones - This interval reference window outcrops along the left side of the Bosso River above the Cagli-Pianello road, at a short distance from the previous one. Also in this case the recent studies by FARAONI et alii (1994, 1996) enhanced the biostratigraphic framework set by FERRERI (1975) and DOMMERGUES et alii (1983), leading to the proposal of the biostratigraphic units adopted here. The window opens onto 26 metres of sequence, divided into 75 layers 43 of which are fossiliferous. The recognised species are summarised in fig. 19; for further details see FARAONI et alii (1996). For the biostratigraphic description of the interval, these authors proposed use of the following biozones:

Orthildaites douvillei (DUMORTIER) and Praemercaticeras sp. can be found along with these, as well as several species of Dactylioceratids still requiring better palaeontological classification. For this association, coinciding with the faunula 3 by CRESTA et alii (1995), FARAONI et alii (1994) propose the name of Hildaites pseudolevisoni Subzone.
**Table: Ammonite species**

<table>
<thead>
<tr>
<th>Bosso river main fossiliferous beds Lower Carixian</th>
<th>Ammonite species</th>
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<tbody>
<tr>
<td>39 45 51 57 55 82 85 89 92 116 125</td>
<td>Galaticeras sp.</td>
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<tr>
<td></td>
<td>Radstockiceras gemmellaroi</td>
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<tr>
<td></td>
<td>Catriceras sp</td>
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<tr>
<td></td>
<td>Catriceras catriense</td>
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<tr>
<td></td>
<td>Polymorphites calensis</td>
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<td></td>
<td>Radstockiceras aff. numismalis</td>
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<td></td>
<td>Aegolytoceras varicosum</td>
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<tr>
<td></td>
<td>Tetrasicoceras quadramatum</td>
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<tr>
<td></td>
<td>&quot;Epideroceras&quot; latinodosum</td>
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<tr>
<td></td>
<td>&quot;Epideroceras&quot; gr. ancyrense</td>
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<tr>
<td></td>
<td>Galaticeras marianii</td>
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<tr>
<td></td>
<td>&quot;Reynesocoeloceras&quot; gr. obesum</td>
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<tr>
<td></td>
<td>Miltoceras sellae</td>
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<tr>
<td></td>
<td>Gemmellaroceras aenigmaticum</td>
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<td>Galaticeras harpoceroides</td>
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<td>Galaticeras flexistriatum</td>
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<td>Polymorphites flexicostatum</td>
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<td>Farinaccites kondai</td>
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<td>Farinaccites clavatus</td>
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<td>Holcophylloceras quadrijugum</td>
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<td>Polymorphites appenninicus</td>
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<td></td>
<td>Tropidoceras bosense</td>
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<td></td>
<td>Miltoceras seguenzai</td>
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<td></td>
<td>Tropidoceras gr. flandrinni</td>
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</tbody>
</table>

**Fig. 18 –** Biostratigraphic distribution of Lower carixian recognized ammonite species of Bosso-River section.

*Metaderoceras gemmellaroi* biozone (layers 141-179, thickness 14.5 metres, 29 fossiliferous levels). Apart from the distribution of *Metaderoceras gemmellaroi* (LEVI), appearing about two metres from its lower boundary, this unit is characterised by a basal biohorizon with *Dubariceras dubari* DOMMERGUES, MOUTERDE & RIVAS and a diverse fauna with *Tropidoceras* (*T. demonense* GEMMELLARO, *T. mediterraneum* GEMMELLARO, *T. calliplocum* GEMMELLARO) and the first representative of *Protogrammoceras*, mainly bisulcate forms of the *P. hungaricum* GECZY group. Three bioevents (*Tropidoceras mediterraneum* GEMMELLARO, *Dayiceras* sp. aff. *D. Dayiceroide* MOUTERDE and *Metaderoceras beirense* MOUTERDE) are recognisable in this biozone, which corresponds to the *Tragophylloceras ibex* Zone.

*Protogrammoceras dilectum* biozone (layers 180-216, 10.5 metres, 14 fossiliferous levels). This unit, partly corresponding to the *P. dilectum* horizon by FERRETTI (1975) proposed by BRAGA *et alii* (1982), is adopted by FARAONI *et alii* (1996) in virtue of the good correspondence between the Apennine and Betic associations (Spain). In this section the lower part of the biozone is characterised by *Reynesocoeloceras simulans* (FUCINI), *Liparoceras (Becheiceras) bechei* (SOWERBY) and *Gemmellaroceras aenigmaticum* (GEMMELLARO), and the upper one by *Protogrammoceras dilectum* (FUCINI) and *Fuciniceras costicillatum* (FUCINI). This biozone is correlated with the *Prodactylioceras davoei* Zone.

The two sections have been correlated to produce the species range chart shown in Fig. 19. Our data indicate that some modifications must be made to the schemes by GECZY (1976) and BRAGA *et alii* (1982). Our proposal includes the following points:

- to subdivide the lower Carixian into the *Tetraspidoceras quadramatum* Oppel Zone (Bosso River section, beds 39 to 81, thickness 19 meters - below) and the *Miltoceras sellae* taxon range zone (Bosso River section, beds 82 to 125, thickness 20 meters - above);
<table>
<thead>
<tr>
<th>Bosso-Stirpeto main fossiliferous beds Middle-Upper Carixian</th>
<th>Ammonite species</th>
</tr>
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<tbody>
<tr>
<td>141 142 147 163 166 167 170 172 180 181 182 183 167 168 180 190 195 216</td>
<td>Juraphyllites libertus</td>
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<td></td>
<td>Juraphyllites diopsis</td>
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<td></td>
<td>Dubariceras dubari</td>
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<td></td>
<td>Tropidoceras mediterraneum</td>
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<td>Tropidoceras demonense</td>
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<td></td>
<td>Tropidoceras calliplocum</td>
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<td></td>
<td>Protogrammoceras cf. hungaricum</td>
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<tr>
<td></td>
<td>Metaderoceras gemmellaroi</td>
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<tr>
<td></td>
<td>&quot;Acanthopleuroceras&quot; sp.</td>
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<tr>
<td></td>
<td>Dayiceras sp.</td>
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<td></td>
<td>Dayiceras aff. dayiceroide</td>
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<tr>
<td></td>
<td>Diaphorites vetulonius</td>
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<tr>
<td></td>
<td>Galaticeras aegoceroide</td>
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<td>Fieldingiceras sp</td>
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<td></td>
<td>Metaderoceras beirense</td>
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<td></td>
<td>Protogrammoceras sp</td>
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<tr>
<td></td>
<td>Juraphyllites planispira</td>
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<tr>
<td></td>
<td>Liparoceras (Becheiceras) bechei</td>
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<td></td>
<td>Gemmellaroceras aenigmaticum</td>
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<tr>
<td></td>
<td>Reynescoeloceras sp.</td>
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<tr>
<td></td>
<td>Reynescoeloceras simulans</td>
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<tr>
<td></td>
<td>Phrycodoceras sp. aff. P. taylori</td>
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<tr>
<td></td>
<td>Protogrammoceras dilectum</td>
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<tr>
<td></td>
<td>Fuciniceras costiclitatum</td>
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<td></td>
<td>Fieldingiceras fieldingii</td>
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</tbody>
</table>

- to use the Metaderoceras gemmellaroi Oppel zone (Stirpeto section, beds 141 to 179, thickness 14,5 meters) for the middle Carixian;
- to use the Protogrammoceras dilectum taxon range zone (sensu BRAGA et alii, 1982) for the upper Carixian (Stirpeto section, beds 180 to 216, thickness 10,5 meters).

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Post-Symposium Field Trip B 4
(19-22 September 2002)

THE SABINA PLATEAU, PALAEOESCARPMENT,
AND BASIN – CENTRAL APENNINES

SCIENTIFIC COORDINATOR

M ASSIMO S ANTANTONIO

CONTRIBUTORS

C RISTINA M URARO & M ASSIMO S ANTANTONIO.
FOREWORD

Despite its rather bulky size, the Jurassic Sabina Plateau, with its generous load of spectacular depositional and erosional geometries and wealth of uncommon to downright unique sedimentological features, had until recently managed to escape the curiosity of geologists.

A geological mapping project by the Servizio Geologico d'Italia (Geological Survey of Italy) during the last decade of the past century gave the present writer – formerly a staff geologist at the Survey – the great opportunity to visit (or, in some cases, re-visit) some of the most beautiful Jurassic localities in the Apennines. After months in the field trying to fulfill the challenging task of mapping ridiculously small patches of condensed pelagic sediments, or to tell Jurassic from Neogene faults, it became evident to Fabrizio Galluzzo and to myself that we were dealing with something BIG. We were familiar with intrabasinal highs whose area did not exceed few square km’s, but here we were surprised we could map a single palaeoescarpment, marginal to a Jurassic plateau, for tens of kilometres.

Once the big picture was clear (?), we realized dozens of sedimentological puzzles were in desperate search of an explanation: shoal-water oolites in a condensed pelagic succession? A breccia with a matrix that is older than the clasts? A nest of multiple unconformities carved on a silicified palaeosurface, all being part of a block fallen into a basin? While ingesting insane doses of recent scree, Neogene thrusts, and Plio-Pleistocene strike-slip duplexes, we tried to figure out what was going on in the Jurassic. Did we succeed? You readers/field-trip participants will judge.

This field trip illustrates the sedimentary geology of a pelagic carbonate platform (Sabina Plateau)/basin (Sabina Basin) system. In designing this field trip, I have chosen to visit those localities where a maximum of unusual features occur over a relatively small area, or those where a longer walk is rewarded by an impressive geological landscape.

The plateau-edge, marginal escarpment, and basin-margin palaeoenvironments will be examined with emphasis on the geometries and facies of pelagic carbonates. High-resolution ammonite biostratigraphy will be used wherever necessary to demonstrate the time-correlation of laterally discontinuous lithosomes and to highlight the changes of sedimentation rates across different parts of the depositional system.

In the Sabina Basin, the influence of the neighbouring Latium-Abruzzi peritidal carbonate platform is seen through the occurrence of abundant gravity flow deposits interbedded with pelagic sediments. The sedimentology of resedimented beds will be discussed, along with the causes for the long-term fluctuations in volume and composition of the platform-derived material in the Middle and Upper Jurassic.

To conclude, I am deeply indebted with several colleagues and friends with whom I have spent years in the field or have freely traded ideas and data. I must start with A. Farinacci, who introduced me to the geology of the Castiglione area. Her collaborators at the time (late 1970’s) were U. Nicosia, G. Pallini, N. Mariotti and F. Schiavinotto, who were generous enough to take me with them to visit all the key Jurassic outcrops in the Umbria, Marche and Sabina regions. My undergraduate colleagues were F. Cecca, S. Cresta, M.C. Giovagnoli and R. Manni. We did a lot of hard ammonite-quarrying work together, and you may notice their contributions in various sections of this volume. Subsequent fieldwork in Sabina was carried out while at the Geological Survey of Italy, and was shared with F. Galluzzo. M.C. Giovagnoli and D. Delogu helped with micropalaeontology. C. Muraro introduced me to some beautiful Jurassic localities in the eastern Sabina Basin. Thank you to all of you!

Massimo Santantonio
INTRODUCTION

This field trip serves to illustrate some aspects of the peculiar Jurassic geology of the Sabina region. Formerly interpreted as an homogeneous platform-to-basin transitional slope linking the Latium-Abruzzi Platform to the Umbria-Marche domain, the area has recently undergone some substantial reinterpretation (SANTANTONIO & GALLUZZO, 1996; GALLUZZO & SANTANTONIO, 2001) (Fig. 1).

While the general view of the typical Sabina basinal facies as characterized by varying amounts of resedimented material of shallow water origin remains confirmed, the discovery of a huge Jurassic intrabasinal high, named the Sabina Plateau and bounding the Sabina Basin s.s. to the west, must change our views on the region. The Jurassic Sabina Basin can in fact be redefined as a basin locked to the east and west by the Latium-Abruzzi Platform and the Sabina Plateau, respectively. Also, the basin hosts in turn lower-rank highs, as seen in the Reatini Mts. (CHIOCCHINI et alii, 1975; LEONARDI et alii, 1997), most of which became buried as early as in the Middle Jurassic (the Sabina Plateau persisted instead until the Early Cretaceous).
Fig. 1 – Simplified Middle Jurassic palaeogeography of Central Italy, with the inferred extent of the Sabina Plateau.
What make Sabina stand apart from the neighbouring regions like the Umbria-Marche, with which it shares essentially the same pelagic stratigraphy, are therefore essentially two features:

1. The larger size of palaeostructural elements, like the Sabina Plateau, that is also accomplished by a greater amount of vertical offset along master palaeofaults. This also resulted in much greater accommodation space available for basinal successions.

2. The strongly resedimented nature of basinal successions.

SEDIMENTATION HISTORY OF THE SABINA AND UMBRIA-MARCHE REGIONS IN THE MESOZOIC

The Jurassic history of the Sabina and Umbria-Marche Apennines in Central Italy starts with the development of a carbonate megabank, occupying most of today’s peninsular Italy, represented by the Hettangian-Sinemurian Calcare Massiccio Fm. This rests on an Upper Triassic succession overlying a deformed Hercynian substrate, and is made of evaporites (Anidriti di Burano Fm.) and shallow shelf carbonates (Rhaetavicula contorta beds) (PASSERI, 1975). Extension may have already been active during deposition of the Calcare Massiccio, although high sedimentation rates could compensate for differential subsidence, preventing the formation of morphological basins (ALVAREZ, 1989). Extensional tectonics, by contrast, did produce a complex pattern of structural highs and intervening basins in the Sinemurian (COLACICCHI & PIALLI, 1967; FARINACCI, 1967; BERNOLLI, 1971). Structural highs survived for some millions of years as productive, though relatively unhealthy, isolated platforms. These hosted a peculiar subtidal facies known as Calcare Massiccio B, where typical shallow-water elements like coated grains, peloids and an assorted micro- and macrofauna are set in a micritic matrix with sponge spicules, radiolarians, and very rare ammonites (CENTAMORE et alii, 1971; BICE & STEWART, 1990). This clearly documents how dramatically changed sea-water circulation around them affected these isolated highs, formerly sheltered areas within a vast intertidal flat, while they still were in shallow water. In the Pliensbachian (middle Carixian Tragophylloceras ibex Zone) these fault-bounded platforms were finally drowned, probably due to a non-tectonic palaeoceanographic eutrophication event, and turned into pelagic carbonate platforms (PCP) (SANTANTONIO, 1993, 1994; SANTANTONIO et alii, 1996; MORETTINI et alii, in press). Slow and discontinuous pelagic sedimentation took place on them in a post-rift regime, until basin-filling was completed in earliest Cretaceous times and submarine topography was leveled by the Maiolica Fm.

FACIES ASSOCIATIONS

In pelagic carbonate platform/basin systems, facies associations are strongly tied to sea-bottom palaeotopography, in turn largely the product – at least initially - of rift tectonics. Three associations have been identified by SANTANTONIO (1993) (Fig. 2):

A. The condensed pelagic facies association. This is typical of PCPs, and is made of condensed pelagic deposits resting in geometrical concordance above the drowned Calcare Massiccio. These deposits are characteristically richly ammonitiferous, and are devoid of chert and of any kind (see stop description for an exception) of gravity flow deposits. The general geometry of these deposits on PCPs is that of a convex-up lens, with drastic thinning toward edges, where the most discontinuous and most fossiliferous sections are found (“panettone” geometry). This duplicates the seamount-top geometry of pelagic deposits described by WINTERER (1991) from the Allison Guyot in the Pacific (Fig. 3) and is probably due to the coupled effects of submarine erosion and the different angle of repose of pelagic mud with respect to the underlying lithified peritidal limestone. A striking regional feature of PCP-top deposits, and one having a strong impact on regional subsidence history, is that of bearing pennular thamnasteriid corals in the Tithonian, interpreted as deep-photic forms by LATHUILLIÈRE & GILL (1995), INSALACO (1996) and SANTANTONIO et alii (1996). Another important feature in Sabina and Umbria-Marche is the occurrence of a hiatus spanning the late Bajocian to the earliest Kimmeridgian (CECCA et alii, 1990). Typical thickness figures for Carixian to Tithonian PCP successions are about 40 m.

B. The “normal” and resedimented pelagic facies association. This is found in basins, and is represented by pelagic deposits derived from the perennial fallout of planktonic organisms, by peri-platform ooze, by admixed terrigenous clays, and by various deposits of gravity flow origin. Basin-margin deposits often host megabreccia
wedges and isolated olistoliths produced by the collapse of marginal PCP escarpments. This is most notable in the lower part of the lower-middle Liassic Corniola Fm., representing syn-rift sedimentation. The thickness of Jurassic basin-fill deposits varies from ~500 m in the Umbria-Marche to ~1500 m in Sabina.

Fig. 3 – Seismic reflection profile of Allison Guyot in the Mid-Pacific Mountains. The reefal sediments comprise two seismic facies, a perimeter reef without coherent internal reflectors, and a central lagoon with continuous reflectors. Volcanic basement is inferred to be a depth of about 600 m (2-way reflection time). The reefal sediments are overlain across an unconformity showing karstic relief by a mound of post-Cenomanian pelagic sediments, shaped by mid-water currents (WINTERER, 1991).

C. The composite pelagic facies association. This typically represents epi-escarpment sedimentation and is made of condensed cephalopod-rich deposits, often identical to their PCP-top counterparts, resting through an angular unconformity above the peritidal limestone (or on older PCP deposits in the uppermost escarpment). On palaeoescarpments, sedimentation could only occur wherever meso-topography permitted, as in block-detachment scars, often in sites where the equilibrium with erosion was unstable. Due to the odds of preservation and to periodic collapses, epi-escarpment deposits form scattered patches of contrasting age along the escarpment profile. Their thickness ranges from a thin veneer to a bed succession that mimics part of the PCP-top succession, which is sometimes found ponded on larger morphological lows and is commonly a site of nested unconformities. Due to their peculiar palaeosetting, epi-escarpment deposits often form a sedimentologically unusual mixture of condensed sediment and lithoclasts (derived from the erosion of higher parts of the local escarpment). The composite pelagic facies association was at home on any substrate that was elevated with respect to the basin bottom, so it also developed on megabreccias and larger olistoliths until they became buried by basinal deposits.

GEOLOGY OF THE SABINI MTS.

The Sabini Mts. form a N-S elongated mountain range that is bounded to the north, south, and east by Quaternary continental deposits of the Terme Plain, The Tiber Valley, and the Rieti Plain, respectively. To the northwest they are instead separated from the NW-SE trending Narni-Amelia range by a syncline mostly made of Neogene flysch deposits (Fig. 4).

GALLUZZO & SANTANTONIO (in press, and bibliography therein) describe the following main structures (see also COSENTINO et alii, 1992), from east to west. 1. A frontal thrust, with superposition of Mesozoic carbonates on Tertiary carbonate and terrigenous deposits. 2. A more internal thrust within the Mesozoic carbonates, having Jurassic deposits at the top and often forming a footwall flat in the Toarcian Marmé di Monte Serrone Fm. 3. The dextral strike-slip “Sabina Fault” (ALFONSI et alii, 1991a, b), with associated (mainly) positive flower structures in the form of west-verging reverse faults. 4. The Jurassic Sabina Palaeofault east-dipping escarpment, with the Sabina Plateau to the west.

Numerous Quaternary normal faults, many having an E-W strike, cut these structures, and the western side of the Sabini Mts. is overall marked by west-dipping normal faults.

JURASSIC TO LOWER CRETACEOUS STRATIGRAPHY OF THE SABINA PLATEAU

On the Sabina Plateau, a condensed and discontinuous Pliensbachian to Tithonian/early Berriasian pelagic succession rests in geometrical concordance on the peritidal limestone (Fig. 5). Younger formations are also very thin, but do not have a condensed appearance and generally have a facies similar to that of basinal successions, as a result of basin filling. The Jurassic pelagic succession is not more than 40m thick but locally even thinner, and is found along a northsouth alignment of outcrops in three main areas: 1. The Stroncone area; 2) the western slopes of Mt. Macchia lunga; 3) the Castiglione di Cottanello area (Fig. 4). Surprisingly enough, only the third area has received some attention from geologists in the past years (MAXIA, 1951; FARINACCI, 1967; CECCA & SANTANTONIO, 1982; CECCA et alii, 1985).
Fig. 4 – Geological map of the Sabini Mts, between the parallels of Terni and Contigliano (after Galluzzo & Santantonio, 2002).
- The Jurassic succession starts with the Calcare Massiccio, a unit built by pure peritidal carbonates, locally organized into evident shallowing-upwards cycles, and bearing numerous subaerial exposure surfaces. The observable thickness amounts to about 0.8 km, but the base is not exposed. The age is Hettangian - Sinemurian.

- The next unit is the Calcare Massiccio "B" sensu CENTAMORE et alii (1971) (= Corniola Massiccia in PASSERI, 1971). It is typically made of white wacke- to grainstones, with coated grains (including small oncolites and lumps), peloids and often a mud matrix with sponge spicules. Crinoids and benthic forams [including Agerina martana (FARINACCI)] are characteristic, with rarer calcareous sponges and small ammonites. This unit does not occur all across the plateau, and can rest unconformably on the previous one. It reaches about 60 m in the Stroncone area (Rio il Fossato), and seems to gradually thin out towards the south: it is 25 m thick near Croce Micciola (Mt. Macchialunga), and virtually disappears in the Castiglione area, where it is replaced by a drowning unconformity. This is interpreted as the result of a northwards tilt of the plateau. The age is not well known, but its stratigraphic position indicates this unit must have been deposited in the Lotharingian - Carixian p.p.

- The Corniola-equivalent Fm. (sensu GALLUZZO & SANTANTONIO, 1994) (= Calcare Stratificati Grigi in CENTAMORE et alii, 1971) is a condensed pelagic wackestone, light brown in colour, with hardgrounds (west of Mt. Macchialunga). It contains a fauna dominated by cephalopods, brachiopods, and crinoids, but calcareous sponges (including sphinctozoans) also occur. Quite unlike other condensed successions in the Umbria-Marche, this unit is completely missing or is extremely thin in most localities (Castiglione). The thickest section is about 7 m thick. The ammonite ages detected are Carixian and, more frequently, Domerian.

- The Rosso Ammonitico-equivalent Fm. (sensu GALLUZZO & Santantonio, 1994) (= Calcari Nodulari e Marne Verdi in CENTAMORE et alii, 1971) is made of red to brown nodular marly limestones and red marls. Despite its name, ammonites are uncommon and other fossils are also rare in this unit, with the exception of posidoniid bivalves. The thickness varies greatly: a maximum of 16 m has been measured in the Castiglione quarry (FARINACCI, 1967) but 0.7 km to the east it is reduced to 7-8 m, which is the average for the plateau. Much thinner sections also exist locally. The age of this formation is Toarcian p.p.

- The Bugarone inferiore Fm. (CECCA et alii, 1990) (= Calcari Nodulari Nocciola in CENTAMORE et alii, 1971) consists of light brown mud- to packstones, locally marly and nodular, dolomitized in places. Posidoniid bivalves characterize this unit, which attains a maximum thickness of ~20 m. Ammonites are sparse, but can be relatively more common in the lowest and uppermost parts. The upper part of the unit contains characteristic protoglobigerinids. The age of this formation is Toarcian p.p. to early Bajocian.

- The Bugarone superiore Fm. (CECCA et alii, 1990) (= Micriti a Cefalopodi in CENTAMORE et alii, 1971) is made of light grey to light brown/green fossiliferous wackestones, locally with an exceptionally rich cephalopod fauna (ammonites, aptychi, belemnites, rhyncholites), allowing for a very high-resolution biostratigraphic control (CECCA & SANTANTONIO, 1982; CECCA et alii, 1985). Bivalves (lower part), brachiopods (Pygope sp.), crinoids, and solitary and colonial corals, mostly pennular (GILL, 1967; SANTANTONIO et alii, 1996, and bibliography therein), are also present. Rare sphinctozoan sponges occur in the Kimmeridgian. The lower part still bears protoglobigerinids, but no more...
posidoniids. The total thickness is extremely variable, and usually ranges from 2 m to about 11 m. Its age is early Kimmeridgian to late Tithonian/Berriasian.

The Bugarone superiore rests on the Bugarone inferiore via a paraconformity, with a hiatus of about 20 million years (see above).

- Maiolicia Fm. This is a white, thinly bedded mudstone, mostly cherty (with the exception of the basal 5-10 m) and locally with thick dolomitic intervals (Castiglione ~17 m). An abrupt fall in macrofossil occurrence is typical for the unit, which contains biostratigraphically useful calpionellids in the lower part, and sparse aptchi. The basal levels at Castiglione bear sparse colonies of pennular corals (lower Berriasian, “B Zone” – F. CECCA, pers. comm.). The thickness ranges from 58 m (Castiglione) to more than 170 m (near Stroncone). The age is Berriasian p.p. - early Aptian.

JURASSIC TO LOWER CRETAUCEOUS STRATIGRAPHY OF THE SABINA BASIN (WESTERN PART)

East of the Papigno - Cottanello meridian alignment, the coeval stratigraphic successions are radically different from those of the plateau (Fig. 5). Besides being much thicker, differences also affect their lithostratigraphy, facies, and geometries.

- Corniola Fm. This is the oldest and thickest basinal unit (> 1 km). It is made of white to light brown, to dark grey pelagic cherty mudstone, with abundant graded and laminated beds (up to several meters thick), slumps, and breccias. Grey shale interbeds are found in the upper part. Resedimented deposits, totalling several hundred meters in thickness, mostly consist of shallow-water sands, with ooids and bioclasts (molluscs, echinoderms etc.), often with a finer tail with pelagic components. They are most abundant in the lower part of the unit. Background pelagic deposits bear radiolarians, benthiic forams, and sponge spicules. The unit characteristically contains megabreccias and huge (up to >1 km across) isolated olistoliths of Calcare Massiccio, which partly account for the abnormal thickness of the unit as derived from geologic cross-sections. The olistoliths are more common towards the west, that is closest to the plateau. Ammonites are extremely rare, but the Corniola is regionally well known to span the Sinemurian through the earliest Toarcian.

- Marne del Monte Serrone Fm. These are grey to greenish marls and shales, with interbedded brown calcarenites bearing rare light brown chert nodules. Less than 1 m above the base, a thin (0.4-0.5 m) black shale interval, with plant and fish remains, marks one of the oceanic anoxic events of Jenkyns (1985) (early Toarcian, Dactylioceras tenuicostatum Zone). The interbedded calcarenites, in beds generally 10-30 cm thick, are usually graded and laminated with spectacular Bouma sequences, locally with small scale (wavelength 20-50 cm) hummocky cross stratification (MONACO, 1992). They contain fine detritus, mostly of unidentified origin, but posidoniid bivalves are present, and ooids and other shallow water material are visible in coarser-grained levels. The Marne del Monte Serrone locally bear olistoliths of Calcare Massiccio. Red nodular marls and shales, also with posidoniids, up to 6-7 m thick and similar to the typical Rosso Ammonitico of Umbria and Marche, are often found at the top of the unit. The total thickness averages 30 m. The age is Toarcian p.p.

- Calcare e Marne a Posidonia Fm. The base of the unit is marked by a sharp increase in carbonate content, and by the appearance of conspicuous chert. This formation is made of light-coloured cherty pelagic mudstone, and is more marly near the base (where it is pinkish and has shaly interbeds) and more cherty towards the top. Macrofossils are extremely rare, with the exception of the lower part, which bears occasional ammonites (Tmetoceras sp., Aalenian) and belemnites. Distinctive constituents are posidoniid bivalves: they often occur in lithogenic quantities, with laminated shell accumulations being more common in the upper cherty portion. Resedimented levels can be locally dominant, with thick packages of graded beds bearing shallow water material (ooids, bioclasts, etc.), often with a laminated top with posidoniids. Olistoliths and breccias are rare in the lower part, but huge isolated blocks appear upsection, and a megabreccia occurs at Castiglione (see stops). The transition to the next unit is gradual, and is represented by an upper member of bedded cherts with little carbonate, but still with posidoniids. The thickness is 60-150 m. The age is latest Toarcian to ?early - late Bajocian (BARTOLINI et alii, 1996).

- Calcare Diasprigni Fm. This formation consists of radiolarian cherts and subordinate cherty limestone in thin tabular to pinch-and swell beds, green, to brown to red in colour, with mm-thick shale interbeds. Most characteristic of the unit is the virtually absolute lack of macrofossils, while the microfauna is dominated by radiolarians. Also typical is the absence of resedimented levels of shallow water origin, with the exception of the Contigliano area. The Calcare Diasprigni can bear huge (long axis up to 0.8 km) olistoliths of Calcare Massiccio, but some of them are actually shared with the units below and above: i.e. certain blocks fell into the upper levels of the Calcare e Marne a Posidonia, and became progressively buried by the next two formations. The total thickness of the Calcare Diasprigni is 20-60 m, the thinnest sections being found in the westernmost part of the basin. Following CECCA et alii (1990), we use this unit name in a restrictive sense, therefore excluding both those cherts and cherty limestone that still bear posidoniids, which we place in the previous unit, and the
younger cherty levels with *Saccocoma*, that are allocated in the next unit. The age of the Calcari Diasprigni is based on radiolarian stratigraphy (Baumgartner, 1987; Bartolini et alii, 1996), and on faunas collected below and above them. Figures may vary in the literature also depending on the choice of lower and upper formation boundaries. The age of this unit - as we defined it above - should encompass the ?late Bajocian/Bathonian through the early Kimmeridgian.

- *Calcari ad aptici e Saccocoma Fm.* This is a calcareous/marly/cherty unit with strong lateral variability. Lithology and texture change from pale radiolarian-rich cherty mudstones with only sparse *Saccocoma* ossicles, to dark red fossiliferous (aptchi, belemnites, rare ammonites etc.) nodular marls, to grey/pink graded and laminated crinoidal sands, locally well sorted and thoroughly silicified. The latter two facies are best developed closer to the plateau, while muddier facies are found more to the east. Sections close to the plateau have bed packages, decimeters to 5 m thick, with intercalations of the Bugarone superiore Fm. in the form of pale-coloured nodular to wackestone with Tithonian cephalopods, bivalves, gastropods, brachiopods, and crinoids (“off-platform tongues” of Santantonio et alii, 1996). The average thickness is about 20 m. The age is Kimmeridgian p.p. - Tithonian.

- *Maiolica Fm.* The unit is almost entirely made of thinly bedded white chalky radiolarian mudstone, with only sparse macrofauna (cephalopods) and calpionellids in the lower part. Resedimented levels of shallow water origin are virtually missing, but evidence of submarine sliding of pelagic mud is provided by common slumps. The base is marked by the disappearance of *Saccocoma*, while the top is placed above the last black chert bed, and can locally bear thin black shales. The Maiolica has a maximum thickness of about 0.5 km. Its age is Tithonian/Berriasian to earliest Aptian.

**STOP 1 – FACIES AND GEOMETRIES OF PLATEAU-TOP, PLATEAU-EDGE AND MARGINAL BASIN DEPOSITS AT CASTIGLIONE**

M. Santantonio

Substop 1.1 – The condensed succession near the plateau edge (see above for a general description of individual formations; only local features will be mentioned here).

The thin Jurassic succession at Castiglione was described by Maxia (1948, 1951, 1952) and by Farinacci (1967). Cecca & Santantonio (1982) and Cecca et alii (1985) described the composition and biostratigraphy of the Kimmeridgian - Tithonian ammonite fauna, and Castiglione is the locality where the Bajocian/Kimmeridgian hiatus was first described and defined with an ammonite-zone resolution. The paper by Farinacci (1967), in particular, contains several useful sedimentological and geometrical observations. Most notably, she described the erosional morphology of the local palaeoescarpment tract and the thickening to the west of the condensed succession. However, her interpretation of subaerial exposure features within the pelagic succession, and the Oxfordian age she inferred for the Rosso Ammonitico cannot be confirmed at present.

A thin Liassic to Lower Cretaceous succession is exposed for 0.7 km along the southern slopes of the hill where the abandoned village of Castiglione was built.

The uppermost meters of the Calcare Massiccio bear traces of repeated subaerial exposures, like reddened surfaces and irregular cavities infilled with brown barren mud, and the top surface of the unit is locally irregular, so it is conceivable that a phase of emersion predated its drowning (more on this below). This could have been related to an isostatic uplift of the footwall (Jackson & MacKenzie, 1983) coincident with the phase of severe extension that gave birth in the Sinemurian to the Sabina Palaeofault and the Sabina Basin to the east.

The Calcare Massiccio B is either missing or is sometimes seen to fill in small pockets at the top of the Calcare Massiccio.

The Corniola-equivalent Fm., representing the lowest bed of the condensed pelagic facies association, is also either missing or it occurs patchily, with a maximum observable thickness of few decimeters. Two main facies can be recognized:

1. Bioclastic wackestones with ammonites (*Emaciaticeras* sp. - Domerian p.p.);
2. Mudstones with ostracods and rare ammonites, in thin alternating red and yellow-green cm-thick bands locally separated by isopachous calcite cement crusts.

The latter facies is especially intriguing. The yellow mudstone is inhomogeneous, but not in the way bioturbation might for example have produced it, nor is any obvious sedimentary structure visible. Rather, cm-size undulations seem to define small lithons, thus seemingly representing a secondary modification of the original homogeneous sediment through some sort of stress and/or plastic flow. This mudstone must then have been sliced into thin sheets, creating stacked laminar cavities that were enlarged and filled with younger silt to mud-size red sediment resembling bedding-parallel neptunian dykes, connected by high-angle fissures (Giovagnoli, 1981). This sediment is sometimes graded and contains internal discontinuities. Also, the cavities remained locally partially empty, forming geopetal
structures, all this suggesting that the infilling was discontinuous and difficult. On top of that, the yellow-green laminites are often crinkled and folded and have small internal thrusts.

This mix of extensional and contractional geometries associated with the above described features and confined to this particular stratigraphic level is strongly suggestive of creeping and detachment along the top of the Calcare Massiccio, which might have occurred even along a minimal slope under the burden of at least the Rosso Ammonitico-equivalent, which provided the infilling material. Analogous sheet cracks received a similar interpretation by TUCKER (1974) in a Palaeozoic condensed succession and by KENDALL (1985) in an ancient forereef.

The Rosso Ammonitico-equivalent overlies in geometrical concordance either the Corniola-equivalent or the Calcare Massiccio, in the latter case marking a drowning unconformity (SCHLAGER, 1989). Its thickness here is ~9 m, but it reaches 16 m less than 1 km to the west, and can be either deep red or yellow, with a distinctive “onion-like” exfoliation.

The Bugarone inferiore is consistently 19 to 21.5 m thick throughout the area. Near the base it yielded latest Toarcian Catullooceras sp., while the top has stephanoceratid faunas indicating the lower Bajocian Stephanoceras humphriesianum Zone.

A paraconformable contact marks the base of the Bugarone superiore. This unit is 1.9 m thick here, but thickens westwards to about 6 m. The Kimmeridgian is locally as thin as 37 cm thick and, besides being thicker, it bears a more

clonologies of microsolenid pennular corals in the upper part (see SANTANTONIO et alii, 1996, and bibliography therein, for an extensive discussion). The condensed ammonitiferous facies typical of the Bugarone superiore also continues into the upper Tithonian and the lower Berriasian, where it still bears occasional pennular corals in a typical Maiolica-like matrix with Calpionella alpina (Berriasella jacobi Zone, F. CECCA pers. comm.) (see also CECCA, 1985).

The Maiolica is 58 m thick and is dolomitic from 3 to 20 m. Chert appears at 8.5 m from the base.

Substop 1.2 - Geometries and lateral variability of the Bugarone superiore, and oolite-rich lenses in the upper beds of the Bugarone inferiore

Less than 20 m to the west of the previous substop, the Bugarone superiore displays some peculiar local geometries. The Kimmeridgian here is a lens that is 60-80 cm thick and, besides being thicker, it bears a more

THIN-OUT AT PCP EDGE - DETAIL OF BIOZONES
Castiglione: edge of the Sabina Plateau

Fig. 6 - Ammonite biozonal correlations, showing disappearance of units towards the east (plateau edge) at Castiglione. Note horizontal scale.

Fig. 7 - Lower Tithonian bed of Bugarone superiore (T) wedging out towards the Plateau edge (east), and resting on the Kimmeridgian (K). Castiglione, condensed succession.
complete biostratigraphic record with the *Mesosimoceras cavouri* Zone, which was missing in the previous section.

Also, the *H. beckeri* Zone here is 15 cm thick (Fig. 6). Above it, the geometry of the lowest Tithonian bed is that of a prominent wedge that changes from 70 to 10 cm eastwards over a distance of a mere couple of meters (Fig. 7). These features are taken as an evidence of the mounded geometry, with drastic thin-out towards the edge (lying to the east, as we shall see), of the plateau-top condensed sedimentary cover.

Below the Bugarone superiore, the highest beds of the Bugarone inferiore are more richly ammonitiferous than the rest of the unit. Two discontinuous lens-like levels occur in its top 3.4 meters, having some intriguing features. Their maximum thickness is 30 cm, and is achieved wherever their base is a concave scour. They are normally graded and parallel to cross-laminated, and are made of a mixed posidoniid/oolite sediment with added mud chips of the host formation (Fig. 8).

In thin section, oolites are seen to belong to the "well rounded micritic ooids with thinly laminated cortices" and the "oolids with thinly laminated fine-radial cortices" types of *STRASSER* (1986) (Fig. 9). So they are typical shallow-water oolites.

This occurrence is quite unexpected, because no trace of a peritidal platform can anywhere be documented in the Bugarone inferiore of the plateau, thus the ooids must be displaced. However they are found on a prominent morpho-structural high, so a gravity flow origin should theoretically be ruled out. This is however not the case here, because their occurrence can indeed be best explained as the result of overbanking of a turbidity flow travelling across the Sabina Basin, and finally impacting the huge obstacle represented by the marginal palaeoescarpment of the plateau (*GALLUZZO & SANTANTONIO*, 2002). Oolite-rich turbidites coming from the Latium-Abruzzi Platform, sometimes in very thick beds, abound in the basinal equivalent of the Bugarone inferiore, the Calcari e Marne a *Posidonia*. Moreover, these resedimented beds are commonly found onlapping the palaeoescarpment, so crashing of turbidity flows against submarine outcrops of Calcare Massiccio must have been common. Given the estimated submarine relief at the time, amounting to no more than 250-350 m, the possibility for a turbidity flow, that is commonly tens to even hundreds of meters thick within the water column, to run up the plateau flanks and sweep its top was fully feasible (*KNELLER & BUCKEE*, 2000) (Fig. 10).

We shall resume this discussion on the occurrence of ooids below, as we shall see that they are also found elsewhere in the area.
Substop 1.3 – The marginal palaeoescarpment, megabreccia, and the epi-breccia deposits

Walking on the top surface of the Calcare Massiccio towards the east for few tens of meters, the plateau-top condensed succession suddenly disappears, and is laterally replaced by a chaotic body made of limestone blocks up to several meters across. They form an heterometric clast-supported megabreccia resting unconformably on the Calcare Massiccio and the Rosso Ammonitico-equivalent through an erosional surface that truncates the normal succession laterally at high angle and dips towards the east. The breccia is in turn seen to be onlapped by east-dipping basal strata of the Maiolica Fm., so the area must represent the local marginal palaeoescarpment of the Sabina Plateau. The blocks are often stacks of beds of Bugarone inferiore, while the number of clasts of Calcare Massiccio increases downwards as a result of sourcing from a relatively thicker section of this unit. The clasts of Massiccio are interesting because they are often made of a spectacular subaerial exposure facies with dissolution cavities infilled with brown sediment, clotted fabrics, etc. The characean-rich continental deposits described by FARINACCI (1967) probably were sampled in these clasts. As mentioned above, this confirms that the upper levels of the unit were subjected to non-marine deposition and vadose diagenesis prior to drowning.

One striking aspect of the breccia resides in its matrix. It is in fact clearly seen that the inter-clast spaces were filled with Rosso Ammonitico-equivalent while it was still plastic: the (light brown) nodular marls often act as cushions between larger blocks, or form load-induced “flames” (Fig. 11). This is unusual for two main reasons: 1. the matrix is in fact older than the clasts - it constitutes some sort of a “recycled material” matrix; 2. the Rosso Ammonitico-equivalent had a slower diagenesis than the Bugarone inferiore, which produced instead angular clasts that were in no way folded. This peculiar behaviour of the Rosso Ammonitico-equivalent is well seen across the whole Castiglione area, because neptunian dykes crossing it often have irregular and ill-defined walls and form a network of irregular anastomosed veinlets.

The contact of the megabreccia with the Calcare Massiccio became the site of fracturing in the Early Cretaceous, as demonstrated by a dyke, probably several meters wide but partially covered by vegetation, made of Maiolica. The megabreccia is seen to rest on the escarpment down to a point of elevation that is about 100 m lower than the local top of the Calcare Massiccio. Here, at the base of the outcrop, the erosional surface of the Calcare Massiccio forms an horizontal plane, thus defining an overall listric geometry that also serves to explain why the tail of the megabreccia remained perched on the escarpment – which is what we see here today - while other blocks must have fallen into the basin.

Epi-breccia deposits occur in two main forms: the rarest is represented by perched ponds of oolite-posidonoid sediment, up to 20 cm thick. Their origin, according to the interpretation offered above, should be the result of overbanking of platform-derived turbidity flows (Fig. 12).

By far the most widespread epi-breccia deposit is a discontinuous veneer of Bugarone superiore levelling the irregular top of the breccia and representing an example of the composite pelagic facies association (see above) resting on both the clasts and the nodular matrix (Fig. 13). Careful inspection of every outcrop demonstrated that no sediments older than the Kimmeridgian (C. divisum Zone) are present. The lower Tithonian often occurs with an ammonite assemblage dominated by large...
specimens of *Hybonoticeras hybonotum*, also with fish teeth. These sediments are in turn unconformably overlain by the onlapping chert-bearing Maiolica and can be locally silicified as a result (see SANTANTONIO et alii, 1996 for a discussion).

Regarding the age of the megabreccia, the most reliable constraint is the occurrence of the oolite-rich ponds. Because this occurrence is so exceptional, an age correlation of the ponds with the lower Bajocian oolite-bearing beds in the upper part of the plateau-top Bugarone inferiore is more than a tempting option. There are at least two lines of evidence suggesting this was probably indeed the case:

1. The facies of the uppermost few meters of the plateau-top Bugarone inferiore is more ammonite-rich than the lower levels. This suggests that a plateau-edge most condensed facies replaced a plateau-interior, less condensed facies as the result of backstepping of the plateau margin due to the rockfall. This means a rejuvenation of the "panettone" architecture.

2. Oolites are also found in *posidoniid*-rich neptunian dykes crossing the Rosso Ammonitico-equivalent. It is conceivable that these fissures, as well as the megabreccia, were formed as the product of some earthquake shock, perhaps related to a minor phase of basin-wide extension. Therefore we can hold a) the initiation of the turbidity current from the slopes of the Latium-Abruzzi Platform, b) the backstepping of the plateau margin and origin of the breccia, c) the eventual breaking of the turbidity current against the escarpment and the overbanking, with the platform-derived sediment climbing the breccia, partly filling the fissures, and scouring the plateau top, as the collective product of the same event.

**Substop 1.4 – Multiple detachment scars carved into the condensed succession, and the erosional palaeomorphology of the plateau margin**

Climbing up the megabreccia, we finally reach one of the areas from which the fallen blocks must have been sourced. This is where the basinal beds of the Maiolica onlap directly the condensed plateau-top succession. The contact is strongly irregular, and one prominent erosional surface defines a scar into the Bugarone inferiore that is subcircular in plane view (Fig. 14). This is several meters across, has steep subvertical walls, and is filled by Maiolica covering an earlier discontinuous drape of Bugarone superiore. Another smaller accessory scar forms a further indentation into the Bugarone inferiore and is completely filled with Bugarone superiore with Tithonian ammonites of the *H. hybonotum* Zone. These scars are sculpted into a gently sloping erosional surface, truncating beds of the Bugarone inferiore, that represents a vestige of the uppermost palaeoescarpment and is onlapped by a Maiolica that is latest Berriasian/Valanginian in age (M.C. GIOVAGNOLI and F. CECCA, pers. comm.) (Fig. 15). Both this palaeosurface and the draping Bugarone superiore are silicified at the contact with the Maiolica. The age of this onlapping Maiolica is younger than the base of the Maiolica in the plateau-top succession, which is also topographically higher, so a Maiolica-on-Maiolica unconformity must have occurred as the final stage of burial of the escarpment, marking the end of the basin-fill history that started in the Sinemurian.

A final general remark on the Castiglione area regards the thickness of the post-Maiolica units. Having seen how the Maiolica onlapped the uppermost escarpment, so that the history of the Sabina Plateau came to an end, one might have expected younger formations to have even thickness across both the former...
plateau and the basin. The Aptian to early Cenomanian Marne a Fucoidi Fm. and the Cenomanian to Eocene Scaglia Bianca and Scaglia Rossa Formations are instead unexpectedly thin on the plateau. This strongly suggests that differential compaction played a significant role, in that the area formerly occupied by the Jurassic Sabina Plateau continued to act as a subdued intrabasinal high flanked by secondary (compaction-induced) slopes for tens of million years after its burial. These slopes were developed above the former plateau/basin transition, and became the sites of sediment sliding and section thinning. Perhaps this was also enhanced by a modest phase of tectonic rejuvenation in the Early Cretaceous that is documented across the whole area by neptunian dykes filled with Maiolica.

Several sedimentary and diagenetic features are most notable in the area.

The Calcare Massiccio is severely silicified, the proportion of visible chert being a direct function of proximity to the contact with the radiolarian cherts. Typical sedimentary structures of the peritidal environment are underlined by chert, like cryptalgal lamination (Fig. 16).

A very condensed succession of Corniola-equivalent, Rosso Ammonitico-equivalent and Bugarone inferiore is found resting unconformably on the block. This must represent a former epi-escarpment composite facies association that remained attached to the fallen block of Calcare Massiccio as the escarpment retreated.

Mapping around Le Cimitelle reveals that the base of the olistolith actually rests on beds belonging to the upper part of the Calcari e Marne a Posidonia, so it is not unlikely that the detachment of this block was synchronous with the emplacement of the megabreccia at Castiglione in the Bajocian. Also, the actual palaeoescarpment tract that sourced the block is exposed a mere 200 m to the west, indicating that the block underwent only minimal transport.

STOP 2 – THE HILL-SIZE OLISTOLITH AT LE CIMITELLE

M. SANTANTONIO

The area of Mt. Cimitella, on which the small village of Le Cimitelle is built, is located near the northern termination of the Sabini Mts. Here a huge block of Calcare Massiccio, more than 100 m across, is seen embedded in the basinal Calcari Diasprigni Fm. representing the westernmost termination of the Sabina Basin succession close to the palaeoescarpment. This block is part of a prominent north-south trending alignment of megabreccias and isolated olistoliths.

STOP 3 – THE BASIN-MARGIN DEPOSITS AND PALAEOESCARPMENT TRACT AT MT. MACCHIALUNGA

M. SANTANTONIO

Along the eastern slopes of Mt. Macchialunga another tract of the Sabina Palaeofault escarpment is beautifully exposed, along with the breccia-bearing termination of the Sabina basinal wedge.
Substop 3.1 – Olistoliths and bedded breccias in the Calcari ad aptici e Saccocoma

The Upper Jurassic deposits found 1 km east of the Mt. Macchialunga summit have quite interesting sedimentological features. An olistolith of Calcare Massiccio bears on its top a mound-shaped bed package of nodular Bugarone superiore (max 5.5 m, but much less near the edges) having at its base an upper Kimmeridgian ammonite assemblage with Taramelliceras (T.) compsum (OPPEL). This is followed by laminated Saccocoma sands with intercalations of Bugarone superiore. Upsection these sands also bear graded and laminated breccias up to few decimeters thick, and they become cherty. Then another olistolith occurs, about 3 m thick, capped in turn by about 2 m of Bugarone superiore and then draped by cherty Saccocoma-rich deposits that in 5-6 m change vertically to the Maiolica (Fig. 17). While it must be stressed that these thickness figures have strong lateral variability, a general interpretation can be offered envisaging the repeated ephemeral development of epi-olistolith condensed sedimentation that could only last until the sea-bottom topography was levelled with bioclastic and lithoclastic deposits.

Substop 3.2 – The upper palaeoescarpment tract

The beds of the basin-margin succession can be traced laterally westwards until they abut the Calcare Massiccio that constitutes the backbone of Mt. Macchialunga (Fig. 18). The contact strikes approximately N-S. Topographically lower, small ponds of epi-escarpment deposits occur between the Calcare Massiccio and the Maiolica, that have yielded a large specimen of the Tithonian species Aspidoceras rafaeli (OPPEL).

STOP 4 – RESEDIMENTED DEPOSITS OF THE SABINA BASIN – (REATINI MTS.)

C. Muraro & M. Santantonio

INTRODUCTION TO THE GEOLOGY OF THE REATINI MTS.

The Jurassic deposits of the Reatini Mts. were originally sedimented in the Sabina Basin s.s. (Fig. 1), as defined in the general introductory chapter. As such, they are typically represented by thick, re sediment-dominated successions (CHIOCCHINI et alii, 1975). In general, the volumes of material derived from the Latium-Abruzzi Platform decrease westwards, i.e. in the areas visited during days 1 and 2 of the present field-trip. Sections
more proximal to the L-A Platform received so much allochthonous sediment that placing formation boundaries is often a difficult exercise. It must be noted that recent research is demonstrating that the Sabina Basin possessed internal structural complications in the Jurassic, in the form of pelagic carbonate platforms and ramps which generally became buried with basinal deposits in the Middle Jurassic (see above) (Leonardi et alii, 1997). This indicates these were relatively deeper-water highs with respect to the Sabina Plateau, with the exception of few small areas where condensed deposits are as young as the Kimmeridgian - Tithonian.

More research is currently underway, including a geological sheet mapping project, which will hopefully result in a better understanding of the palaeofault and facies architecture of the Reatini Mts., and of the processes that influenced the shedding of shallow-water carbonate into the basin during the Jurassic.

The structural setting of the Reatini Mts. is, like the Sabini Mts., dominated by east-verging thrusts bounding discrete tectonic units mostly made of Mesozoic and Early Tertiary carbonate formations (Cosenzino et alii, 1991). One peculiar stratigraphic aspect of the area is the local outcrop of Upper Triassic peritidal dolostones at the hangingwall of thrust faults.

**THE COLLE CASARINE SECTION**

C. Muraro

This section crops out along the dirt road connecting Gli Osti to Fontanile Versanello, between Colle Varco and Colle Casarine (Cantalice Alto, RI). It is a typical mixed pelagic-resedimented section with several sediment gravity flows. These include: turbidites, composed of carbonate platform-derived grains (oolids, peloids, oncoids, benthic forams, algae, skeletal debris) and lithified clasts, with incomplete Bouma sequences (generally T_ab, rarely T_ac, T_b, T_c); debris flows with soft, rounded and flat micritic clasts, and flat calcarenitic clasts. Examples of deposits with border-line features between different kinds of sediment transport often occur, including beds with very thick non-organized conglomeratic bases followed by much thinner graded and laminated intervals.

In this stop the Calcari e Marne a Posidonia Fm. and Calcari Diasprigni Fm. only will be treated (upper Toarcian p.p. - Kimmeridgian p.p.). The top of the latter unit is not well exposed, due to minor faulting and soil cover. The transition between the Calcari e Marne del Serrone and Calcari e Marne a Posidonia Fms is continuous and very gradual. The base of the latter is marked by an increase in carbonate content and by the appearance of chert. The thickness of the measured section (Fig. 19) totals about 225 m. Six intervals, with different resediments/pelagites ratio, have been recognized. In general the frequency and thickness of resedimented deposits increase up-section, along with changes in their composition.

The interval I, from 0 m to 30.6 m, comprises grey to pale brown micritic (mudstone to wackestone) limestone and marly limestone. Grey chert occurs in nodules and rarely ribbons. Centimetric greenish marly intercalations are also present. The limestone contains radiolarians and posidoniids. Rare ammonites occur only in the lower beds. Bed thickness ranges between 10 and 30 cm.

The interval II, from 30.6 m to 101.2 m (70.6 m), is characterized by the appearance of gravity flow deposits. Grey to pale brown limestones, cherty limestones and radiolarian sands are interbedded with sporadic detrital beds (resediments/pelagites ratio: 1/4). In the pelagic levels grey chert occurs as nodules and, more frequently, as ribbons, and becomes reddish upsection. White chert is typical of resedimented beds. Resedimented levels consist of white packstone, rarely grainstone, to wackestone, normally graded (incomplete Bouma sequence T_a,b). Turbidites with conglomeratic bases and debris flow deposits occur at several levels. The clasts in these deposits are generally flat and several centimeters across, and are made of a pink micrite and/or of calcarenite, with a very coarse-to-medium sand matrix. Bed thickness ranges between 10 and 40 cm (limestones), 10 and 20 cm (chert ribbons). Resedimented levels are 10 to 255 cm thick. Pelagic deposits only bear posidoniids and radiolarians.

The interval III, from 101.2 to 152.6 m (51.4 m) records an increase in resediments/pelagites ratio (1/3). The pelagic beds comprise radiolarian sands with posidoniids, and subordinate ribbon cherts, red and pink in colour. Parallel lamination occurs in almost all these beds, mostly a product of changes in the average size of biogenic components. The last occurrence of posidoniids is recorded at 150 m. The resedimented levels are normally graded (incomplete Bouma sequence T_a,b), medium to very fine sand-size. Isolated T_a (fine or very fine sand) divisions occur in beds 10-20 cm thick. All detrital beds contain oolites and other platform-derived grains (ooloids, peloids, oncoids, benthic forams, skeletal debris). Bed thickness ranges between 3-10/40 cm (pelagic limestone), 5-30 cm (chert) and 10-80 cm (detrital levels).

With the exception of one gravel-size level (131.8 m to 132 m), this interval is characterized by the absence of coarse resediments.

The interval IV, from 152.6 m to 171 m (18.4 m), is characterized, again (like the first interval), by the complete absence of platform-derived gravity flow deposits. It comprises white-greenish thin bedded (1-10
Fig. 19 – The Colle Casarine section.
cm) radiolarian sands with subordinate white-greenish radiolarian-rich micrites, interbedded with red ribbon cherts. Parallel lamination occurs in almost all beds.

The interval V, from 171 m to 192.7 m (21.7 m), marks the reappearance of gravity flow deposits, with a resediments/pelagites ratio of 1/1. Amorphous cherts, radiolarian sands and subordinate radiolarian-rich micrites are interbedded with normally graded turbidites, very coarse to very fine sand-size. Resedimented beds contain oolites up to 189.35 m and become more bioclastic up-section. In the upper portion of this interval (up to 185 m), green and red chert with pinch and swell structures occurs in the pelagic beds. Bed thickness ranges between 2-10 cm (pelagites), and 10-90 cm (resediments).

The interval VI, from 201.2 m to 225 m, is almost solely constituted by resedimented deposits, with the exception of few centimeters (between 199.5 m and 201.2 m) of grey/green thin parallel- and cross-laminated calcareous radiolarites with sponge spicules, probably the product of current winnowing. The turbidites are normally graded, generally from medium/fine to very fine sands. This is the first interval with common Bouma $T_{ac}$ sequences. Isolated $T_c$ beds also occur. Only three detrital beds are coarse-grained, with centimetric flat micritic clasts at the base, scattered in a medium-coarse sand matrix. These levels are poorly sorted and normally graded. White chert occurs as nodules, lenses and ribbons. All detrital beds show a variable degree of silicification and desilicification. Bed thickness ranges between 15 cm and 3 m.

As noted above, the striking feature of this section resides in the occurrence of abundant platform-derived material. Additional evidence in this respect is found in another section, at Fosso Versanello (~2 km NE of Colle Casarine), where a continuous succession ranging up to the Maiolica Fm. is strongly resedimented throughout the Cretaceous.

These mixed pelagic/resedimented successions record the ongoing productivity of the Latium-Abruzzi carbonate platform during the whole Jurassic. However, a comparison with other coeval successions in the western, more distal, part of the Sabina Basin clearly shows that the late Bajocian to Oxfordian was a time of severe contraction of sediment export from the platform. This is evidenced by the virtually complete absence of resedimented beds in the Calci Diasprigni Fm. (radiolarian cherts). Several Authors have noted that basinal pelagic successions in the Umbria-Marche and Sabina regions document discrete steps in the palaeoceanographic, palaeobiological, and carbonate productivity history of the Western Tethys, which are also recorded as shifts in the $\delta^{13}$C curve. The palaeoceanographic significance of the enigmatic posidonid-bivalve deposits, and of the strikingly oligotypic-bivalve deposits, that characterized such an abnormally long time span (~10 My) over vast submarine areas of our planet is relatively poorly understood. The fossil content of the radiolarian cherts is even more discouraging, since radiolarians apparently became the almost exclusive inhabitants of the water column over a period of ~20 My. Although it is clear that what we see today is also the product of preservation, it has been argued that the long-lasting dominance of radiolarians, and the fact that they form deposits that are often entirely carbonate-free, corresponds to a period of crisis of carbonate productivity in the marine environment that occurred almost on a global scale. This is supported by the commonly accepted notion that carbonate mud in pelagic successions at the time (and earlier in geologic time) was essentially derived from peritidal platforms in the form of peri-platform ooze: calcareous nannoplankton accounts for only a very minor proportion of the carbonate rock constituents in pre-Tithonian pelagic successions. If we accept this, then pelagic successions become genetically linked to the platform successions, so that a pelagic succession that is starved in carbonate must record a carbonate productivity crisis, or a turnover of carbonate producers, that affected both the shallow-water and (to a relatively minor extent) the pelagic carbonate factories.

In our case, the sedimentary record from the Latium-Abruzzi Platform/Sabina Basin system suggests that the time of deposition of Middle-Upper Jurassic radiolarian cherts saw changes that affected several variables within the carbonate system: 1. type of organic and inorganic products (e.g. drastic reduction of mud); 2. production rates on the platform, and export rates (both reduced); 3. maximum distance covered by sediment gravity flows (limited to a relatively narrow belt outside the platform).


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Post-Symposium Field Trip B5
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THE TRENTO RIDGE AND THE BELLUNO BASIN

Scientific Coordinators
Pierangelo Clari & Daniele Masetti

Contributors
Marco Avanzini, Adriana Bellanca, Pierangelo Clari, Miriam Cobianchi, Monica Ghirotti, Daniele Masetti, Rodolfo Neri, T. Padovese, Giulio Pavia, Vincenzo Picotti, Renato Posenato & Edoardo Semenza.
The present guide results from the joint effort of several researchers of different universities of Northern Italy. All of them have worked, often independently, on the Jurassic formations of Southern Alps in the last 25 years. While some researchers have abandoned this area of study since the early nineties, some others still work actively in the region. Different personal backgrounds and above all different grades of updating may be recognized in the treatment of different stops but we hope that discussion in the field will remove possible doubts and fill up the gaps.

PierAngelo Clari & Daniele Masetti
INTRODUCTION

The Southern Alps (S.A.) are a large structural unit of the southern part of the Alpine Chain (Fig. 1). To the north, the S.A. are separated from the main body of the Alps by the major tectonic Periadriatic Line. To the south the crystalline and sedimentary rocks of the S.A. are buried below the alluvial sediments of the Po plain. Along the Southern Alps, that stretch for about 700 km in a W-E direction in Northern Italy, a tilted, nearly complete, crustal section is exposed. At the westernmost end, the deep continental crust rocks of the Ivrea-Verbano Zone crop out, while Mesozoic-Cenozoic sedimentary covers characterize the eastern sector, which is the goal of our field trip. Since the early seventies, the sedimentary cover of Southern Alps has been considered as a well-preserved section of the southern (Apulian) continental margin of the Mesozoic Tethys, characterized by a horst and graben structure inherited from the rifting associated with the opening of the central North Atlantic. The rifting phase took place in the Late Triassic (Rhaetian) and the Early Jurassic, and gave origin to high-standing blocks separated by troughs. All the western sector of the margin (Piedmont and Lombardy) rapidly drowned in Early Liassic times. In the eastern sector, instead, two structural and palaeo-geographical highs, known as the Trento Ridge (or Trento Plateau) and Friuli carbonate platform, separated by the relatively shallow Belluno Trough, persisted at least for the whole Jurassic.

The purpose of the field trip is to illustrate the complex stratigraphical and sedimentological features of two of the Jurassic palaeogeographic domains of the Southern Alps: the Trento Ridge and the Belluno Basin.

THE TRENTO RIDGE

It covers a wide area in NE Italy extending in a N-S direction from Verona to Bolzano and Cortina d'Ampezzo (Figs. 2, 3). Toward the east it passes into the Belluno through (see below), whereas to the west it is separated from the Lombardian basin by the “Garda escarpment” fault-system, active during the Jurassic and Cretaceous. The stratigraphical evolution of the Trento Ridge (T.R.) during the Jurassic recorded the sinking of this sector of the southern Tethys margin. Two main stages can be recognized, each one represented by a typical formation: a first phase of peritidal to shallow-water sedimentation during the Early-Middle Liassic that resulted in the thick pile of the Calcari Grigi di Noriglio Fm., and a second one of pelagic “condensed” sedimentation on the top of the drowned Trento platform epitomized by the Rosso Ammonitico Veronese Fm. (upper Bajocian to Tithonian). In the central part of the Trento Ridge (Altopiano di Asiago) these two formations are in direct contact, separated only by a mineralized discontinuity surface that underlines a gap ranging from the Toarcian to early Bajocian. In the marginal parts of the T.R., notably its western edge, on the contrary, a complex of oolitic and sponge-rich limestones (San Vigilio Group, Toarcian to Aalenian) separates the two formations. This group, about 500 m thick near the Garda escarpment, wedges out to zero towards the east.

THE BELLUNO BASIN

It is a narrow basin intervening between the Trento and Friuli platforms (Figs. 2, 3). It acquired its topographic identity in Early Liassic time during the breakup of a widespread Upper Triassic shelf. During the Early Jurassic the Belluno Basin was a starved depression accumulating fine-grained periplatform deposits as thin bedded cherty micrites. In Dogger time, ooid sands, derived from the Friuli Platform, filled in the Belluno Basin that turned, by the end of the Middle Jurassic, into a gentle slope connecting the Friuli Platform to the sunken Trento Ridge. A more detailed stratigraphy of the Belluno Basin can be found in the introduction to the third day stops.
AN INTRODUCTION TO THE JURASSIC SUCCESSION OF THE TRENTO RIDGE

P.A. CLARI & D. MASSETTI

During the first day we will cross the western margin of the Trento Ridge and we will see, with a different degree of detail, all the terms of the Jurassic succession of this domain. A brief summary of the Jurassic lithostratigraphy of this plateau is hence necessary before introducing the description of the stops (Figs. 3, 4).

THE CALCARI GRIGI DI NORIGLIO FM. (CG)

This formation, several hundred metres thick, and characterized by very rich fossil assemblages, has been studied by many researchers since the eighteenth century. More recently it has been split up into three

Fig. 3 - Biostratigraphic ages of the Jurassic formations in the eastern Southern Alps (modified from BAUMGARTNER et alii, 1995).
informal members, called Membro Inferiore (Lower Member), Membro Medio (Middle Member) and Membro di Rotzo (Rotzo Member) (BOSELLINI & BROGLIO LORIGA, 1971). The Lower and Middle members cover the Early Liassic, while the Rotzo Member corresponds to the Middle Liassic. Each member has a thickness that can exceed two hundred metres and is laterally continuous nearly all across the Trento Ridge. The most typical and renowned facies are those found in the Rotzo member, with abundant plant remains and extensive banks of oyster-like “Lithiotis”, probably the most representative and famous fossil of the Calcari Grigi Formation. However, the Lower and Middle members show facies sensibly different from the one of the Rotzo member, and a short description of the three members is therefore necessary.

**Lower Member (CG1)** - In the western sector of the Trento Ridge the upper portion of the lower member consists of cyclically arranged peritidal facies whose supratidal part has laminated dolomitized horizons, stromatolitic bindstones and desiccation features. Eastward, however, evidence of supratidal facies decreases, being replaced by subtidal micrites with sparse molluscs, benthic foraminifera and dasycladacean algae cyclically alternating with cm-thick levels of green clays.

A new genetic interpretation of these subtidal cycles has recently been presented (MASETTI et alii, 1998). This member, devoid of the attractive fossil remains of the Rotzo Member, has been little studied in the past. In recent years, however, the discovery at Lavini di Marco (see Stop 1) of several dinosaur tracks has focused on it the attention of many sedimentologists and vertebrate palaeontologists.

**Middle Member (CG2)** - It is an oolitic unit that covers most of the Trento Ridge and reaches a maximum thickness in excess of 200 m at its western margin. In the Altopiano di Asiago area it has a thickness of 30-40 m. It thins out to the east of Gallio. The transition from the peritidal facies of the Lower Member to the oolitic shoals of the Middle member probably records a deepening which corresponds to a general trend recognized across vast areas of the Tethys (Lombardy, Northern Apennines, Tunisia). The sea level increase was however accompanied on the Trento Ridge by a tectonic tilting or collapse of its western part, as suggested by changes in thickness and fossil assemblages.

**Rotzo Member (CG3)** - As mentioned above, this member is the more studied part on the Calcari Grigi Formation and will be observed in several stops, so only the most important features will be given here. Lagoonal
facies prevail, bearing abundant bivalve accumulations both of oyster-like "Lithiotis" and of megalodontid taxa. Bivalve species are indeed numerous in the Rotzo Member; several genera are grouped under the catch-all name of "Lithiotis", all sharing the ability to produce up to several metres thick lens-shaped beds, packed with large thick shells. A more detailed description of the paleontology and stratigraphy of the Rotzo Member can be found in the description of Stop 3.

THE SAN VIGILIO GROUP (SVG)

The bulk of this unit corresponds to those facies generally known in the literature under the name of Calcari oolitici di San Vigilio or Oolite di S. Vigilio, following works of BENECKE (1865), DE GREGORIO, (1886), and VACEK (1886) about the fossil locality of S. Vigilio on the eastern coast of the Garda Lake.

Recent research by BARBUJANI et alii (1986) has demonstrated that, at least in the Monte Baldo area between the Garda Lake and the Adige Valley, three formations make up the SVG, from bottom to top: the Misone Limestone, the Tenno Formation and the San Vigilio Oolite (SVO). During the excursion we will see only the S. Vigilio Oolite as the other two formations are limited to the westernmost part of the Trento Ridge. The SVO is made up of ill-stratified oolitic and encrinitic grainstones, with well-developed festoon cross-lamination, interlayered with thin biomicrites. These are the best known facies of the western edge of the Trento Ridge and are particularly thick in the southern part of Monte Baldo. This is the type locality of the formation, which attains a thickness of more than 200 metres. In the areas visited during our field trip, the SVO gradually thins out, and oolitic grainstones are replaced by sponge- and oncoid-rich wackestones and packstones, associated with bioclastic, mainly encrinitic, sediments.

THE ROSSO AMMONITICO VERONESE FM. (RAV)

It is perhaps the most renowned, red nodular limestone of the Tethyan realm, and can be regarded as the paradigm of the ammonitico rosso facies. Early descriptions of this fascinating limestone were given by DE ZIGNO (1852) and CATULLO (1853).

Interest in the RAV has not been purely academic, as the red nodular limestone has been actively quarried both in the Verona district and in the Altopiano di Asiago area for millennia. This beautiful stone can be seen in historical buildings not only in the nearby cities of Verona, Padova and Mantua but also in Bologna and throughout northwestern Italy.

Fig. 5 - Location of the stops of Field trip B5.
In the southern part of the Trento Ridge this formation consists of two calcareous members. The lower one everywhere begins with a stromatolitic layer, late Bajocian in age, resting on a severely mineralized surface. Rather massive, locally nodular, facies follow up to another stromatolitic layer of early and middle Callovian age. The upper Rosso Ammonitico starts with a stromatolitic bed (middle Oxfordian) overlain by nodular facies of the lower Kimmeridgian, grading upward to less nodular micrites (upper Tithonian) and then to the Cretaceous Biancone formation.

In many parts of the Trento Ridge (Monte Baldo, northern Monti Lessini, Altopiano di Asiago) a third unit is sandwiched between the two described above. It consists of thin planar beds with chert nodules and lenses bearing solely calcitic and siliceous skeletal remains. In the upper part of this member some 3 to 5 bentonitic clay layers make up a useful key-horizon for regional correlation. Ammonites and nannofloras, although sparse, indicate the late Callovian-middle Oxfordian. Abundant ammonites in the over- and underlying calcareous members, on the other hand, provide valuable biostratigraphic constraints evidencing that frequent stratigraphic gaps, some of which being major hiatuses like the Callovian-Oxfordian or the Oxfordian-Kimmeridgian gaps (Clari et alii, 1984; Pavia et alii, 1987), widespread discontinuity surfaces and repeated stages of reworking all account for the reduced thickness of the formation (20-25 m).

STOP 1 - THE DINOSAUR SITE AT THE LAVINI DI MARCO AND THE LOWER JURASSIC CALCARI GRIGI MEGATRACKSITE

M. AVANZINI

The dinosaur site at the Lavini di Marco is one of the richest in Europe. Three dinosaur tracks were first discovered in 1989 by L. Chemini. Many other footprints and tracks were found by a systematic field exploration of the site carried out from 1991 on (Leonardi & Mietto, 2000).

The trampled layers

The trampled sediments have been ascribed to the middle part (peritidal unit) of the Lower Member of the Calcari Grigi Formation. There are seven levels with footprints in a six metres thick section (Avanzini et alii, 1997) (Fig. 6); they can be traced over an area of a hundred of metres. The richest levels are 104, 105 and 106.

Layer 104 - It refers to the upper 10 to 15 cm of a 70 cm-thick subtidal bed (Fig. 6). It is a bioclastic packstone to rudstone which grades upwards to a peloidal wackestone containing ostracods. Locally, the topmost surface shows small-scale depressions, from a few mm to 100 mm deep, separated by hillocks. The depressions are commonly filled by laminated, ostracod-bearing mudstone and wackestone, which are capped by a dolomitic crust, clay, and iron oxides. These microtopographic features seem indicative of lateral karstification by analogy with observations on modern tropical carbonate islands (Borrouhill-Le Jean, 1993). The influence of freshwater is indicated by the stable isotope trend and, in particular, by δ18O values below -2‰ (Land, 1986).

At the top of layer 104 there are few trackways

Fig. 6 - Log showing stratigraphy, occurrence, and type of footprints for the studied stratigraphic interval. The dinosaur sketches represent the most common types observed at Lavini di Marco. The black dinosaurs are plant-eaters, the white ones are carnivorous.
exhibiting excellently preserved Ceratosauria footprints, *Eubrontes* ichnogenus (Fig. 7A).

Layer 105 - It consists of alternating stromatolitic laminae and light grey peloidal mudstones, dark grey bioclastic wackestones and reddish mudstones (Fig. 6). The lower boundary is marked by a light brown, laminated mudstone which levels the irregular surface topography of layer 104. The boundary with the overlying layer 106 is marked by mud cracks. A continuous layer of dark-grey wackestone, about 10 mm thick, containing *Thaumatoporella parvovesiculifera* is intercalated within the inter-supratidal stromatolitic bindstones. This continuous layer, probably a storm layer, grades into hazel-colored mudstone spotted by iron oxides, and is eventually capped by a pedogenetic rubefaction horizon characterized by iron-rich glaebules (BAIN & FOOS, 1993), clotted micrite and circum-granular cracking, all features indicative of supratidal conditions. SEM observations and EDAX analyses reveal that the red, pedogenetic horizons consist of a mixture of dolomite, limestone, clay and iron oxides. As a whole, layer 105 represents a first marine transgression after the emergence of layer 104, followed by seaward progradation of the tidal flat system which ended with subaerial exposure and inceptisol formation.

Smaller theropod prints are common where layer 105 is thinner. Larger, deeper theropod and sauropod prints, occur in thicker parts (Fig. 7B).

Layer 106 (100-120 mm thick) - It exhibits lateral facies variations in different sectors of the outcrop. The boundary with layer 105 is marked by dark grey stromatolitic bindstone and fenestral mudstone with iron oxides concentrated between cyanobacterial laminae. The top of the stromatolitic layer is pervasively dolomitized in the northern sectors of the outcrop (Colatoio Chemini) and exhibits deep sauropod footprints and tracks (Fig. 7C).

Layer 106 shows a series of parallel, low-relief belts separated by elongated ponds and shallow tidal channels (Fig. 8). The tops of the emergent areas were subjected to strong evaporation as indicated by mud cracking and dolomitization. In the Colatoio Chemini area a more depressed topography allowed the persistence of a water lens, such as a large pond, over a relatively long time span. Geochemical signals from this area indicate early diagenesis occurred by marine water.

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**Fig. 7** - The most common dinosaur footprints at Lavini di Marco. (A) Theropod trackway (*Eubrontes* sp.) at the top of layer 104 (scale bar: 10 cm). (B) Theropod footprint (*Eubrontes* sp.) at the top of layer 105 (scale bar: 10 cm). (C) Sauropod track (*Parabrontopodus* sp.) at the top of layer 106 (scale bar: 10 cm). (D) Small squatting ornithopod footprints (*Anomoepus* sp.) at the top of layer 106 (scale bar: 10 cm). (E) Undetermined bipedal track that show a striking similarity to large ornithopods.
In this case, dolomite precipitation may have contributed to the fossilization of the tracks (AVANZINI et alii, 1997; AVANZINI, 1998; BALTZER et alii, 1994; FAIRCHILD et alii, 1991; FRISIA, 1994).

THE ICHNOASSOCIATION

The footprints and tracks testify the presence of many dinosaurs. The most abundant are theropods, probably Ceratosauria, then there are early sauropods, some advanced ornithopods, bipedal dinosaurs (possibly small-size primitive ornithopods) and, finally, some unidentified dinosaurian footprints.

THEROPODS - The dinosaurs represented by tridactyl footprints, with slender and clawed digits of predators, are the most common in the site. The identified ichnotaxa are Grallator and Eubrontes (Fig. 6A, B). This association is similar to others found in the Lower Liassic. The trackmaker must belong to the suborder Ceratosauria, which was the only theropod group definitely alive during Early Jurassic times, even if a Tetanure specimen has recently been discovered in coeval beds in the Lombardian Basin (DAL SASSO, 2001).

SAUROPODS - There are many middle to large-size footprints and associated tracks which are quadrupedal, narrow gauge tracks attributed to primitive sauropods (Fig. 6C). They represent the oldest sauropod tracks found up to now in the world (DALLA VECCHIA, 1994). They resemble the Parabrontopodus ichnogenus of the Upper Jurassic of USA and Breviparopus from the Upper Jurassic of Morocco. The lateral position of the manual prints suggests a sauropod as the trackmaker, with a rather broad shoulder girdle and particularly well developed fore-limbs. This, as well as the age, suggests attribution to the poorly known family Vulcanodontidae (LEONARDI & MIEFF, 2000).

ORNITHOPODS - Some of the tridactyl footprints belong to primitive ornithischians, and include the Anomoepus ichnogenus, belonging to primitive ornithopods (perhaps “fabrosaurids”) (AVANZINI et alii, 2001) (Fig. 6D). There are also very deep and evident tridactyl or tetradactyl footprints associated in bipedal tracks (Fig. 6E). They show a striking similarity to the Late Jurassic and Early Cretaceous footprints attributed to iguanodontids. The trackmakers could be identified as

![Detailed map of the study area and facies distribution with respect to layer 106. Colatoio Chemini is the sector that is accessible to the public for guided visits. (1) dolomitized sector; (2) mudcracked facies; (3) flat-pebble breccias; (4) inter-supratidal mudstones with fenestrae; (5) intertidal facies with ripples.](image-url)
large, graviportal ornithopods, very ancient but not very primitive from an ichnological point of view (LEONARDI & METTO, 2000).

The ichnofauna of Lavini di Marco is quite different from other more or less coeval ichnofaunas (HAUBOLD, 1986), except in the case of theropods. Consequently we have to admit that the dinosaur fauna in the carbonate platform environment of this region was more evolved than in other regions of the world (LEONARDI & METTO, 2000).

THE MEGAICHNOSITE OF THE CALCARI GRIGI

The area where the Calcari Grigi Fm. crops out is defined as a megatracksite (LOCKLEY, 1991) composed by the single (Lower Member, peridital unit) track-layer at Chizzola (LEONARDI & METTO, 2000), Lavini di Marco (LEONARDI & METTO, 2000), Val Gola-Becco di Filadonna (AVANZINI, 1998), Cima di Vezzena (AVANZINI & TOMASONI, in press), Monte Pasubio and Monti Lessini (AVANZINI, 2001) (Fig. 9). Other tracksites occur in the upper part of the Calcari Grigi Fm. in the Alti Lessini (METTO et alii, 2000) and in the Valle del Sarca (AVANZINI et alii, in press) (Fig. 10).

As to the Lower Member, quantitative analysis carried out on palinomorphs showed that dominantly dry conditions documented by abundant circumpollens (Corollina ssp.) were interrupted by a humid event, demonstrated by abundant bryophyte (Porcellispora sp.), typical freshwater forms. This event, already recorded in Vallarsa, has been recognized also at Chizzola and Lavini di Marco within levels corresponding to the dinosaur footprints layers (AVANZINI et alii, 2000) (Fig. 9).

The footprints found at the Middle Member – Rotzo Member boundary are preserved in sediments that, toward the inner Trento Platform, have increasingly higher content in organic matter. Continental vegetables and ferns pollen in these facies document humid conditions that would have favored the formation of wide brackish ponds (AVANZINI et alii, 2000).

The dinosaur tracks of Valle del Sarca occur in the upper part of the Rotzo Member (Domerian), and demonstrate a turnover in the dinosaur fauna, with the presence of strongly different forms (probable Prosauropoda and Tyreophora) from those discovered through the lower part of the Calcari Grigi Formation.

The general conclusions are:

1) The continuous record of large vertebrate populations on the Trento Platform seems to indicate a constant link to continental areas during the whole Early Jurassic.

2) The presence of pollens in the trampled horizons show that in the Early Jurassic general dryness conditions were interrupted by a humid event.
3) The faunal change in the Late Liassic (with the presence of only small dinosaur forms) could be related to the drowning of the Trento Platform and the eventual separation of the tidal flats from the continental emerged land.

STOP 2 - SERRADA. THE "DROWNING SEQUENCE" OF THE TRENTO PLATFORM (LATE LIASSIC - MALM)

P.A. CLARI

The upper part of the Calcari oolitici di S. Vigilio (SVO) and the whole Rosso Ammonitico, crossed by some faults, are exposed along a road cut near the small town of Serrada. This section, only cursorily described in the literature (Assereto et alii, 1975), offers the possibility to see for the first time some peculiar facies of the Calcari oolitici di S. Vigilio and the three members of the Rosso Ammonitico Veronese.

CALCARI OOLITICI DI SAN VIGILIO FM.

About 30 metres of the SVO are exposed along the lower road cut (Fig. 11). In the first 10 metres white oolitic grainstones prevail with some minor intercalations of oncoid- and sponge-rich reddish wackestones and packstones. Bioclastic, oncoidal grainstones to wackestones with locally abundant inozoan sponges remains follow up to the contact with the RAV that is badly exposed in this section due to the presence of an iron grid. The color is generally red and yellow and several discontinuity surfaces are recognizable.

Oolitic grainstones show festoon cross-bedding and correspond to the typical facies of the SVO along the western border of the Trento Ridge in the type area. Oncoid and sponge rich grainstones to wackestones are on the contrary nearly completely absent in the westernmost sector and seem to characterize the more "internal" part of the Trento Ridge, testifying apparently a deeper sedimentary environment and a discontinuous sedimentation.

ROSSO AMMONITICO VERONESE FM.

The Lower Member of the RAV is exposed along the same road cut, while the Middle and Upper Members can be better observed along the same road few tens of metres uphill.

Lower Member (RAI) (3 m) - It is composed by massive pseudonodular beds. At the base, a thin stromatolitic layer rests on the top of the S. Vigilio Fm. This lower unit is in turn truncated by a spectacular mineralized hard ground, that cuts a thin bed full of polymetallic nodules and mineralized intraclasts, and is coated with a thick, laminated black Mn-Fe crust. The age of the Lower Member is here ill defined for the lack of ammonites; the top may be tentatively referred to the early Callovian.

Middle Siliceous member (about 4 m) - The first 50 cm are made up of thin planar beds. The remainder of the unit, still made up of thin beds, is rich in large reddish chert nodules and ribbons. In the median part of this unit three thin bentonitic layers are present (Fig. 12); the thickest of them, at about two metres from the top, may be correlated with analogous layers in other sectors (Altopiano di Asiago) described by Bernoulli & Peters (1970). In another section in Asiago this bentonitic layer is bracketed between calcareous beds containing badly preserved ammonites indicating the
middle to upper Oxfordian transition (CLARI et alii 1990). The age of the unit cannot be defined in this section but, by analogy with the Altopiano di Asiago, it may be late Callovian to middle Oxfordian.

Upper Member (RAS) (7-8 m) - It is represented by nodular beds several decimetres thick. The first bed contains an ammonite assemblage representative of the Crussoliceras divisum Zone (upper lower Kimmeridgian). A gap exists between the middle and upper units, encompassing the late Oxfordian and early Kimmeridgian. At 1.10 m from the base, most likely already in the Aspidoceras acanthicum Zone, a 40 cm thick, flaser-nodular bed has a clay-rich matrix predominating over the lighter-coloured calcareous ellipsoidal nodules. Beds having a similar facies and stratigraphic position occur in other sections of the Trento Ridge and can represent marker beds for correlation. The colour of the nodular facies changes in the upper part of the RAS from red to pink and then to white (“White Tithonian”), eventually passing to the overlying Lower Cretaceous Biancone Formation.

The characteristic facies of the Biancone, a marly micritic limestone with conchoidal fracture and brown grey chert nodules, is well seen in a downfaulted block few metres down the road. In this small outcrop some folded slumped beds are recognizable (Fig. 13). Folding also affected the chert layers, suggesting an early timing for silica migration.

Fig. 12 - Bentonitic layers of the middle siliceous member. The middle one is marked with a B.

Fig. 13 - Lower Cretaceous Biancone Fm. At the base of the outcrop a slumped horizon is clearly recognizable. Sisediementary folding is evidenced by chert layers.
THE ROTZO MEMBER OF THE CALCARI GRIGI FORMATION

The Rotzo Member is characterized by a rich paleontological content, described since the eighteenth century (DAL POZZO, 1764). The terrestrial plants, dominated by bennettitals and subordinately by Coniferae, filicals and equisetals, are well known thanks to the monographs of DE ZIGNO (1856, 1885) and WESLEY (1956, 1958). The Calcari Grigi Fm. is also famous all around the world thanks to its abundant, large aberrant bivalves, notably the genus Lithiotis, described in the second half of the nineteenth century. For a bibliographic review see LORIGA BROGLIO (2000).

Palaeontological research and taxonomical revisions performed in the Seventies (BERTI CAVICCHI et alii, 1971; ACCORSI BENINI & BROGLIO LORIGA, 1974, 1977; BROGLIO LORIGA & NERI, 1976; ACCORSI BENINI, 1979) revealed that several genera had in fact been grouped under the "Lithiotis" name, including Lithiotis (Fig. 14), Cochlearites (Fig. 15), and Lithioperna (Fig. 16). The morphology, microstructure and functional morphology of these, and other less frequent genera (i.e. Opisoma, Mytiloperna, Gervilleioperna, etc.) were described by CHINZEI (1982), SEILACHER (1984), SAVAZZI (1996), and BROGLIO LORIGA & POSENATO (1996).

The unusual shape of the Lithiotis and Cochlearites shells, extremely elongate and narrow (Figs. 14, 15), characterized by a spoon-like body space placed in a high position, which is rarely preserved, suggests adaptation to soft and muddy bottoms with an high sedimentation rate (mud-sticker of CHINZEI, 1982 and SEILACHER, 1984). The young shells were cemented to hard substrates often represented by adult valves. The adult shell, elongated in a dorsal-ventral direction, was almost completely infaunal and supported by mud and by other shells (LORIGA BROGLIO, 2000).

Lithiotis is characterized by a markedly inequivalve shell, 30-40 cm high, with a free valve, perhaps right, laminar and elastic, not thicker than 1-2 mm. The attached valve, 1-2 cm thick, is commonly preserved by fossilization. That valve shows a middle furrowed plate interpreted as a ligament area (SAVAZZI, 1996), laterally bounded by two plume-like areas recording the growth phases of the mollusc.

Cochlearites, on the contrary, shows a subequivalve shell, up to 60-70 cm thick, which is cemented with the left valve during the juvenile stage, always thicker than the right valve. Also in this genus the lateral plume-like areas are present, but here they limit a median region markedly different from that of Lithiotis. The left valve shows a median concave area becoming convex in the right one; this region is characterized by some ligament grooves in the umbonal region (ACCORSI BENINI & BROGLIO LORIGA, 1974).
**Lithioperna** is an isognomoid bivalve with a byssate juvenile stage, whilst during the adult stage living habits changed depending on the individual density and on firmness of the bottom (Broglio Loriga & Posenato, 1996). The ecomorphic variability is continuous from individuals with concave-convex cup-shaped shells, lying with the commissural plane horizontal, to thin, flat and elongated semi-infaunal shells, with the commissural plane vertical. The last one formed crowded, book-shaped, associations (Seilacher, 1984).

All the three genera above described developed mounds, in the most part monospecific, rising few metres above the sea floor, in which only the *Lithioperna* shells often show a vertical posture. *Lithiotis* and *Cochlearites* on the contrary have in general an inclined posture or form mechanical accumulations with a shells fabric parallel to bedding. The body geometries and their settlement mode have been discussed by Bosellini (1972), and, more recently, by Masetti et alii (1998) and Posenato et alii (2000).

In addition to these large bivalves, other gregarious byssate bivalves such as *Gervilleioperna ombonii* and *Pseudopachymytilus mirabilis* are present. They form lenticular bodies, no more than 1 m thick, normally intervening in the cycles between the "Lithiotis" mounds and the marly, coal-rich deposits. This latter lithofacies is referable to a marsh environment, representative of the most internal areas of the lagoon, and, where present, it is always found in a sequence-top position. For this reason, the *Pseudopachymytilus* and *Gervilleioperna* associations, sometimes containing rare *Mytiloperna* sp. and *Opisoma excavatum*, have been considered as indicating shallow subtidal or intertidal environments (Broglio Loriga & Neri, 1976; Loriga Broglio, 2000). The megalodontacean *Protidiceras pumilum* was also a gregarious form, common in the upper part of the Rotzo Member and characterized by small shells living partially buried in the mud. The marsh deposits also contain, both scattered and concentrated in lags, *Pachyrisma* (*Pachymegalodon*) chamaeformis, *P. (Durga) crassa*, *P. (D.) nicolisi* and *Pseudopachymytilus lepsii*.

The most diverse bivalve associations, representative of brackish to euryhaline environments, are on the contrary found in the marl-limestone alternations characterizing the lower part of the asymmetric cycles (see below), and which will be described below. The following genera were found: *Musculus*, *Trichites*, *Pteria*, *Camptonectes*, *Plicatula*, *Placunopsis*, *Plagiostoma*, *Protocardia*, *Anisocardia*, *Pholadomya*, *Pleuromya*, and *Gresslya*. These associations sometimes contain also brachiopods (*Lychnothvris rotzoana*), echinoids and crinoids (Padovese, 2001; see Substop 3.2).

Among Foraminifera, *Orbitopsella praecursor* and *Planiseptra compressa* (Loriga Broglio, 2000) are the most representative species occurring in the Rotzo Member. *Orbitopsella* is easily seen in the field thanks to its large size (1-1.5 cm) and to its biconcave lens shape (Fig. 17). The *Orbitopsella* Zone should indicate the late Sinemurian-early Pliensbachian (Fugagnoli & Loriga Broglio, 1998; Loriga Broglio, 2000) and characterizes the lower part of the Rotzo Member. The *Lituosepta compressa* Zone has been recently dated as late Pliensbachian (Septfontaine, 1984; Fugagnoli & Loriga Broglio, 1998; Loriga Broglio, 2000); it corresponds to the upper part of the member, where the

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**Fig. 16 - Lithioperna scutata** Accorsi Benini. Morphologic scheme of the right valve. (simplified from Broglio Loriga, 2000).

**Fig. 17 - Orbitopsella praecursor** Gümelp. About 20x.
"Lithiotis" beds are best developed (LORIGA BROGLIO, 2000).

The depositional environment of this unit has been referred to by BOSELLINI & BROGLIO LORIGA (1971) as a lagoon closed by a barrier island complex; its western margin coincides with the Monte Baldo massif; the eastern margin with the Monte Grappa. CLARI (1975) defined more precisely the depositional model of the Rotzo Member, still interpreted as a lagoon. Although largely correct, this interpretation does not take into account both the asymmetric facies distribution within the Trento Platform and the observed facies organization into asymmetric, thickening-upward cycles.

**FACIES, CYCLICITY AND DEPOSITIONAL ENVIRONMENT OF THE ROTZO MEMBER**

D. MASETTI

MASETTI et alii (1998) recognized in the Rotzo Mb. thickening-upward cycles at metric scale, predominantly subtidal, having a characteristic asymmetric profile (Fig. 18) due to the different erodibility of the component lithofacies. Within these general characteristic, is it possible to identify a complex typology of the facies sequences, the most classical expression of which is illustrated in Fig. 18 and consists of the superposition of the "Lithiotis" beds to the limestone-marl alternations.

The limestone-marl alternations represent the base of the facies sequences and consist of decimetric beds of grey, peloidal packstone/wackestone interlayered with grey-greenish marls; in this facies the carbonate beds are dominant over marl levels, showing a clear thickening-upward trend. Thin (1-10 cm) storm layers are locally present with disarticulated valves of bivalves or gastropods belonging to the genus *Aptyxyella* (Fig. 19). While this facies is commonly interpreted in the literature as inter-supratidal, MASETTI et alii (1998) considered it as deposited in a quiet subtidal environment, which was only occasionally swept by storm waves.

"Lithiotis" beds - This term is here used in a wide sense to indicate depositional bodies characterized by a shell-supported framework provided by the large gregarious bivalves cited above. The most common geometries of these bodies are thick (2-4 m) tabular (at least at the outcrop scale) beds or lens-shaped accumulations (*mounds*) (Fig. 20). Mounds can rise above the surrounding sea-floor more than 3-4 m. Settlement is allowed by the complex interaction between

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*Fig. 18 – Left: thickening-upward cycle in the Rotzo Member produced by the emplacement of the "Lithiotis" bed onto the limestones-marl alternations in the lower portion of the cycles. Center: blow-up of the facies composing the cycle; above, the "Lithiotis" bed showing the crowded packing of the shells; below, the limestone-marl alternations exhibiting mm-thick concentrations of bivalve shells as lags deposited by storm waves. Right: the outcrop aspect of the asymmetric cycle clearly displaying a thickening upward trend of the carbonate beds.*
biological and physical factors; these latter are basically linked to the quality of water (temperature, turbidity, oxygen levels, etc) and to the bottom firmness. This latter property is strictly linked to water turbulence which is, in turn, a function of depth: water energy is higher on shallow bottoms, resulting in dominantly coarse-grained deposits, while deeper areas are calmer and covered by muddy deposits. The first settlement of the "Lithiotis" beds within the Rotzo Mb. must have required a hard bottom, since the juvenile Cochlearites shells are directly cemented to the substratum; in a subsequent phase of development the right posture of individuals was granted by mud and by the high density of the settlement (LORIGA BROGLIO, 2000). That said, the birth of the "Lithiotis" beds must be linked to shallowing, since they are only found in the upper part of cycles.

In summary, each of the facies sequences above described in the Rotzo Mb. records gradual shallowing along an outer to inner ramp profile. Inner ramp environments were more turbulent, and covered by sand and by "Lithiotis" mounds, whilst in the outer and deeper sectors the limestone-marl alternations characterizing the base of cycles were being deposited.

The regional geometry of the Rotzo Member, coupled with the facies distribution across the Trento Platform, suggests that the sea-floor gently sloped westward, from the Asiago area towards the Adige Valley (Fig. 21). The marly facies, typical of the deepest part of the ramp, prevail in the western sector of the platform, from the Adige Valley to the Folgaria, Lavarone and Pasubio areas. Eastward, in the Altopiano di Asiago, the marly facies are thinner and reduced to few decimetres thick levels at the base of cycles.

A peculiar quality of this ramp is its lateral (western) closure by the coeval oolitic bodies outcropping in the M. Baldo group (Massone Oolite), which are typically missing in this kind of depositional environment, and which are instrumental in producing a lagoonal physiography. So the Rotzo Member probably represents a gently sloping ramp, although with a sandy rim enclosing a lagoon. Modern equivalents of this ancient environment, also perfectly comparable in size, are represented by the coastal lagoons in the western sector of the Persian Gulf, the best known modern example of a depositional ramp.

This novel depositional model is likely valid throughout much of the Trento Platform and especially for its north-western portion. In the Monti Lessini area, located in southernmost sectors of the same platform, the Rotzo Member is characterised by facies sequences quite different from the subtidal asymmetric cycles described above. In particular, the great diffusion in this area of coal-rich deposits derived from terrestrial plants seems to suggest that the depositional environment of the Rotzo Mb. here was closer to the emerged land and more restricted.

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Fig. 19 - The Aptyxiella level and the mollusc assemblage in the marls near the base of a thickening-upward cycle of the Rotzo Member, along the old road near the Valbona Pass.

Fig. 20 - The "Lithiotis" mound located along the Folgaria-Tonezza road cut, east of the Valbona Pass.
Substop 3.1 - Valico di Valbona: the mollusc assemblage in the marls of the Rotzo Member

R. Posenato, D. Masetti & T. Padovese

From the Valbona Pass, we shall follow the (no longer used) road leading to the old military site of Mt. Toraro. The roadway is cluttered by boulders and debris sometimes bearing interesting palaeontological material slid down from the walls along the road. Few hundreds of metres from the pass, we will encounter the typical asymmetric cycle illustrated in Fig. 19. It is characterized by a rich fossil assemblage in the basal marls, and by abundant Aptyxiella, Orbitopsella and Lithiotis problematica. This outcrop is stratigraphically correlated to the upper part to the Orbitopsella Zone.

The base of the thickening-upward cycle is made up by micrites with Lychnothyris rotzoana, followed by burrowed grey marls 100 cm thick, bearing an association dominated by the infaunal bivalves Gresslya elongata (50%), Pholadomya athesiana (8%) and rare individuals of Pleuromya calciformis (1%) and Aniscocardia sp. (1%). In addition, byssate (Pteria sp., 12%) and cemented (Placunopsis, 1%) pelecypods are also present. Moreover, this assemblage yields frequent articulated shells of brachiopods such as Lychnothyris rotzoana (20%), and turbinate gastropods (7%).

The relative abundance of brachiopods, with shells still articulated, suggests a depositional environment with normal salinity, below wave base, characterized by alternating conditions of muddy bottoms both soupy and semiconsolidated (Padovese, 2001). A micritic bed, 40 cm thick, with abundant Aptyxiella and rare brachiopods follows. Gastropods are largely oriented NS and EW suggesting a taphonomic reworking due to wave currents.

Above the Aptyxiella level a bed, 140 cm thick, follows rich in Lithiotis problematica shells lying horizontally, and thus not retaining their life position. This bivalve species is easily identified by the characteristic umbonal cavity visible on a transversal section. Scattered brachiopods are found throughout the bed; at its base solitary corals, and at the top, immediately below a thin calcarenite bed with Orbitopsella, a small bivalve (possibly Lithioperna) lag is present.

The palaeontological content, and the evolution of fossil assemblages through the whole thickening upward cycle described in this stop suggest deposition in an open lagoon. Its shallowing upward trend starts with quiet bottoms, below the normal wave base but occasionally reworked by storm events, and open to clay supply. The cycle ends with the deposition of the Lithiotis problematica bed in a more turbulent setting. The abundance of marine stenohaline taxa (i.e. brachiopods and Orbitopsella) suggests that Lithiotis was probably settled close to the open lagoon and that this genus
inhabited those portions of the lagoon directly fed by euhaline waters.

Substop 3.2 – Geometry and vertical evolution of the Cochlearites Mound, Cima di Valbona

D. Masetti

Along the Folgaria-Tonezza road, east of the Valbona Pass, a “Lithiotis” mound crops out (Fig. 20A-E) at the top of an asymmetric cycle whose lower portion is constituted by the limestone-marl alternations (A). On top of these alternations, the first colonization phase is recorded by a tabular body made up by small and thin “Lithiotis” shells (B). This first settlement fades upward into a thick and crowded colony constituted by the classic large “Lithiotis” shells representing the bulk of the entire mound (C). The last phase is represented by the infilling of the depression adjacent to the mound; the corresponding deposits (E) rest in onlap on the flank of the mound.

Trying to reconstruct the vertical and lateral evolution of this mound, also in terms of sequence stratigraphy, the vertical transition between B and C can be interpreted as a backstepping phase leading to the retreat of the colony towards the left of the figure. The oblique surfaces dipping to the right record the progradation in the same direction of the mound; the shell fabric, flat at the top, inclined and parallel to clinoforms at the flanks of the mound, suggests that mound progradation was allowed by the continuous growth of shells along the accreting mound flank. This shell addition to the flanks of the mound is interpreted as a primary living posture of the molluscs and not as a mechanical accumulation. Death of the colony is recorded by the storm layer represented by a “Lithiotis” rudstone (D) truncating the top and draping the flanks of the mound. The last phase is represented by the infilling of the depression adjacent to the mound; the corresponding deposits (E) rest in onlap on the flank of the mound.

THE DROWNING OF THE TRENTO RIDGE
STRATIGRAPHIC INTRODUCTION

P.A. Clari

During this second day of excursion we move eastward following the gradual thinning out of the San Vigilio Group. In the central part of the Trento Ridge, in the Altopiano di Asiago area, sediments of the S. Vigilio Group are in fact completely absent and the Rosso Ammonitico Veronese rests directly, through a sharp planar surface, on the Calcari Grigi Fm. The causes of this omission and of the genesis of the disconformity surface that separates the Calcari Grigi from the Rosso Ammonitico have been much debated. Current explanations take into account two nearly antithetic mechanisms: prolonged subaerial exposure (STURANI, 1971; ZEMPOLICH, 1993); sudden drowning of the Calcari Grigi platform, that became a current swept plateau with null sedimentation (WINTERER & BOSELLINI, 1981; WINTERER et alii, 1991).

A key element here is the interpretation of the peculiar deposits known as “Lumachella a Posidonia alpina” that are locally found between the two formations.

The Lumachella a P. alpina consists of spar-cemented thin-shelled bivalve coquinas (Posidonia alpina Auctt = Bositra buchi), locally packed with small ammonites. These coquinas generally fill irregular, dm-sized cavities in the topmost 0.50–2.50 m of the Calcari Grigi Fm.; locally coquinas grade into red, biomicritic limestones. Coquinas filling different cavities may have strongly contrasting ages “each of them representing an extremely short stratigraphical interval (part of single subzones) within the Humphriesianum, Subfurcatum and Garantiana zones of the Bajocian” (STURANI, 1971). The basal surface of the Rosso Ammonitico Veronese Fm. is perfectly flat and truncates both the cavity fillings and the encasing rocks (Fig. 22).

According to Sturani’s interpretation, the central part of the Trento Ridge was emergent from the Domerian to the Bajocian, and the topmost beds of the Calcari Grigi were subjected to meteoric diagenesis with formation of karstic dissolution cavities. In Aalenian-Bajocian times, molluscan and encrinitic coquinas were deposited inside these karstic cavities by hurricane-induced tides casting large amounts of shells ashore on a flat rocky island. In the alternative hypothesis proposed by WINTERER et alii (1991), the cavities filled by coquinoïd deposits are interpreted as slide-induced neptunian dykes filled by shells transported on a submerged current-swept plateau. Contrasting evidence seems to support either of these two interpretations from place to place. On one hand, for example, geochemical evidence of subaerial diagenesis has been discovered by MARTIRE (1992) and ZEMPOLICH (1993). On the other hand some of the cavities look more like simple cracks than karstic cavities and the filling of the cavities probably took place under water. Whatever their origin, sediments of the Lumachella a P. alpina are among the most beautiful and intriguing facies of the Mediterranean Jurassic.

Another intriguing facies of the Jurassic of the Trento ridge is the Rosso Ammonitico Veronese. As noted above, the RAV is a thin (about 25 m) lithostratigraphic unit consisting of red pelagic
limestones, commonly nodular and rich in ammonites, that was deposited during the Middle to Late Jurassic on the top of the drowned Calcari Grigi Platform. It is followed transitionally by the Lower Cretaceous thin bedded, white, micritic limestone of the Biancone, the Venetian equivalent of the ubiquitous Maiolica of central Southern Alps and the Apennines.

The RAV has been the subject of palaeontological studies since the Eighteenth century because of the richness of some layers in ammonites moulds (e.g. CATULLO, 1853; BENECKE, 1865; PARONA, 1880). After more than half a century, since 1960, a renewed interest in the RAV resulted in several studies both on the stratigraphy and the sedimentology of these peculiar limestones. A modern stratigraphic framework for the RAV was established by STURANI (1964) and led to the distinction of two members separated by an important hiatus: a Lower Member (RAI: Rosso Ammonitico Inferiore, upper Bajocian-lower Callovian) and an Upper Member (RAS: Rosso Ammonitico Superiore: upper Oxfordian-Tithonian). More recent papers have improved the biostratigraphy and addressed the problems of discontinuities and of the development of nodular facies (CLARI et alii, 1984; SARTI, 1985, 1986, 1993; PAVIA et alii, 1987). Moreover a third non-nodular, siliceous member is locally found between the two above described calcareous members, as already mentioned in the foreword to Stop 2.

The nodular structure that characterizes the RAV through most of its outcrop area is produced by the juxtaposition of cm-sized, rounded portions of lighter colored, nearly pure limestones (the nodules) and of the so-called matrix consisting of dark red marls or marly limestones. The genesis of the nodular structure of the Rosso Ammonitico facies has been extensively discussed by L. Martire in the foreword to the pre-congress excursion (this volume).

MASSARI (1981) remarked that many “nodules” are in fact oncoids or dome-shaped structures due to the binding and cementing action of biomats. CLARI et alii (1984) separated two types of nodules: 1) pre-depositional nodules, that is all those volumes of sediment that possessed a rocky coherence at the moment of their deposition (e.g. intraclasts, oncoids, reworked ammonite moulds), and 2) diagenetic nodules, generated by selective early cementation during long periods of residence of the sediment near the sediment/water interface. Both types could be displaced and disrupted by burrowing activity of firm ground dwellers, or exhumed and transported by bottom currents.

STOP 4 - THE JURASSIC SUCCESSION AT THE CIMA CAMPO DI LUSERNA FORTRESS

P.A. CLARI & G. PAVIA

This locality, first described by TRENER (1910) and by PARONA (1931), is interesting in several respects. Highlights include: very thin SVO compared to the Serrada section; the Rosso Ammonitico Veronese, here represented only by the calcareous Lower and Upper members; the coquinoid deposits of the Lumachella a Posidonia alpina. Several workers have studied these outcrops both for the Rosso Ammonitico (STURANI, 1964; MARTIRE et alii; 1991, SARTI, 1993) and the Lumachella a P. alpina (WINTERER et alii, 1991).
Substop 4.1 - San Vigilio Oolite

After a short walk we will reach the artificial cut leading to the lower fort of the Cima Campo World War I complex. The SVO crops out for a thickness of only about 5 m but its facies is relatively uncommon, and deserves a close look. The contact between the SVO and RAV is exposed, whereas the contact of the SVO with the underlying CG is not visible. The SVO consists for the first 3 m of oolitic and bioclastic grainstones with several discontinuity surfaces. A well recognizable layer 40 cm thick of sponge and oncocoids rudstones follows. Sponge remains mostly belong to the group Inozoa and oncocoids are made up of encrusting taxa (annelids, briozoans, encrusting foraminifers). This bed contains upper Toarcian nannofossil floras (Lozar, 1996, pers. comm.). The topmost two metres of the SVO below the RAV consist of bioclastic grainstones rich in benthic foraminifera (Vidalina and Lenticulina). All the sediments are pinkish to dark red; in thin section most grains (intraclasts are common) look broken, abraded and deeply stained by iron oxides. These features point to a reduced, episodic, sedimentation and to a prolonged reworking of grains, often followed by a phase of early cementation.

Substop 4.2 - Calcari Grigi, Lumachella a Posidonia alpina, Rosso Ammonitico Veronese

The direct contact between the CG and RAV, with no SVO interposed, is seen few hundred metres from the previous stop along the trench leading to the upper, main fort of Cima Campo. These outcrops were first studied by STURANI (1964), for the whole CG to RAV succession. In more recent times, WINTERER et alii (1991) considered the fissure deposits of the Lumachella a P. alpina, MARTIRE et alii (1991) examined the RAV succession in order to define and date the RAI and RAS members, and finally SARTI (1993) performed the biostratigraphic log deriving from the ammonite assemblages richly documented in the lower part of the RAS.

On the left side of the trench near the entrance of the fortress the Lower Member of the RAV rests directly on a “Lithiotis” bed (Fig. 23), while on the right side brecciated micritic layers of the CG contain red pelagic micritic sediments and some lenses of coquoinid deposits. No data on the fossil content and on the age of these coquinas is so far available. A wealth of data is instead available on the RAV. The RAV succession can be subdivided into 12 levels (MARTIRE et alii, 1991: Fig. 24): the lowermost level (number 2) refers to the RAI and the others (3-12) represent the RAS. The rich ammonite assemblages are dominated, as usual, by typical Mediterranean phylloceratids and lytoceratids, like Sowerbyceras silenum and Lytoceras polycyclum. The biostratigraphy established by MARTIRE et alii (1991) can be summarized as follows, also integrating data by SARTI (1993).

Level 2 (250 cm) - Massive red limestone, pseudonodular and mineralized facies (see Substop 6.1 for details). The age (late Bajocian to early Callovian) is essentially based on correlation.

Levels 3-5 (90 cm) - This set of beds used to be wonderfully exposed in a pinnacle, recently destroyed by environmental restructuring; it can still be observed in the small cliffs around the fortress. The whole interval is represented by massive stromatolitic and mineralized facies; its basal boundary is marked by a lag of cm-sized nodules with Fe and Mg oxides.

In Level 3 ammonites indicate the middle to upper Oxfordian transition, with both the Gregoryceras transversarium Zone [Paraspidoceras helymense and P. (Dichotomosphinctes) sp.] and the P. (Dichotomoceras) bifurcatus Zone [Gregoryceras fouquei and Passendorferia cf. uptonioides].

The Kimmeridgian starts with Level 4. This level can be subdivided into two beds separated by a sharp, planar surface: the basal bed contains a rich ammonite...
Level 6 (95 cm) - Brown-red, marly packstones with abundant Saccocoma and aptychi; the lithofacies is flaser nodular (subnodular type). Although ammonites are uncommon, Sarti (1993) was able to refer the middle part of this level to the Aspidoceras acanthicum Zone, in the lower upper Kimmeridgian. For a long time this level has played an important role for establishing the correlation of the RAV members across the whole Trento Ridge. In fact Sturani (1964) believed it was equivalent to the siliceous middle member of the Rosso Ammonitico (RAM). Assuming a Kimmeridgian age for the RAM, at least for the Altopiano di Asiago, resulted in a seemingly heterochronous RAM across the Trento Ridge. The biostratigraphic studies of Martire et alii (1991) modified Sturani's interpretation and stated that the RAM is absent in the Cima Campo area; the RAM was thus confirmed as a discontinuous intermediate unit between the RAI and RAS, and spanning the middle Callovian to middle Oxfordian.

Level 7-12 (390 cm) - The nodular facies prevails here, with nodules made evident by differential weathering of the brick-red, clay-rich matrix. Levels 7 and 8 belong to the upper part of the A. acanthicum Zone, due to the presence of Progeronia cf. eggeri. The next levels did not deliver biostratigraphically useful ammonites, except the top of the section (Level 12), where scattered specimens of Discosphinctoides sp. ind. indicate the Hyboniticeras beckeri Zone, the topmost biozone of the upper Kimmeridgian.

STOP 5 - THE SUCCESSION FROM THE CALCARI GRIGI TO THE ROSSO AMMONITICO VERONESE AT FRATTE

P.A. CLARI

In this locality the whole SVO, between the top of the CG and the Lower Member of the RAV, is most reduced in thickness (less than 9 m). It is also worth noting that the Upper Member of the RAV is missing here.

On the way to the main outcrop, in a small abandoned quarry, the uppermost beds of the Calcari Grigi crop out along the road, with Cochlearites banks and a typical thickening upward cycle like the ones described in Stop 3 (Fig. 25). In the small quarry, the SVO starts with about 40 cm of winnowed foraminiferal grainstones resting on the bored and encrusted surface of the Calcari Grigi (Fig. 26). About 3 metres of oncoidal packstones and grainstones and 4.5 metres of bioclastic grainstones follow. The SVO ends with 130 cm of crinoidal grainstones with festoon cross-bedding and a
thin lenticular level (max. thickness 50 cm) of oolitic grainstone with low angle oblique laminae. A sharp planar surface truncates these oolitic grainstones, overlain by the Lower member of the RAV, consisting of rather massive-looking pseudonodular facies.

The thickness of the Rosso Ammonitico inferiore is 360 cm, and it is overlain by about 80 cm of cherty limestones of the middle member. The white micrites of the Lower Cretaceous Biancone Formation rest directly on the cherty limestone, without any trace of the RAS.

The lack of this calcareous member is rather unusual, and was possibly the product of sliding of the RAS along a gently sloping detachment surface at the top of the cherty unit.

Substop 6.1 - The complete Rosso Ammonitico Veronese at the Voltascura quarry

In this large quarry the massive Lower Rosso Ammonitico is actively exploited and a complete section of the RAV is exposed along several fronts. All the three members are present and different facies can be easily recognized. Moreover, it will be also possible to have a new look at the coquinoid deposits of the Lumachella a Posidonia alpina. The quarry floor corresponds to the topmost surface of the Calcari Grigi, whose uppermost 50-80 cm are cut by a complex set of fractures and cavities filled by red biomicrites and by pink to whitish bivalve coquinas with some ammonites (these fossil assemblages were not described by Sturani in the sixties as the quarry was not in activity at that time; they are now under study by G. Pavia). This topmost layer of the Calcari Grigi with its coquina-filled cavities is strongly welded to the first massive bed of the Rosso Ammonitico. Quite often quarried blocks of this bed of RAV have a “socle” of Calcari Grigi, some tens of centimetres thick, with coquina filled cavities that are sawn away in order to commercialize the blocks. Uncut blocks and discarded slices of this horizon with coquina lenses should be found in the rubble of the quarry.

The complete section of the RAV exposed in the Voltascura quarry is one of the most important among the 25 sections studied in detail on the Altopiano di Asiago by Martire (1989, 1996), to which the interested reader is referred. The three units forming the RAV are clearly recognizable (Fig. 27A and B): the Lower Member (RAI) calcareous, massive and essentially nodular (upper Bajocian to lower Callovian); the Middle Member

STOP 6 - THE JURASSIC SUCCESSION AT THE VALLE DEL GEHPACH AREA: VOLTASCURA AND CIMA TRE PEZZI QUARRIES

P.A. Clari & G. Pavia

Ponte sul Ghelpach (Ghelpach bridge) is a classic locality of the Lumachella a Posidonia alpina, described in the remarkable monographs by De Gregorio (1886) and Parona (1896). It was later revised by Sturani (1964, 1971) and by Winterer et alii (1991). The original outcrops studied by De Gregorio and Parona are unknown (see Sturani 1971) but the ones studied by Sturani himself are still exposed, and some new outcrops due to recent activity are also available.

Fig. 25 - The small abandoned quarry of Fratte.

Fig. 26 - Photomicrograph of the boundary between the Calcari Grigi and the Oolite di San Vigilio. Arrows indicate borings and encrusting anellids on the top of Calcari Grigi.
(RAM) well bedded, non-nodular and cherty (Callovian to Middle Oxfordian); the Upper Member (RAS) calcareous, richer in clay and typically nodular (lower Kimmeridgian to Tithonian). Most of the 8 lithofacies recognized by MARTIRE (1989) in the RAV are well seen at the Voltascura quarry.

Three lithofacies characterize the RAI:

**Pseudonodular facies** - This facies is organized into metre-thick beds and is quite massive-looking as nodules and matrix do not weather differentially. For this reason this facies is still actively quarried and, after cutting and polishing, is used for stone facings. On polished surfaces the heterogeneity of the rock becomes apparent because of the strong color contrast between pink nodules and the brick-red matrix. The nodules consist of intraclasts, oncoids, ammonite moulds and early diagenetic nodules. The dark matrix is made up of a packstone with bivalves, echinoderms, peloids, benthic foraminifers and *Globochaeta* (Fig. 28).

**Mineralized facies** - This facies differs from the pseudonodular one for the abundance of mineralized bioclasts and intraclasts, and the darker, brown color due to the greater amount of small, mineralized grains. The matrix is less abundant too. The intraclasts, up to 2 cm across, are always bored and coated by black Fe-Mn oxides crusts up to 1 mm thick (Fig. 29).

**Bioclastic facies** - It consists of a bivalve, echinoid and benthonic foraminifers grainstone which makes up a massive bed at the top of the Lower Member. Most of the

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**Fig. 27** - The Voltascura Quarry A) Schematic log of the RAV. B) The lower and middle member of the RAV. "Chairman" G. Pavia for scale.

**Fig. 28** - The pseudonodular facies on a sawed surface.
grains are microbored and iron-stained. Distinctive features are the presence of a regular network of *Thalassinoides* burrows and of geopetal structures that demonstrate the intense early cementation of these bioclastic sands (Fig. 29).

The RAM is typically non-nodular and well bedded, the beds being less than 10 cm thick. Also in this member three different facies can be recognized (Fig. 30).

**Calcareous stratified facies** - At the base of the siliceous member this lithofacies consists of pink to red wackestone with scattered bivalves, echinoid fragments and calcitized radiolarians.

**Cherty stratified facies** - It differs for the higher abundance of siliceous skeletal grains (radiolarians, sponge spicules and rhaxes) and for the presence of red chert nodules and lenses.

**Subnodular facies** - At the top of the siliceous member this lithofacies consists of packstones with clasts of radiolarian-rich micrites, with scattered red chert nodules. Undulose dissolution seams lend a sort of nodular look to the rock.

The RAS consists entirely of the nodular facies, enhanced by the differential weathering of the pink calcareous nodules and of the brick-red, clay-rich matrix. Intraclasts, oncoids and stromatolitic domes are very rare and nodules are represented only by early diagenetic nodules and ammonite moulds. Nodules consist of uncompacted *Saccocoma* grainstones and packstones with sparse benthic foraminifers and micritic moulds of radiolarians. The brick-red, clay-rich matrix is a *Saccocoma* packstone with fitted-fabric (Fig. 31).

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*Fig. 29* - The boundary between the mineralized and bioclastic facies marked by a thin, stromatolitic layer.

*Fig. 30* - The middle siliceous member, the well bedded cherty stratified facies and subnodular facies are easily recognizable. The darker interbeds are bentonitic layers.

*Fig. 31* - The nodular facies in outcrop; the more calcareous nodules stand out on the darker clay-rich matrix. Percentage of nodules is quite different in different layers.
Along the fronts of the Voltascura quarry the Middle Member beautifully exposes the bentonitic levels already seen during the first day in the Serrada section (Stop 2). At least three levels are easily seen and along the new fronts a maximum of five has been counted.

This locality is not one of the richest for ammonites. Nevertheless first MARTIRE (1989) and later SARTI (1993) were able to find biostratigraphic constraints useful for correlation with other more fossiliferous sections across the Altopiano di Asiago.

- Lower Member. The basal stromatolitic layer of the RAI has been referred to the Parkinsonia parkinsoni Zone thanks to scattered specimens of Parkinsonia sp. and Cadomites rectelobatus. The bioclastic facies at the top of the Lower Member contains taxa indicative of the lower Callovian (MARTIRE, 1989).

- Middle Member. The thin bedded limestone facies at the base of the RAM is completely devoid of significant macrofossils; the only data available come from a cursory study of calcareous nannofossils carried out by E. Erba (1988, pers. comm.) which indicate the late Callovian. The top of the member is instead middle Oxfordian (Gregoryceras transversarium Zone), by analogy to what happens in nearby more fossiliferous sections (e.g. Kaberlabia: MARTIRE, 1989).

- Upper Member. The base of this member could not be dated at Voltascura quarry but again by analogy with the Kaberlabia section, the first nodular layers mark the passage between the Metahaploceras strombecki and the Crussoliceras divisum Zones. More detailed information came from the paper by SARTI (1993), who reported ammonite assemblages of the whole upper Kimmeridgian, from the Aspidoceras acanthicum to the Hyboniticeras beckeri Zones. In two beds at 200 cm and at 300 cm from the base of the RAS, ammonites are particularly frequent; they indicate the middle A. acanthicum Zone (Sowerbyceras loryi, Nebrodites ferrarii, N. heimi, Aspidoceras pl. sp.) and the middle H. beckeri Zone (Phylloceratidae pl. spp, Taramelliceras pugile, Discosphinctoides campanai, Hyboniticeras pressulum, H. harpephorum), respectively. The middle biozone within the upper Kimmeridgian, i.e. the Mesosimoceras cavouri Zone, is represented by specimens of Mesosimoceras risoviense from about 25 cm from the base of the RAS.

Substop 6.2 - The Posidonia alpina beds at the Cima Tre Pezzi quarry

An easy walk of about 2 km leads to the Cima Tre Pezzi quarry, a classic locality of the Lumachella a P. alpina described by STURANI (1964, 1971) and WINTERER et alii (1991). Along the way, the contact between the Calcari Grigi and the Rosso Ammonitico Fms., already seen in the Voltascura quarry, crops out several times. In the RAV it is possible to follow the gradual pinch out of the siliceous member. It is along this road that BERNOULLI & PETERS (1970) described for the first time the bentonitic layers encountered both at Serrada (Stop 2) and in the Voltascura quarry (Substop 6.1). The road ends at a small abandoned quarry where thin, interstratal layers of the Lumachella a P. alpina are still exposed at the CG to RAV transition (Fig. 32). From the small coquina lenses in the topmost 50 cm of Calcari Grigi, STURANI (1971, p. 52) found an ammonite assemblage indicative of the lowermost Stenoceras niortense Zone (Teloceras banksi Subzone) at the base of the upper Bajocian.

The biochronological significance given to the ammonite assemblage of Cima Tre Pezzi is more or less the same assumed for that labelled as "Ponte sul Gelpach 2" by STURANI (1971, p. 60) among the classic localities of the Valle del Gelpach described by PARONA (1896). The absence of specimens of Normannites was considered sufficient to refer the assemblage of Cima Tre Pezzi to a slightly older horizon than the Ponte sul Gelpach 2, within the T. banksi Subzone, i.e. just above the very base of the upper Bajocian. Nevertheless these two assemblages represent one of the richest ammonite records so far known in the literature for the T. banksi Subzone. The taxonomic content of these two Gelpach localities totals 26 taxa, here listed as (a) Cima Tre Pezzi and (b) Ponte sul Gelpach. Figs. 33-35 re-illustrate all the Gelpach specimens already figured in the literature (STURANI, 1971; PAVIA, 1983).

(a b) Phylloceras kudernatschi
(a -) Adabofoloceras pl. spp.
(a -) Calliphylloceras disputabile
(a -) Holcophylloceras zignodianum
(a b) Ptychophylloceras xenosulcatum sturanii
(- b) Ptychophylloceras longarce
(a b) Nannolytoceras polyhelicum
(a b) Lissoceras oolithicum
(-) Oppelia cf. subradiata
(a b) Oppelia subtilicosta (Fig. 33/8)
(-) Strigoceras aff. bessinum
(-) Strigoceras aff. septicarinatum
(- b) Strigoceras trubiedi
(a -) Normannites pl. spp. (Fig. 33/1)
(a b) Polyplectites (? venetus (Figs. 33/2, 4)
(a b) Sphaeroceras brongnarti globus (Fig. 33/3)
(a b) Chondroceras canovense (cf. Fig. 34)
(- b) Chondroceras flexuosum
(- a) Torrensia sturani (cf. Fig. 35A)
(- b) Torrensia n. sp. ind. (cf. Fig. 35B)
(a b) Subcollina lucitett (Figs. 33/7, 11, 13)
(a b) Parastrenoceras aff. caumontii (Fig. 33/5)
(a -) Parastrenoceras sp. ind. (Fig. 33/10)
(a b) Patruilia aemignatica (Figs. /33, 12)
(- b) Leptosphinctes conclusus (Fig. 33/6)
(a -) Leptosphinctes sp. ind.
1 to 6: Calcari Grigi, Domerian. (1) Massive limestone bed, packed with Lithiotis still in life position; their shell has been leached during early diagenesis and replaced by drusy spar. (2) Bed 1 ends with a subaerially eroded surface, coated by a thin layer of red, argillaceous calcilutite which also fills the empty casts of Lithiotis lying close to this surface. (3) Light tan colored, barren calcilutite with shrinkage structures. (4) Intrasparitic, fossiliferous calcarenite with Vidalina martana. (5) Like 2. (6) Scarcely fossiliferous, slightly dolomitic calcilutite, with traces of bioturbation; in its upper part this bed is riddled by shrinkage cracks, filled with red, penecontemporaneous internal sediments (black in this figure).

7: Lumachella a Posidonia alpina. Large, mainly interstratal solution cavities filled by spar cemented coquinas, which grades upward into a crinoidal calcarenite. Thick linings of radiarial spar have grown both on the roof of the solution cavities and on the floors formed by coquina facies. Voids left between two such linings were later filled by brick-red argillaceous, thinly laminated biomicrite, packed with comminuted Bositra shells. The age of the coquina is the same in all the cavities: the lowermost Stenoceras niortense Zone of the basal upper Bajocian. 8: Rosso Ammonitico Veronese. Red nodular crinoid-rich limestones, possibly latest Bajocian in age.

[B]: The Cima Tre Pezzi section in November 2001. Numbers as in Fig. 32A.
Fig. 33 - Ammonites from the Lumachella a Posidonia alpina of the Gelpach area, Asiago plateau, T. banksi Subzone, basal S. niortense Zone, lower upper Bajocian (photos from Sturani, 1971).
1) Normanmites sp. ind. Cima Tre Pezzi quarry (Sturani, 1971, pl. 14, fig. 14). 3.3x.
2, 4) Polyplectites venetus (Parona). 2) Cima Tre Pezzi quarry (ibidem, pl. 13, fig. 2). 2.7x. 4) Holotype, Ponte sul Gelpach (ibidem, pl. 13, fig. 3). 2.6x.
3) Sphaeroceras brongniarti (Sowerby) globus Buckman. Cima Tre Pezzi quarry (ibidem, pl. 12, fig. 12). 3.7x.
5) Parastrenoceras aff. caumonti (D’Orbigny). Ponte sul Gelpach (ibidem, pl. 14, fig. 13). 3.4x.
6) Leptosphinctes conclusus (Parona). Ponte sul Gelpach (ibidem, pl. 15, fig. 12). 2.8x.
7, 11, 13) Subcollina lucretii (D’Orbigny). 7, 11) Cima Tre Pezzi quarry (ibidem, pl. 14, figs. 1, 2). 3.3x. 13) Ponte sul Gelpach (ibidem, pl. 14, fig. 4). 3.3x.
8) Oppelia subtilicostata Parona. Ponte sul Gelpach (ibidem, pl. 6, fig. 21). 2.9x.
9, 12) Patrulia aenigmantica Sturani. 9) Paratype, Cima Tre Pezzi quarry (ibidem, pl. 14, fig. 6). 2.8x. 12) Holotype, Ponte sul Gelpach (ibidem, pl. 14, fig. 5). 2.7x.
10) Parastrenoceras sp. ind. Cima Tre Pezzi quarry (ibidem, pl. 14, fig. 14). 3.5x.
The cavity infillings of Lumachella a *P. alpina* in the Valle del Gelpach area are surely those most frequently recorded in the literature, though many other localities are known in the surroundings of Gallio, north of Asiago, e.g. Longara di Sotto, Monte Meletta, Troch (STURANI, 1971 with references). All these fossiliferous lenses share similar taphonomic characteristics: (1) fossils, mainly brachiopods and ammonites, are usually preserved as internal moulds with spar infillings of the same type of the surrounding calcitic cement (fossils in a given cavity have the same state of preservation, an evidence that they are of the same age); (2) their size is always reduced, down to very few centimetres of diameter; (3) brachiopods are represented by immature specimens or adult individuals of small-sized species; (4) similarly, ammonites are represented by a large amount of small microconchs (e.g. stephanoceratids and sphaeroceratids) or by immature specimens of both dimorphic forms (e.g. phylloceratids, strigoceratids, perisphinctids), along with fragments of larger shells. The diminutive size of all the fossils was believed by ancient authors to represent an example of dwarfism. STURANI (1971) criticized such an interpretation and discussed two hypotheses: (1) the reduced size of ammonites was due to a sieving effect of the mechanical transport that controlled the deposition of coquina beds; (2) biological sorting for autoecological requirements between macro- and microconchs (cf. the abundance of the latter) and between adult and juvenile individuals. In both cases the presence of algal meadows on a rocky bottom at shallow depth was suggested; here microconchs were secluded and/or adults came for breeding leaving there only juveniles, which supplied most of the biogenic remains of the coquina beds during storm deposition (cf. immature specimens complete of body-chamber). Nevertheless the hypothesis of “stunted faunas” was revived by MIGNOT (1992) who, at least for sphaeroceratids and based on septal growth rate, concluded for dwarfism at least for selected taxons like *Sphaeroceras brongniarti*, after comparison with cospecific specimens from Normandy whose size average is three times greater.

Over 90 species and subspecies were described by STURANI (1971) from the *P. alpina* beds. One of his major contributions to the ammonite systematics was the identification of many new microconch taxa, along with the description of dimorphic species deriving from the pairing of macro- and microconch counterparts within sphaeroceratids (Fig. 34). Actually some ammonite taxa were only later defined, for example the representative of the taxon *Torrensia* along with the types of different new species (PAVIA, 1983: Fig. 35); others are awaiting revision, as well as the huge brachiopod samples never considered in modern analyses. Yet, necessity for an update does not reduce the importance of Sturani’s research; on the contrary, it reflects the special interest that the Lumachella a *Posidonia alpina* still arises. New outcrops with ammonite coquinas will hopefully provide further collecting, like the fossiliferous lenses presently exposed in the Voltascura quarry.
The birth of the Belluno Basin is linked to the Early Jurassic rifting, which produced a system of faults roughly striking NS; they cut the wide peritidal platform where the Dolomia Principale had formerly been deposited, and separated areas with different subsidence rates: a horst and graben submarine topography thus arose (Fig. 36).

During the Early Liassic, the birth of the ancestral Belluno Basin, intervening between the Trento Ridge to the west and the Friuli Platform to the east, is linked to the first activation of the Marmol Fault. The sedimentation patterns clearly differ at either limb of this fault: to the west shallow marine oolitic grainstones (lower unit of the Calcari Grigi Fm) were deposited, while to the east deep water dark grey dolomitic
and cherty mudstones, locally associated with debris flow breccias (Soverzene Fm.), were accumulated during most the Early Liassic. In the Sinemurian, the activation of the Coro Monte Medone Valley Fault, located west of the Marmol line, caused the downstepping of a marginal sector of the Trento Ridge (Ardo Valley); the platform margin shifted to west, as can be seen along the eastern flank of the Cordevole Valley. This event can be correlated with the wide transgression across the entire Trento Ridge recorded by the superposition of the Middle Oolitic Member to the Lower Member of the Calcari Grigi Formation.

The Early Liassic transgression was followed in the Middle Liassic by a phase of stability which allowed the platform to prograde over the previously drowned margin (Fig. 36). Around the Domerian-Toarcian boundary most of the Trento Ridge was drowned. Starting from the latest early Toarcian the carbonate factory recovered and shallow water oolitic and crinoidal grainstones spread across its western margin. The final sinking of the Trento Ridge occurred between the early Aalenian and early Bajocian. The causes of this event are still a debated problem, partly discussed during the second day of this excursion.

The Early Toarcian oceanic anoxic event (Jenkyns & Clayton, 1986) is recorded in the Belluno Basin by discontinuous levels of black-shales (see Stop 8) contained within the Igne Formation, which mainly consists of decimetric rhythms of grey marls and marly mudstones. At the top of the black shales interval, nodular limestones of Ammonitico Rosso facies occur, pertaining to the Hildoceras bifrons Zone, H. sublevisoni Subzone (Jenkyns et alii, 1985).

One of the most interesting features of the Belluno Basin is represented by the Vajont Limestone. This is a thick interval (up to 600 m) predominantly composed of oolitic sand and biogenic skeletal debris. Classically interpreted as a shallow-water deposit, this unit was re-interpreted as the product of gravity flow processes transferring oolitic sands from the western edge of the Friuli Platform into slope and basin environments (BoSELLini & Masetti, 1972; BoSELLini et alii, 1981: Fig. 37). Depositional units include metre-scale debris flows and oolitic turbidites, with rarer interbedded hemipelagic mudstone. Palaeogeographic reconstructions suggest that the Vajont Limestone is an eastward-thickening wedge with a depositional area in excess of 100 km along its strike and 50 km across, thinning basinward and onlapping parts of the Trento Ridge to the west (Figs 36, 37). Subsequent researches by Zempolich (1995) allowed to detail the depositional environment of the Vajont Limestone as a carbonate slope apron. Well penetrations in the Po Plain and northern Adriatic Sea show that the Vajont Limestone is present to the south in the subsurface (BoSELLini et alii, 1981; Catì et alii, 1987).

The age of the Vajont Limestone has been a matter of debate. The biostratigraphic study performed by Casati & Tomai (1969) suggested an upper Bajocian-Bathonian age based on the co-occurrence of Protopeneroplis striata and Trocholinae, and the absence of Kurnubia palastiniensis. A general age assignment to the Bajocian-Callovian interval for the Vajont Limestone was supported also by other authors (e.g. BoSELLini et alii, 1981), based on the stratigraphic constraints provided by the age of the underlying Igne and overlying Fonzaso formations. Recently, Zempolich & Erba (1999) assigned the Vajont Limestone to the latest Aalenian-late Bajocian interval, based on few and poorly preserved nannofossil assemblages from the Col Visentin section. Finally, the nannofossil biostratigraphy presented here for the Jurassic Belluno sequence results from careful study of several sections spanning the whole Toarcian-Tithonian interval (Picotti and Cobianchi, pers. data). As proposed by Casati & Tomai (1969), the age of the Vajont Limestone falls in the late Bajocian-Bathonian interval, being the topmost Igne Formation late Bajocian in age (see Vajont Gorge section) and the base of the overlying Fonzaso Formation Callovian. During the Dogger the deposition of the Vajont Limestone progressively levelled up the previous high-relief, tectonically controlled morphology.

Fig. 37 - Paleogeography of the Venetian Alps near the end of Dogger time. The Figure shows the Belluno Basin filled to the brim by shallow-water carbonate sands coming from the Friuli Platform. Turbidity currents then spilled over the east edge of the Trento Ridge, already definitively drowned. Over most of the plateau, pelagic red nodular limestones of the Lower Ammonitico Rosso were deposited directly on the older platform rocks.
Consequently, by the end of the Middle Jurassic, the Belluno Basin turned into a gentle slope connecting the Friuli Platform to the deeper Trento Ridge (BOSELLINI et alii, 1981).

The Fonzaso Formation (Callovian to lower Kimmeridgian) overlies the Vajont Limestone and consists of cherty mudstones and skeletal-rich turbidites and debris flows. The Fonzaso Formation grades upward into nodular, micritic red limestone very similar to the Rosso Ammonitico Veronese (Upper Member, upper Kimmeridgian to lower Tithonian). Toward the east, the Fonzaso Formation passes to thick skeletal-rich beds to massive coral and Ellipsactinia (hydrozoan) reefs prograding toward west (Fig. 36).

The Early Cretaceous palaeogeographic scenario of the eastern Southern Alps reflects fairly faithfully the Late Jurassic heritage, characterized by an eastern, shallow-water domain of the Friuli Platform facing the western, deeper-sea area including the Lombardy Basin, the Trento Ridge, and the Belluno Slope (Figs. 36, 37). At the end of the Jurassic and during the Early Cretaceous, while shallow-water sedimentation persisted on the Friuli Platform, the deep-sea domain of the Southern Alps was blanketed by calcareous pelagic ooze, mostly consisting of nannofossils. These white mudstones have been called the Maiolica in Lombardy (at the base, Fig. 39/2) and pelagic pelecypods (abundant Bositra buchi). At the top, red peloidal packstone with ooids deriving from the Vajont Limestone, and abundant Fe-Mn crusts (Fig. 39/4a, 4b). This facies bears at the very top a monospecific assemblage of irregular echinoids (Pygorhytis castanea; sampling and determination by A. Ferrari: Fig. 39/3), well preserved as biosomata in living position, which suggests they were abruptly covered by the overlying turbidite (Rosso Ammonitico Veronese, Lower Member).

The sequence of Stops 7 to 9 has the purpose to illustrate the lateral transition between the Trento Ridge (hence simply Plateau) and the Belluno Basin. Before visiting the depocenter of the Jurassic Belluno Basin, the first stop will illustrate the well known Ponte Serra section (BOSELLINI & DAL CIN, 1968), the type-locality of the Fonzaso Formation. The goal of this stop is to show a typical marginal setting, where an early drowned marginal sector of the Calcari Grigi is covered by a basal condensed interval and onlapped by the periplatform turbidites. The second and third stops of the day deal with a thicker basinal succession, about 50 km east of Ponte Serra, near the depocenter of the Belluno Basin, with detailed observations on the Toarcian to Bajocian interval. In particular, the excursion will be focused on the black shales of the lower Toarcian, in the well known locality of Longarone.

STOP 7 - PONTE SERRA SECTION: THE MIDDLE AND UPPER JURASSIC PELAGIC SUCCESSION AT THE TOP OF THE DROWNED LIASSIC PLATFORM

M. COBIANCHI, V. PICOTTI

LITHOLOGICAL DESCRIPTION

The section is located 3.5 km NW of Fonzaso (BL) at the confluence of the Senaiga and Cison creeks. The total thickness of the measured section is 78.8 m. Eleven lithological intervals have been distinguished (A to K in Fig. 38) from bottom to the top as follows: A - 8 m: thick bedded grain-peloidal packstone, with crinoids and lagenids, ooclasts and rare bivalves and Involutina liassica (Jones) (Fig. 39/1). At the very top it shows dissolution vugs and mouldic porosity (Encrinite di Fanes).

B - 2.5 m: with a basal sharp contact, thick bedded, locally nodular red pack-wackestone rich in Conoglobigerina (at the base, Fig. 39/2) and pelagic pelecypods (abundant Bositra buchi). At the top, red peloidal packstone with ooids deriving from the Vajont Limestone, and abundant Fe-Mn crusts (Fig. 39/4a, 4b). This facies bears at the very top a monospecific assemblage of irregular echinoids (Pygorhytis castanea; sampling and determination by A. Ferrari: Fig. 39/3), well preserved as biosomata in living position, which suggests they were abruptly covered by the overlying turbidite (Rosso Ammonitico Veronese, Lower Member).

C - 2.5 m: well bedded white peloidal wackestone, with rare pelagic pelecypods and echinoid fragments (Fig. 39/5) (Vajont Limestone).

D - 6 m: thin bedded red and green cherty limestones, with red marly interbeds; red chert in nodules and layers. Abundant radiolarians and rare sponge spicules (Fonzaso Formation).

E - 4 m: well bedded white peloidal and oolitic grainstones with marly interbeds. Parallel and wavy laminae. Grains are composed of concentric ooids, frequent miliolids and agglutinated foraminifers (Fig. 39/6) (Fonzaso Formation, oolitic member).

F - 5 m: thick bedded white oolitic and peloidal grainstones, rich in chert nodules at the top. Grains similar to those described in E (Fonzaso Formation, Oolitic member).

G - 4 m: thin bedded light grey peloidal mudstones, rich in brown chert nodules (Fonzaso Formation, oolitic member).

H - 1 m: Oolitic rudstone grading to oolitic grainstone at the top. Occurrence of Trocholina sp., Kurnubia cf. palastiniensis, fragments of echinoids, brachiopods, calcareous sponge and molluscs, rare
Fig. 38 - The Ponte Serra measured section.
agglutinated foraminifers and miliolids (Fig. 39/7) (Fonzaso Formation, micritic skeletal member).

I - 8.50 m: thinning upward interval of well bedded light grey mudstone and oolitic grainstones interbedded, followed by thin bedded white mudstones, rich in chert nodules (Fonzaso Formation, micritic skeletal member).

J - 19 m: thin bedded grey-green cherty limestones, with marly interbeds, rich in chert in nodules and ribbons, with abundant radiolarians. At the top, red chert (Fonzaso Formation, micritic skeletal member).

K - 21.80 m: thin bedded to nodular (Ammonitico Rosso facies) reddish radiolarian-rich wackestone, with green and red marly interbeds. Red to green chert nodules at the base and at the top. White smectitic interbed 8.8 m from the base of the interval. Saccocoma-rich turbidite at 12.8 from the base (Fonzaso Formation, micritic skeletal member).

CALCAREOUS NANNOFossil BIO- AND CHRONOSTRATIGRAPHY

Calcareous nannofossils from the Ponte Serra section were used for biostratigraphic analysis (see COBIANCHI, 1990, 1992, 2002; ERBA, 1990; MATTIOLI, 1995; MATTIOLI & ERBA, 1999; Picotti and Cobianchi, pers. data). Seventy four samples were analyzed; nannofossil preservation and abundance fluctuate throughout the section. Assemblages have been strongly altered by diagenetic processes and show the effects of dissolution and calcite overgrowth.

The lowest sample for nannofossil analysis was collected at the top of the Rosso Ammonitico, immediately below the Vajont Limestones. The nannofossil assemblage is characterized by Watznaueria barnesae and W. communis, W. contracta, W. manivitae. The occurrence of W. barnesae documents an age not older than the early Bajocian, because the first occurrence of this taxon was recorded close to the Bajocian/Bathonian boundary (ERBA, 1990, Digne area). The calcareous nannofossil events recognized in the studied section, from older to younger, are: first occurrence (=FO) of Cyclagelosphaera wiedmanni (12.5 m from the bottom of the section); last occurrence (=LO) of Lotharingius velatus (14.5 m from the bottom); LO of Cyclagelosphaera wiedmannii (18.8 m); LO of Lotharingius hauffii (61.5 m); FO of Conusphaera mexicana minor (63 m); FO of Conusphaera mexicana mexicana (67.5).

The FO and LO of C. wiedmannii fall in the late Bathonian, close to the upper boundary of the Callovian stage (REALE & MONECHI, 1994; MATTIOLI & ERBA, 1999), whereas Lotharingius velatus seems to disappear in the early Callovian as documented also by DE KAENEL et alii (1996). The absence of Watznaueria contracta, from sample PS22 upwards, testifies a Kimmeridgian age, as its LO was documented at the end of the Oxfordian (MATTIOLI, 1995). The LO of L. hauffii falls in the upper Kimmeridgian and the FOs of C. mexicana minor and C. mexicanamexicana, respectively, pre- and postdates the Kimmeridgian/Tithonian boundary (MATTIOLI, 1995; BRALOWER et alii, 1989).

With reference to foraminifers, the basal crinoidal grainstones bear Involutina liassica along with a rich assemblage of crinoids and lagenids. Its occurrence documents a Liassic age not younger than the Pliensbachian. These open shelf deposits are, therefore, the lateral equivalent to the middle Liassic Rotzo Member of the Calca Grigi Fm.

The overlying Rosso Ammonitico Veronese (Lower Member), with its typical microfacies (Conoglobigerina and Bositra buchi) is referable to the Bajocian. The top of this interval reaches the lower Bathonian. The occurrence of ooids of the Vajont Limestone within the topmost beds documents: a) the age of the Vajont Limestone and b) the periplatform origin of the Rosso Ammonitico calcareous mud. The overlying Vajont Limestone is again Bathonian in age. The Fonzaso Formation spans the Callovian to the lower Tithonian interval. In particular, its oolitic member is Callovian-Oxfordian in age, its micritic skeletal member should represent the uppermost Oxfordian-lower Kimmeridgian interval, and finally the upper Kimmeridgian to the lower Tithonian red nodular facies is correlatable to the Rosso Ammonitico Veronese (Upper Member).

STRATIGRAPHICAL AND SEDIMENTOLOGICAL SYNTHESIS

The Encrinite di Fanes, Pliensbachian in age, represents the open shelf condensed deposits coeval to the thicker carbonate platform (Calca Grigi, Rotzo Member). It follows the early Sinemurian drowning of the platform margin and should be considered as a deepening-upward succession, due to its limited thickness (about 10 m compared with the about 150 of the Rotzo Member). Therefore, assuming for this peripheral portion of the Trento Ridge a relative sealevel rise comparable with that in the inner part of the same platform, the Ponte Serra palaeobathymetry at the end of the Middle Liassic was at least more than 100 m. The subsequent gap must therefore be submarine and due to increased winnowing. A decrease of bottom currents led to the aggradation of the strongly
condensed Rosso Ammonitico Veronese (Lower Member). The concentration of shells in the latter is possibly due once more to winnowing. At the top, sediments of this interval consist of overbank deposits of the Vajont Limestone. The superposition of the Vajont Limestone on the Rosso Ammonitico suggests a complete infilling of the Belluno Basin at that time (Bathonian). In fact, the turbidites finally covered this marginal sector, which since shared the same bathymetry as the whole basin, allowing for the accumulation of the thick Fonzaso Formation representing the periplatform sedimentation of the nearby Friuli Platform.

STOP 8 - THE LONGARONE SECTIONS: THE RECORD OF THE TOARCIAN OAE IN THE BELLUNO BASIN

M. COBIANCHI, D. MASETTI & V. PICOTTI

LITHOLOGICAL DESCRIPTION

The sections are located 1.5 km south of Longarone, on the old road to Igne and Zoldo, near a locality called Pirago. Here, a deep scour infilled by the Vajont Limestone is cut within the Igne Formation (BOSELLINI et alii, 1981). The composite section (Fig. 40), 27.5 m thick, describes the base of the Igne Formation up to the Vajont Limestone, whose basal erosion cuts off about 15 m of the section, as measured in the nearby Vajont Gorge. The section has been divided into ten (A-J) lithological units from the base as follows:

A - About 10 m (outcropping): laminated black shales with regularly bedded manganese limestones and marls.
B - 6 m: cyclical couplets of thin bedded light grey limestones and dark marls.
C - 2 m: alternating well bedded grey limestones and laminated dark marls. The thickness of the marly interbeds decreases upwards.
D - 1 m: grey nodular limestone with thin marly interbeds.
E - This lithological interval shows a marked change in thickness being 2 m in Longarone West and 0.5 m in Longarone East (200 m of distance). Red, locally grey to reddish, nodular limestones with brown cherts and marly interbeds. In thin section they are peloidal wackestones with abundant pelagic pelecypods and rare radiolarians and sponge spicules.
F - 1.5 m: thin bedded grey limestones and green marls with brown cherty nodules.
G - 2.4 m: well bedded grey dolomitic limestones and marls. In thin section they are peloidal wackestones with pelagic pelecypods. From this level upwards, the fabric is often obscured by a frame of idiotopic dolomite.
H - 2.5 m: alternation of well bedded dolomitic limestones and thick marly interbeds. Abundant brown chert in nodules. In thin section they are peloidal wackestones rich in pelagic pelecypods and with rare radiolarians.
I - 3.4 m: thick grey, locally nodular, dolomitic limestone with thin marly interbeds. Visible chert decreases upwards. In thin section they are wackestones with echinoderm fragments and pelagic pelecypods.
J - 1.2 m: whitish well bedded dolostones, with rare cherty layers and nodules.

CALCAREOUS NANNOFOSSIL BIO- AND CHRONOSTRATIGRAPHY

Forty-nine samples from the Longarone sections were analysed for nanno-biostratigraphy. Preservation and abundance of nannofloras decreases from the bottom of the succession upwards. The nannofossil assemblages of lithological units A to C are characterized by the co-occurrence of Carinolithus...
LONGARONE SECTIONS

Fig. 40 - The Longarone measured sections.
cantaluppii, C. superbus and Discorhabdus sp. Biostratigraphy documents an early Toarcian (H. serpentinus Zone) age for this black shales interval. The FO of Discorhabdus striatus, which approximates the base of the H. bifrons Zone (MATTIOLI & ERBA, 1999), was observed at the base of the subsequent red nodular interval. Above these intervals, in the Longarone east section, two other biostratigraphic events were recognized: the FO of Discorhabdus criotus, which marks the base of the upper Toarcian, and the FO of Watznaueria contracta, which documents the lower Aalenian.

The uppermost 1.2 m of the Igne Formation are dolostones completely barren in calcareous nannofossils; however this interval could be also Aalenian in age. The overlying Vajont Limestone cannot be older than the late Bajocian, as previously discussed. Therefore, although the erosional gap between the Vajont Limestone and the Igne Formation could be wider, it spans at least the lower Bajocian.

THE TOARCIAN OAE IN THE BELLUNO BASIN

In the early Toarcian (H. serpentinus Zone) organic carbon-rich sediments corresponding to an Oceanic Anoxic Event (OAE) were deposited worldwide. The Longarone section represents the best exposed section of the Belluno Basin, and it was studied by CLAPS et alii (1995) and BELLANCA et alii (1999). In this section a black shale unit crops out, about 12.5 m thick, containing a cyclic alternation of three different lithotypes: 1) grey, bioturbated, manganese limestone (75-90% CaCO$_3$, TOC lower than 0.4%), 2) grey marlstone with partially obliterated lamination (35-70% CaCO$_3$, 0.5% of average TOC) and 3) black, well-laminated, organic carbon-rich shale (CaCO$_3$ lower than 35% and TOC up to 3%) (Figs. 41, 42).

The observed alternation of lithotypes is interpreted to represent the sedimentary record of variations in CaCO$_3$ supply and O$_2$ fluctuations at the seafloor. Anoxic conditions led to the preservation of well-laminated shales, while relatively more oxygenated bottom waters resulted in the deposition of manganese, bioturbated limestones. Cross correlation of CaCO$_3$ and TOC values shows that the curves have opposite phases. Assuming micrite had a planktonic origin, high nannoplankton production in the surface water masses should have occurred with disoxic conditions at the sea bottom. Conversely, low carbonate production should have been coincident with oxygen-depleted bottom waters. The simultaneous occurrence of these conditions in surface and bottom waters suggests a palaeoceanographic scenario able to explain both the changes in calcareous nannoplankton production at the surface waters and the oxygen content at the sea-floor.

To determine the periodicities of these cycles, spectral analysis was applied to bed thickness, TOC and lithotype time series. The analysis revealed three main ranges of periodicities in tune with the Milankovitch short eccentricity (100 ka), obliquity (41 values were ka) and precession (21 ka) cycles shown in Fig. 43. These were obtained both using a constant sedimentation rate (3.3 cm/ka assuming a duration of 0.5 My for the event: JENKINS et alii, 1985) and also interpreting the spectral results through the ratio between the significant peaks. In the spectrum of the lithologic alternations (Fig. 3.2.4B), there are three significant peaks corresponding to frequencies of 410 cm, 120 cm, and 68 cm. Their ratio with respect to the shortest value is 6:1.8:1, which is
similar to the ratio among the Milankovitch mean cycles estimated for the Early Jurassic (5 : 2 : 1). The organic carbon-rich black shales of the Lower Toarcian OAE in the Southern Alps are thus interpreted as the result of the orbitally-controlled climatic and oceanographic changes in surface productivity and oxygen content of bottom waters. The cyclic orbital changes (short eccentricity, obliquity and precession cycles) control the insulation pattern and therefore affect climate by inducing variations between low and high seasonality scenarios. This results in a variable contrast between the summer and winter seasons. In turn the oceanic water masses respond to this situation with substantial variations in temperature, circulation patterns and current velocities (De Boer, 1991). Under high seasonality conditions, the oceans are characterized by stronger currents, more efficient circulation and nutrients recycling. Under low seasonality conditions, smaller gradients would induce a slower large-scale circulation, stratification of the water masses and, consequently, less efficient nutrients supply to the upper water masses. Claps et alii (1995) proposed that the distribution of nannofossil assemblages in the Toarcian black shales of the Belluno Basin, in the limestone-marlstone-shale alternations, was produced by fluctuations in water fertility and therefore in carbonate production. In this interpretation, blooms of various types of phytoplankton are induced by turbulence and fertility of the water
column, so the changes in Liassic nannofloras should reflect variations in the characteristics, structure and dynamics of the upper water masses. The authors propose that under oligotrophic conditions (stratified water masses), with a well developed thermocline and relatively deep nutricline, schizospheres overwhelmed coccolithophorids (Fig. 44A). A relative enrichment of nutrients (mesotrophic environment) in the surface waters would have induced a higher growth of coccolithophorids with respect to schizospheres (Fig. 44B). Finally, undereutrophic conditions (highly turbulent water masses), dinoflagellates would have outcompeted calcareous nannoplankton (Fig. 44C). The lithologic changes from limestones to marlstones and shales would represent the sedimentary response to schizosphere-dominated oligotrophic times, coccolithophorid-enriched mesotrophic times and dinoflagellate-dominated eutrophic times, respectively. This model implies that the rhythmic lithologic changes in the Toarcian black shale unit were produced by fluctuating fertility and productivity of surface waters. In turn, the occurrence in such fluctuations of a high frequency control in tune with the Milankovitch orbital forcing periodicities suggests a link with the global alternation of high- and low seasonality conditions.

Under eutrophic conditions, higher productivity of dinoflagellates with respect to calcareous phytoplankton caused very low carbonate fluxes and induced an expansion of the oxygen-minimum zone. Anoxia developed in mid- and deep waters interfering with the sediment/water interface and allowing the preservation of laminae and storage of organic matter in the shales. Oligotrophic and mesotrophic conditions favoured schizospheres and coccolithophorids, which produced higher fluxes of biogenic carbonate. Because the oxygen-minimum zone was not expanded, dysoxic deep waters resulted in bioturbation of sediments and oxidation of the organic matter in limestones and marlstones.

**Fig. 44 -** Changes among oligotrophic, mesotrophic and eutrophic conditions and their possible effects on the vertical development of the oxygen-minimum zone. The arrow marks the inferred position of the Belluno Trough floor (Longarone section). The squared area represents the location within the water column of the nannofossils. Vertical distribution blown up on the right side. A: during oligotrophic times schizospheres overwhelm coccolithophorids. B: during mesotrophic times coccolithophorids bloom. C: during eutrophic times a higher productivity of dinoflagellates outcompetes calcareous nannoplankton and induces an expansion of the oxygen-minimum zone (from CLAPS et alii. 1995).
GEOCHEMICAL CONSIDERATIONS

A. BELLANCA & R. NERI

From a geochemical point of view, BELLANCA et alii (1999) stated that high TOC and V and relatively high Ba values in the black shales of the Longarone section are consistent with conditions of low to very low dissolved oxygen at the seafloor coupled with high productivity in surface waters. Based on chemical characteristics, the bioturbated limestones should represent periods of well-oxygenated bottom waters. The presence of abundant Mn-rich carbonates in partially laminated marlstones suggests that they formed under intermediate conditions in terms of both bottom-water oxygen concentrations and supply of organic carbon to the seafloor. In the middle part of the Longarone section, a negative carbon-isotope shift correlative to higher TOC, V/Rb, and Ba/Rb values identifies, within the Toarcian anoxic event, a stage of maximum bottom-water anoxia associated with high surface fertility.

STOP 9 - THE VAJONT GORGE SECTION: THE TOARCIAN TO BAJOCIAN IGNE FORMATION AND THE UNCONFORMABLE BASE OF THE VAJONT LIMESTONE

M. COBIANCHI & V. PICOTTI

LITHOLOGICAL DESCRIPTION

The section extends along a gravel road, about 1 km east of Longarone, on the left side of the Vajont gorge. Here, the Igne Formation (55 m thick) is well exposed: the base of the section starts with the lower Toarcian black shales, whereas its top is abruptly overlain by the Vajont Limestone (Fig. 45). Within the Igne Formation, nine lithological units, A-I, have been distinguished, from bottom to top as follows (Fig. 46):

A - 4 m: well bedded grey manganese-rich limestones, locally interbedded with marlstones, showing frequent black Chondrites burrows. In thin section, they are wackestones with pelagic bivalves, ostracods, echinoid fragments and sponge spicules referable to mono-triaxon types.

B - 4 m: cyclical alternation of thick bedded (80-100 cm) manganese-rich grey limestones and black to brown organic-rich marls laminated to a millimetre scale. fault: 2 m lost

C - 6.60 m: well bedded light grey limestones with marly interbeds. In the middle portion of the unit, limestones show wavy bedding; the thickness and occurrence of marly interbeds decrease upwards. In thin section, they are peloidal wacke-packstones with crinoids, lagenids, rhaxes of selenasters, rare pelagic bivalves and mono-triaxon spicules. Radiolarians “bloom” only in the lower portion of this interval, where their abundance reaches more than 30% of the rock volume (Fig. 47).

D - 3.5 m: thick wavy bedded grey limestones, only locally interbedded with marls at the base and cyclical alternations of thin bedded limestones and marly interbeds at the top.

E - 1 m: wavy bedded grey to reddish nodular limestones with dissolved phragmocones of ammonoids. Thin sections show wackestones with abundant pelagic bivalves, crinoids and ammonoid protoconchs.

F - 12.1 m: light grey dolomitic limestones, locally laminated, and thin marly interbeds. In thin section, they are peloidal wacke-packstones with iso-oriented bivalve shells, crinoids, rhaxes of selenasters, lagenids and rare radiolarians. This fabric is often obscured by a frame of ipidiotopic, late diagenetic dolomite.

G - 5.5 m: thick and wavy bedded dark grey dolomitic limestones, locally laminated. The bed thickness increases upwards, from 20-80 cm to 50-100 cm.

H - 14.5: well bedded grey dolomitic limestones and rare marly interbeds with abundant brown and red cherts in ribbons and nodules. The abundant chert corresponds to increased radiolarian abundance, which fluctuates from 20% to 40%. In thin section, they are wacke-packstones with frequent Bositra buchi shells and abundant radiolarians.

I - 6 m: grey - whitish wavy bedded dolostones, with abundant cherty layers and nodules. In thin section, dolostone shows ghosts of Bositra buchi shells and radiolarians.
Fig. 46 - The Vajont Gorge measured section.
The Igne Formation is unconformably overlain by the massive base of the Vajont Limestone, characterized by ooidal grainstones with abundant micritic intraclasts. Ooid structure is either radial, with endolithic borings, or micritic. The brittle micritic intraclasts at the base are bored by clionids and infilled with ooids (Fig. 47).

**CALCAREOUS NANNOFOSSIL BIO- AND CHRONOSTRATIGRAPHY**

Seventy five samples were analysed in their calcareous nannofossil content for biochronostratigraphy. Preservation and abundance decreases from the bottom of the section upwards, owing to increasing dolomitization; the uppermost 6 m of the Igne Formation are completely barren of calcareous nannofossils.

The lowest 18.1 m of the section are characterized by moderately preserved nannofossil assemblages with specimens of Carinolithus cantaluppii, C. superbus, Crepidolithus crassus, Discorhabdus sp., Lotharingius hauffii, L. sigillatus. This assemblage represents a biostratigraphic interval correlatable with the lower Toarcian H. serpentinus ammonite Zone (COBIANCHI, 1990, 1992; ERBA, 1990; MATTIOLI, 1995; MATTIOLI & ERBA, 1999). Discorhabdus striatus first occurs at 19 m from the bottom of the section. This event was documented at the base of the H. bifrons Zone by MATTIOLI & ERBA (1999). Other biohorizons recorded in the section investigated are: the FO of Watznaueria contracta (25 m from the bottom), the FOs of W. aff. manivitae and of W. aff. contracta, the FO of W. manivitae, the FO of a large-sized variety of W. britannica. The first occurrence of W. contracta documents an early Aalenian age, whereas the adaptative radiation of the genera Watznaueria in the Tethyan domain, marked by the appearance of several species, was observed in the lower Bajocian (opp. citt.).

The chronostratigraphy of the section is discussed as follows: the organic carbon-rich horizons of the lowermost 8 m correspond to the lower Toarcian (H. serpentinus Zone), therefore they are correlatable with the widespread Toarcian Oceanic Anoxic Event (OAE), as previously discussed by JENKYNS et alii (1985). The 1 m thick red to green nodular limestone beds, outcropping at 18 m from the base of the section, correspond to the H. bifrons Zone (middle Toarcian). Though the topmost part of the Igne Formation is completely barren in calcareous nannofossils, it could reach the upper Bajocian. Finally, the age of the Vajont Limestone falls in the late Bajocian-Bathonian interval. In fact, some samples collected at the Vajont dam in the Fonzaso Formation, immediately above the Vajont limestone, were dated as Callovian (see Stop 10).

**STRATIGRAPHICAL AND SEDIMENTOLOGICAL SYNTHESIS**

The sediments of the Igne Formation derive from three main sources:

1) a shallow-water origin of the lower Toarcian limestones has been documented by COBIANCHI & PICOTTI (2001) and is suggested also for the Vajont Gorge section, also due to the abundance of peloids in the Toarcian to Aalenian interval. The planktonic contribution to calcareous sediments was probably less than 10%;

2) terrigenous source for the shales, although continental masses had to be very distant;

3) biogenic origin for the lower Toarcian organic carbon (marine and terrestrial) and for the biosiliceous sediments of the lower Toarcian (rhaxes, rare radiolarians) and lower Bajocian (radiolarians).

The periplatform origin of the limestones creates a provenance puzzle. In fact, most platforms were drowned at that time: some parts emerged, but no shallow water deposits are known in the lower Toarcian in both the Trento and Friuli platforms. Therefore we should hypothesize continuous winnowing of the shallow water environments and the shedding of mostly diluted flows into the basin. The increased influence of bottom currents could be due to the passage from Middle Liassic rimmed to Upper Liassic open platforms, as suggested by COBIANCHI & PICOTTI (2001).

Finally, the unconformity at the base of the Vajont Limestone is documented not only by its erosional geometry, but also by the features of the clasts (endolithic boring, possibly by clionids), ripped off from the topmost surface of the Igne Fm. by the turbulence of the dense flow.
STOP 10 - THE VAJONT LANDSLIDE: A BRIEF HISTORY OF THE VAJONT LANDSLIDE NARRATED BY ITS DISCOVERER

E. SEMENZA & M. GHIROTTI

The Vajont Landslide is one of the major tragedies of recent Italian history. On October 9, 1963, a huge rock mass fell from Monte Toc in the Vajont Lake (Fig. 48) causing a giant wave that climbed over the dam and destroyed the Longarone village, killing more than two thousand people. The present short report on the event is due to the discoverer of the landslide, Prof. Edoardo Semenza, geologist at the Ferrara University and son of the dam designer, engineer Carlo Semenza.

The first idea of a dam in the Vajont Valley dates back to the Twenties and its placing in the Colomber gorge was defined in the Thirties. The dam, designed by C. Semenza, director of the Servizio Costruzioni Idrauliche of the Società Adriatica di Elettricità (SADE) and built in the years 1958-1960 by this Society, is 261 metres high and is of the arc-dome type.

In the gorge, the thick beds of the Vajont Limestone dip about 20° to the W, from the valley bottom (about 460 m above s.l.) up to an altitude of 730 m. Along the basin slopes, due to the bed dip, younger formations, consisting of various lithologies, crop out. According to the geological culture of that time, relatively poor in the field of landslide hazard, the studies on the stability of the valley slopes in function of the height of waters in the basin were not very accurate. Only in July 1959, after the fall of a landslide in another basin close to the Vajont Valley, a detailed geomorphological study of the basin was started involving Prof. L. Müller as a consultant.

This study was performed by E. Semenza and soon it led to the discovery of an old (post-Würm), quiescent landslide, afterwards quantified in 250 millions of m³, just few hundreds of metres up-hill from the dam, near the Toc locality on the left side of the basin. The landslide involved Jurassic and Cretaceous rocks (limestone and marls of the Fonzaso and Socchêr formations) more or less fractured, slid down along a roughly concave surface, corresponding to the top of the Vajont Limestone. Moreover, E. Semenza inferred that the landslide could have moved downslope again during the progressive infilling of the basin.

This hypothesis was tested by means of 1) geoseismic surveys and mechanical drilling, to ascertain the depth of the basal surface of the landslide mass and 2) topographic measurements all around the suspect area, to verify slope movements caused by the rising of the water level during the infilling of the reservoir, that started in February 1960. Minor, horizontal displacements took place in May 1960, when the water level in the basin reached the height of 600 m. In October, movements increased dramatically, exceeding 3 cm per day as water level arrived at 650 m, and a surface landslip of about 700,000 m³ came off from the front of the major landslide. As the water level was slowly lowered, movements virtually stopped. New geoseismic surveys were performed and piezometers were installed.

As the landslide motion stopped, it was decided to continue the plant operation, but also to excavate a bypass tunnel connecting the two parts of the reservoir that would otherwise have become disconnected in case further motion of the mass had occluded the valley. At the end of October 1961, after C. Semenza’s death and according to his plan, the water level was progressively raised very slowly and, after more than one year, it reached the height of 700 metres. The landslide motion, very slow until the month before, accelerated to 1,5 cm per day, and the reservoir level was again gradually lowered to 650, when the motion stopped.

At this point, on March 1963, the plant direction was transferred from SADE to ENEL (Ente Nazionale per l’Energia Elettrica). The need of electric energy in the whole country was serious and all resources had to be employed, so the rise of the reservoir level was immediately renewed, with rates less prudential than those used until that moment. In August and September 1963 the rise to an height of 710 m was followed by new movements. A further lowering to 700 m began only in September 26th but could not reduce the landslide motion; on the contrary a rapid increase took place from about 3 cm per day at the beginning of October, to 30 cm per day the 9th of October in the morning, culminating in 60-100 Km per hour in the evening, when the devastating landslide collapse took place. The slide mass moved as a whole and reached the opposite side of the valley without any change in shape except for a general rotation. The thrust of the slide mass was so strong to push uphill for
about 50 metres onto the right side of the valley a large hill called Colle Isolato (about 2.5 millions of m³), representing the vestiges of an older land-slide. The mass drove forward the water of the reservoir, raising a wave two hundred metres high, which overtopped the dam and hit right in the middle the Longarone village and other smaller centers.

Subsequent studies attempted to address the causes of the high velocity reached by the land-slide. The presence of clay levels just below the detachment was recognized, as well as the existence of a deep aquifer in the Vajont Limestone, poorly karstified, below the aquifer contained inside the land-slide mass, highly permeable by fissuring. The pressure exerted by the deep aquifer can be considered as one of the causes of the movement. The friction angle of the clays, at that moment estimated in 8°, and later in 4° may explain the high velocity reached.

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CONTRIBUTOR ADDRESSES

GLORIA ANDREINI, Dipartimento di Scienze della Terra, Università degli Studi di Perugia, Piazza Università, 06100 Perugia, Italy, e-mail: gparisi@unipg.it

MARCO AVANZINI, Museo Tridentino di Scienze Naturali, Via Calepina 14, 38100 Trento, Italy.

ANGELA BALDANZA, Dipartimento di Scienze della Terra, Università degli Studi di Perugia, Piazza Università, 06100 Perugia, Italy

ANNACHIARA BARTOLINI, Laboratoire de Micropaleontologie, case 104, Université Pierre et Marie Curie, 4 Place Jussieu, 75252 Paris, France, e-mail: chiara@ccr.jussieu.fr

PAOLA BECCARO, Dipartimento di Scienze della Terra, Via La Pira 36, 90123 Palermo, Italy, e-mail: bellanca@unipa.it

CARLO BERTOK, Dipartimento di Scienze della Terra, Università degli Studi di Perugia, Piazza Università, 06100 Perugia, Italy, e-mail: strangott@unipg.it

JESUS E. CARACUEL MARTIN, Dpto. Ciencias de la Tierra, Fac. Ciencias, Univ. Alicante, Apdo. 99, San Vicente del Raspeig 03080 Alicante, Spain, e-mail: Jesus.Caracuel@ua.es

DANIELA CASSIOLI, Via Ciceruacchio 7, 00015 Monterotondo (Roma), Italy

RAIMONDO CATALANO, Dipartimento di Geologia e Geodesia, Università di Palermo, Via Archirafi 26 – 90123 Palermo, Italy, e-mail: rctatal@unipa.it

FABRIZIO CECCA, Università "Pierre et Marie Curie" - Paris VI, Laboratoire de Micropaléontologie, case 104, 4, place Jussieu - 75252 Paris cedex 05, France, e-mail: cecca@ccr.jussieu.fr

PAOLO CENSI, Dipartimento di Scienze della Terra, Università di Catania, Viale Italia 55, Italy, e-mail: pcensi@mbox.unict.it

MARCO CHIARI, Dipartimento di Scienze della Terra, Università di Catania, Via G. La Pira, 4 Firenze, Italy, e-mail: mchiari@geo.unifi.it

PIERANGELO CLARI, Università di Torino, Dipartimento di Scienze della Terra, Via Accademia delle Scienze 5, 10123 Torino, Italy, e-mail: clari@dst.unito.it

MIRIAM COBIANCHI, Dipartimento di Scienze della Terra, Via Ferrara 1 - 27100 Pavia, Italy, e-mail: miriam@unipv.it

RODOLFO COCCIONI, Museo Civico "Brancaleoni", Piobbico (PU), Italy, e-mail: cron@info-net.it

JOHN W COPE, Department of Geology, University of Wales, P.O. Box 914, CF1 3YE Cardiff, UK, e-mail: copeJCW@cardiff.ac.uk

STEFANO CRESTA, Agenzia Regionale Parchi del Lazio, Via Indonesia 33 – 00144 Roma, Italy, e-mail: geositi@parchilazio.it

CAROLINA D'ARPA, Dipartimento di Geologia e Geodesia, Università di Palermo, Via Tukory 131, 00134 Palermo, Italy, e-mail: mgup@unipa.it

ANTONIO DILIGENTI, Istituto di Geologia Università di Urbino, Località Crocicchia, Urbino, Italy, e-mail: bradfaust57@inwind.it

DANIELA DI PIETRO, Museo Civico "Brancaleoni", Piobbico (PU), Italy, e-mail: dpdaniela@katamail.it

PIERO DI STEFANO, Dipartimento di Geologia e Geodesia, Università di Palermo, Via Archirafi 22 – 90123 Palermo, Italy, e-mail: pdstefano@unipa.it

FABIO DURONIO, Museo Civico Brancalonei, Piobbico (PU), Italy, e-mail: ineluttabile@inwind.it

PAOLO FERLA, Dipartimento di Chimica e Fisica della Terra ed Applicazioni alle Georisorse e ai Rischi Naturali, Università di Palermo, Via Archirafi, 36 – 90123 Palermo, Italy, e-mail: pferla@unipa.it

ANDRAS GALACZ, Department of Paleontology, Eotvos Lorand University, H-1117 Budapest (Hungary), Pázmány Péter setány 1/C, Hungary, e-mail: galacz@ludens.elte.hu

FRANCESCA GASPARRI, Via Alessandria 154, 00185 Roma, Italy

MONICA GHIROTTI, Dipartimento di Scienze della Terra Geologico-Ambientali, Via Zamboni 67- 40127 Bologna, Italy, e-mail: ghirotti@geomin.unibo.it

ALESSANDRO GRIPPO, Dep. Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, USA, e-mail: grippo@earth.usc.edu

MARIA GULLO, c/o Dipartimento di Geologia e Geodesia, Università di Palermo, Via Archirafi, 22, 90123 Palermo, Italy, e-mail: mariagullo@libero.it.

ROBERTO LANZA, Dipartimento di Scienze della Terra, Via Valperga Caluso 35, 10125, Torino, Italy, e-mail: lanzad@dst.unito.it

GIOVANNA LO CICERO, Dipartimento di Geologia e Geodesia, Università di Palermo, Via Archirafi 26 – 90123 Palermo, Italy, e-mail: locicero@unipa.it

FRANCESCA LOZAR, Dipartimento di Scienze della Terra, Via Accademia delle Scienze 5, 10123 Torino, Italy, e-mail: lozar@dst.unito.it

GIANNI MALLARINO, Dipartimento di Geologia e Geodesia, Università di Palermo, Via Archirafi 22 – 1 – 90123 Palermo, Italy, e-mail: giannimallarino@usa.net

AGOSTINO MARINI, Via Venezia 42, Cagli (PU), Italy

MARIA CONCETTA MARINO, Dipartimento di Scienze Geologiche, Università di Catania, Palazzo delle Scienze, Corso Italia 55, 95100 Catania, Italy, e-mail: marinom@mbox.unict.it
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