

9th International Congress on the Jurassic System, Jaipur, India

Abstracts

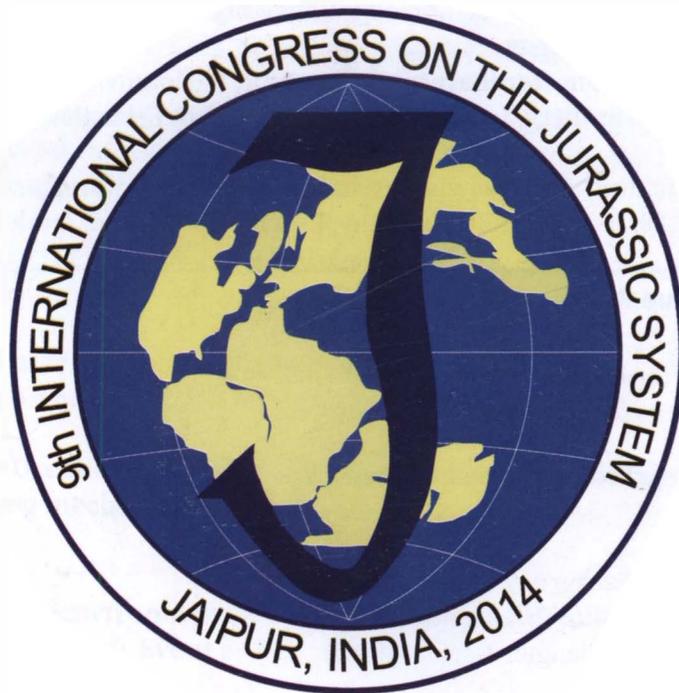
D. K. Pandey, F. T. Fürsich & M. Alberti (Eds.)



9th International Congress on the Jurassic System, Jaipur, India

Abstracts

Dhirendra K. Pandey, Franz T. Fürsich & Matthias Alberti (Eds.)



Beringeria Special Issue 8 - Erlangen 2014

Cover photographs

Front: The facade of the Hawa Mahal or Palace of Winds in Jaipur.

Back: A mural in the Nahargarh Fort near Jaipur.

Addresses of the editors:

DHIRENDRA K. PANDEY, Department of Geology, University of Rajasthan, Jaipur, 302004, India;
E-mail: dhirendrap@hotmail.com

FRANZ T. FÜRSICH, GeoZentrum Nordbayern, Fachgruppe Paläoumwelt der Friedrich-Alexander-Universität Erlangen-Nürnberg, Loewenichstr. 28, D-91054 Erlangen, Germany; E-mail: franz.fuersich@fau.de

MATTHIAS ALBERTI, Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Ludewig-Meyn-Str. 10, D-24118 Kiel, Germany; E-mail: alberti@gpi.uni-kiel.de

Beringeria, **Special Issue 8:** 213 pages

Erlangen, 01.12.2013

ISSN 0937-0242

Publisher:

Freunde der nordbayerischen Geowissenschaften e.V.

Editorial Office:

GeoZentrum Nordbayern, Fachgruppe Paläoumwelt,
Friedrich-Alexander-Universität Erlangen-Nürnberg
Loewenichstr. 28, D-91054 Erlangen, Germany.

Print:

Tiwari Printers

Jhotwara, Jaipur, 302012, India.

Contents

A sequence stratigraphic interpretation of the contact between the Lathi and Jaisalmer formations, Jaisalmer Basin, Rajasthan, India <i>by</i> A. Agarwal, A. S. Kale & P. B. Jadhav	11
Ammonites of the family Mayaitidae SPATH, 1928 from the Oxfordian of Kachchh, western India <i>by</i> M. Alberti, D. K. Pandey, M. Hethke & F. T. Fürsich	13
Stratigraphy, facies analysis and reservoir characterization of the Upper Jurassic Arab "C", Qatar, Arabian Gulf <i>by</i> H. Al-Saad & F. Sadooni	16
Re-evaluating the Toarcian Oceanic Anoxic Event from the Southern Hemisphere, Neuquén Basin, Argentina <i>by</i> A. H. Al-Suwaidi, G. N. Angelozzi, F. Baudin, D. Condon, S. E. Damborenea, S. P. Hesselbo, H. C. Jenkyns, M. Manceñido & A. Riccardi	17
Carbon and oxygen isotope record of the Jurassic bulk carbonates and calcareous fossils from the Pieniny Klippen Belt (Carpathians) <i>by</i> A. Arabas, J. Schlögl & A. Wierzbowski	19
Micropalaeontological study at the Oxfordian–Kimmeridgian boundary in Central Poland – a preliminary report <i>by</i> M. Barski, M. Hodbod, B. A. Matyja & A. Wierzbowski	21
Palaeoecological significance of the Callovian-Oxfordian trace fossils of Gangeshwar Dome, southeast of Bhuj, Mainland Kachchh, India <i>by</i> N. Y. Bhatt & S. J. Patel	23
Jurassic basins of India: Tectonic set up and sediment fill <i>by</i> S. K. Biswas	26
Early Jurassic (Sinemurian/Pliensbachian) ammonites of the Central Apennines (Monte di Cetona and Acquasparta, Italy) <i>by</i> J. Blau & C. Meister	28
Life in a Late Jurassic Subboreal Sea and on its coast: a new taphonomic window of exceptionally preserved fauna at Owadów-Brzezinki (Central Poland) <i>by</i> B. Błażejowski, B. A. Matyja, A. Wierzbowski & H. Wierzbowski	29
Geodynamic events and the drowning history of a Jurassic carbonate platform: a case study from the Aurès area (NE Algeria) <i>by</i> El Hadj Y. Brahim & M. Chadi	31
The Upper Bajocian <i>Cranocephalites</i>-succession in East Greenland: achieving the highest possible biostratigraphic resolution <i>by</i> J. H. Callomon, P. Alsen & F. Surlyk	32
The Early Toarcian Oceanic Anoxic Event in Western North America: Testing regional vs. global controlling mechanisms <i>by</i> A. H. Caruthers, D. R. Gröcke, P. L. Smith, B. C. Gill, S. J. Porter & P. Hou	34
The impacts of palaeoenvironmental change on benthic and pelagic fauna during the Toarcian Oceanic Anoxic Event <i>by</i> B. A. Caswell & A. L. Coe	36
Center of gravity and shell volume calculations for some Jurassic ammonoids from Kachchh, India <i>by</i> A. Chaudhari	38

Ductile deformation in Jurassic sequence of Kachchh rift basin: A clue to Median High tectonics, Western India <i>by G. Chauhan & M. G. Thakkar</i>	39
Integrated stratigraphy of the Oxfordian succession on the Isle of Skye, Scotland <i>by A. L. Coe</i>	40
Nodularity vs. geochemistry in Ammonitico Rosso: a preliminary report from the Upper Jurassic (Betic Cordillera, SE Spain) <i>by R. Coimbra & F. Olóriz</i>	41
Palaeolatitudinal patterns of diversity and distribution in Early Jurassic South American bivalves <i>by S. E. Damborenea & J. Echevarría</i>	43
The terrestrial Triassic–Jurassic boundary in China <i>by S. Deng, Y. Lu, R. Fan & X. Li</i>	45
Continental drainage and oceanic circulation during the Jurassic inferred from the Nd isotope composition of biogenic phosphates and sediments <i>by G. Dera, J. Prunier, P. L. Smith, J. Haggart, E. Popov, A. Guzhov, M. A. Rogov, D. Delsate, D. Thies, G. Cuny, E. Pucéat, G. Charbonnier & G. Bayon</i>	48
Palynology of Missão Velha and Brejo Santo formations (Jurassic) of the Araripe Basin, Northeastern Brazil <i>by S. Duarte, M. Arai & N. Jha</i>	50
Correlation of the Boreal Jurassic–Cretaceous boundary strata by means of belemnites <i>by O. S. Dzyuba</i>	52
Bajocian ammonoids and depositional events of the Arequipa Basin (southern Peru): evidence from Rio Pumani area (Ayacucho) <i>by S. R. Fernandez-Lopez, V. C. Caillaux, E. G. Saldivar & C. C. Budiel</i>	54
The ecological role of the Jurassic seafloor: benthic ecological functioning during the Kimmeridgian OAE <i>by C. L. J. Frid & B. A. Caswell</i>	57
Facies patterns and environmental evolution of the Amu Darya Basin and associated basins in central Asia during the Jurassic <i>by F. T. Fürsich, M. Wilmsen & H. Munsch</i>	59
Palaeobiogeography and evolutionary trends in the Oxfordian subfamily Prososphinctinae GŁOWNIAK, 2012 (Ammonoidea, Perisphinctidae) <i>by E. Głowniak</i>	60
Jurassic geology and biostratigraphy of the Early Callovian in the Kanev district area (Cherkassy region, Ukraine) <i>by D. Gulyaev, A. Ippolitov & D. Kiselev</i>	62
Morphological variations in the ichnogenus <i>Hillichnus</i>: a record from the Jaisalmer Formation, Rajasthan, India <i>by S. S. Gurav & K. G. Kulkarni</i>	65
Early–Middle Jurassic chemostratigraphy, black shale, and sea-level change: evidence for cyclically repeated global change events <i>by S. P. Hesselbo, C. Korte & C. V. Ullmann</i>	66
Refined palaeoenvironmental analysis based on changes in macrobenthic communities – A case study from the Kimmeridgian of Normandy <i>by M. Hethke, T. Felsch & F. T. Fürsich</i>	67

Foraminifera and the end-Triassic biotic crisis at the T-J boundary in the Northern Calcareous Alps <i>by</i> A. von Hillebrandt	70
Sinemurian (Early Jurassic) Ammonites from Five Card Draw, Nevada and Last Creek, British Columbia <i>by</i> P. Hou, P. L. Smith, A. H. Caruthers & S. J. Porter	73
Evolutionary significance of latest Jurassic-earliest Cretaceous hydrocarbon seep assemblages from Central Spitsbergen, Svalbard <i>by</i> K. Hryniewicz, C. T. S. Little, H. A. Nakrem, Ø. Hammer, M. R. Sandy, A. Kaim & V. Olev	75
Tetragonal serpulids from the Jurassic: testing the phylogenetic relationships by ultrastructural and mineralogical tube studies <i>by</i> A. Ippolitov & E. Kupriyanova	77
Belemnite zonal scale for the Late Sinemurian – Pliensbachian of Eastern Europe: an update based on data from the Ukrainian Carpathians <i>by</i> A. Ippolitov & J. Schlögl	79
Microfossil research using 3D imaging technology: an experimental study of Jurassic radiolarian fossils using X-ray micro-computed tomography <i>by</i> N. Ishida, N. Kishimoto, A. Matsuoka, K. Kimoto, T. Kurihara & T. Yoshino	81
Paleoenvironment and sedimentation of deep marine spotted limestones and marls, Lower and Middle Jurassic (Western Carpathians, Tatra Mts.) <i>by</i> J. Iwańczuk & K. Sobieć	83
Middle Jurassic Bivalves from Charu area, Jaisalmer district, Rajasthan, India <i>by</i> R. L. Jain, R. P. Kachhara & R. L. Jodhawat	85
Palaeobiogeographic significance of the Middle Jurassic pholadomyoid bivalves from Kachchh, western India <i>by</i> A. K. Jaitly	86
Jurassic-Cretaceous plant mega- and microfossils from subsurface Gondwana sediments of the Jangareddygudem area, Chintalapudi subbasin, India <i>by</i> N. Jha, N. Prakash & H. Joshi	87
Environmental significance of the trace fossils of Middle Jurassic rocks, Patcham Island, Kachchh, western India <i>by</i> J. K. Joseph, S. J. Patel & N. Y. Bhatt	88
Towards an integrated Jurassic biostratigraphy for eastern Greenland <i>by</i> S. R. A. Kelly, F. J. Gregory, B. Braham, D. P. Strogon & A. G. Whitham	92
Palaeoenvironmental changes through a Panthalassic margin record of the early Toarcian Oceanic Anoxic Event <i>by</i> D. Kemp & K. Izumi	93
High-resolution microfossil results from the Toarcian Oceanic Anoxic Event, Yorkshire, UK <i>by</i> A. E. Kennedy, A. L. Coe, W. D. Gosling & J. B. Riding	94
Palaeobiogeographical study of the Middle-Upper Jurassic corals in East-Central Iran <i>by</i> K. Khaksar, M. Farboodi & A. Khaksar	96
An overview of the Jurassic dinosaur fossil record from India: Implications for depositional facies and palaeoenvironments <i>by</i> A. Khosla	98

Ostracod biostratigraphical zonation of the Middle Jurassic beds of western India - a review <i>by</i> S. C. Khosla	100
The Jurassic-Cretaceous short-lived atoll coral reefs around active volcanoes in the Western Tethys (Ukrainian Carpathians) <i>by</i> M. Krobicki, A. Feldman-Olszewska, J. Iwańczuk & O. Hnylko	101
Palaeoenvironmental context and palaeoecological significance of microbialites - metazoan assemblages from condensed deposits at the Middle–Upper Jurassic transition (Getic Unit, Southern Carpathians, Romania) <i>by</i> I. Lazăr & M. Grădinaru	103
Jurassic - Early Cretaceous evolution of the passive margin of the Moesian Plate (Danubian Unit, Romanian Carpathians) <i>by</i> I. Lazăr, M. Krobicki, M. Grădinaru & M. E. Popa	105
Jurassic ammonite faunas of northern Iran and their palaeobiogeographic significance <i>by</i> M. R. Majidifard	107
Middle Jurassic ostracod fauna from Jaisalmer, Rajasthan, India <i>by</i> K. Manisha, M. M. Lal & S. Vidhya	108
Recent progress in ecological studies on living radiolarians and its application to the Jurassic ecosystem - End-Triassic mass extinction and early Jurassic recovery in the pelagic realm <i>by</i> A. Matsuoka	110
On the Oxfordian-Kimmeridgian (Upper Jurassic) boundary - current state of knowledge <i>by</i> B. A. Matyja & A. Wierzbowski	111
Ammonite distribution in late Middle-Upper Jurassic deposits of epicratonic Poland: the key to ecology, biogeography, palaeogeography and geotectonic events <i>by</i> B. A. Matyja & A. Wierzbowski	113
Phricodoceratinae SPATH, 1938 (Mollusca, Cephalopoda): ontogeny, evolution & paleobiogeography <i>by</i> C. Meister & J.-L. Dommergues	115
Microfacies of the Bathonian sediments of the Jumara Dome, Kachchh, western India: Inference of depositional environments <i>by</i> A. Misra	116
Ammonite zonation of the Boreal Bathonian Stage of Greenland <i>by</i> V. Mitta & P. Alsen	118
Boreal-Tethyan correlation of the Bajocian-Bathonian boundary beds in the Sokur section (Central Russia): new insights into an old story <i>by</i> V. Mitta, V. Kostyleva, O. S. Dzyuba, L. Glinskikh, B. N. Shurygin, V. Seltzer & A. Ivanov	120
Brachiopod diversity in the Jurassic of the Kutch and Jaisalmer basins, western India <i>by</i> D. Mukherjee	122
Life in a Jurassic shelf lagoon: The Kamar-e-Mehdi Formation of east-central Iran <i>by</i> Y. Pan & F. T. Fürsich	124

- A review of *Virgatosphinctes densiplicatus* (WAAGEN) from the Tithonian beds of Kachchh Basin, west India** by D. K. Pandey & S. Bhaumik 126
- Sequence stratigraphic framework of the Oxfordian to Tithonian sediments (Baisakhi Formation) in the Jaisalmer Basin** by D. K. Pandey & D. Pooniya 127
- Record of a condensed late Early to Middle Callovian horizon (Rehmanni-Obtusicostites zones) from the eastern part of the Jaisalmer Basin, western India** by D. K. Pandey & N. Swami 128
- Sedimentological and palaeoecological significance of trace fossils from the Jurassic succession of the Jhura Dome, Mainland Kachchh, Western India** by S. J. Patel & N. J. Patel 129
- Discovery of Early Bathonian ammonites from Kachchh, western India and their biostratigraphic implications** by D. B. Pathak & B. Pandey 133
- Parkinsoniids and garantianids (Late Bajocian Ammonoidea) as guide fossils and biostratigraphic indices** by G. Pavia & S. R. Fernandez-Lopez 134
- A first Upper Jurassic ⁴⁰Ar/³⁹Ar date from Oxfordian ammonite-calibrated volcanic layers (bentonites) from the Rosso Ammonitico Veronese, Italy** by P. Pellenard, S. Nomade, L. Martire, F. Monna & H. Guillou 137
- Integrated stratigraphy of the potential candidate Oxfordian GSSP at Thuoux and Saint-Pierre d'Argençon (France)** by P. Pellenard, A. Bartolini, S. Boulila, P.-Y. Collin, D. Fortwengler, B. Galbrun, S. Gardin, V. Huault, E. Huret, D. Marchand & J. Thierry 139
- Evolution of Volgian–Valanginian microphytoplankton communities in the Olenyok River region, North Siberia** by E. B. Pestchevitskaya 141
- Marine (black) and marginal-marine (green) Toarcian shales in Europe – carbon isotope consistency, TOC inconsistency** by G. Pieńkowski & M. Hody 143
- End-Triassic biota crisis and earliest Jurassic recovery in continental strata of Poland in relation to rapid climatic reversals associated with CAMP volcanism** by G. Pieńkowski, G. Niedźwiedzki & P. Brański 145
- New high-resolution geochemistry of Sinemurian marine sections in British Columbia and Nevada** by S. J. Porter, P. L. Smith, A. H. Caruthers, P. Hou, D. R. Gröcke & D. Selby 147
- An overview of Upper Gondwana fossil floral assemblages of the Kachchh Basin, India** by N. Prakash 148
- When did the twain meet? The epeiric Ethiopian Gulf with the Western Indian craton; Coccoliths, the beacon of light!** by J. Rai 150
- Integrated nannofossil-dinoflagellate cyst – ammonoid biostratigraphy from Wagad area, Kachchh, Western India** by J. Rai, S. Garg, M. Gupta, A. Singh, D. K. Pandey & R. Garg 151

Nannofossil biostratigraphy of the Chari Formation, Jumara Dome, Kachchh, western India <i>by</i> J. Rai, M. Gupta, S. Garg, A. Singh, S. Jain & D. K. Pandey	153
Middle-Jurassic age calcareous nannofossils from Habo Dome, Kachchh, western India <i>by</i> J. Rai, S. J. Patel, A. Singh, M. Gupta, S. Garg, B. Thakur & H. Shukla	155
Continental Jurassic of peninsular India – A floristic and stratigraphic riddle <i>by</i> A. Rajanikanth & C. Chinnappa	158
An overview of yellow Limestone deposit of Jaisalmer Basin of Rajasthan, India <i>by</i> T. S. Ranawat & N. Srivastava	161
Limit of Upper Bathonian-Lower Callovian in Ankilizato region (Morondava Basin) <i>by</i> H. N. Randrianaly & A. Rasoamiaramanana	162
Stable isotopes of foraminifera and ostracods for interpreting the Toarcian Oceanic Anoxic Event at the South Iberian palaeomargin <i>by</i> M. Reolid	163
Ecostratigraphy of foraminiferal assemblages and geochemistry for approaching the incidence of Early Toarcian environmental changes at the North Gondwana palaeomargin (Traras Mountains, Algeria) <i>by</i> M. Reolid, A. Marok & A. Sebane	165
The Early Toarcian Oceanic Anoxic Event in the External Subbetic (South Iberian Palaeomargin, westernmost Tethys): geochemistry, nannofossils, and ichnology of the La Cerradura section <i>by</i> M. Reolid, E. Mattioli, L. M. Nieto & F. J. Rodríguez-Tovar	167
Preliminary report on the ammonite fauna and stratigraphy of the Beckeri Zone (Upper Kimmeridgian) of the southern Crimea (Ukraine) <i>by</i> M. A. Rogov	169
Quantitative and qualitative aspects of changes in shell size through the evolution of Volgian ammonites in the Russian Sea: Cope's rule, Lilliput effect, dimorphism, and polymorphism <i>by</i> M. A. Rogov	171
New data on the Lower-Upper Kimmeridgian boundary beds of southern Tatarstan, Central Russia <i>by</i> M. A. Rogov, A. Wierzbowski, E. V. Shchepetova & H. Wierzbowski	174
<i>Distichoceras bicostatum</i> (STAHL) (Ammonoidea) from Kutch, western India; its stratigraphic and palaeoecological significance <i>by</i> P. Roy	176
Integrated biostratigraphy across the Aalenian/Bajocian boundary of the Central High Atlas, Morocco <i>by</i> D. Sadki	177
Middle Jurassic coral biohermal limestones from pelagic carbonate platforms (Pieniny Klippen Basin, Western Carpathians) <i>by</i> J. Schlögl, A. Tomašových, D. Ivanova, B. Lathuilière, L. Villier & M. Golej	179
Distribution of the Jurassic Pectinoida and Ostreoida from the Tanggula Mountains, China: Biogeographic relations and importance of trans-Pacific migration and the Hispanic Corridor <i>by</i> J. Sha & P. L. Smith	181
Palaeobiogeography and evolution of Kutch Virgatospinctinae <i>by</i> S. Shome & S. Bardhan	182

- Jurassic Boreal zonal standard: Possibilities of Boreal–Tethyan correlation based on an integrated bio-, magneto- and chemostratigraphic approach** *by* B. N. Shurygin & O. S. Dzyuba 185
- Ammonite biostratigraphy of the Pliensbachian-Toarcian transition at Westgate, Nevada, USA** *by* P. L. Smith & A. H. Caruthers 188
- Ichnology of the Callovian-Oxfordian of Katrol Hill Range, Southwest of Bhuj, Kachchh, western India** *by* P. M. Solanki, N. Y. Bhatt, S. J. Patel & J. M. Patel 190
- Response of Jurassic strata of Kachchh to Quaternary tectonics in an active intra-plate basin of Kachchh, western India** *by* M. G. Thakkar 192
- Untangling real from apparent seawater temperature variability during the Late Jurassic** *by* A. Tomašových, D. Jacob, M. Joachimski, M. López Correa, J. Schlögl 193
- Ichnological record of food content change in Middle–Upper Jurassic pelagic sediments of the Fatricum domain in the Tatra Mountains, southern Poland** *by* A. Uchman & R. Jach 195
- First contribution to precise biostratigraphy of Upper Tithonian rocks from the Veracruz Basin (SE México)** *by* A. B. Villaseñor & F. Olóriz 197
- Foraminiferal zonation of the Jurassic of the Caucasus and Precaucasus** *by* V. J. Vuks 200
- Syn- and post-tectonic palaeomagnetism of Jurassic sediments from the Velebit Mts (Karst Dinarides, Croatia)** *by* T. Werner, I. Vlahovic, M. Sidorczuk & M. Lewandowski 204
- Oxygen and carbon isotope records of uppermost Callovian–Lower Kimmeridgian belemnite rostra and bulk carbonates from the Polish Jura Chain (central Poland): environmental changes in the Submediterranean Province of Europe** *by* H. Wierzbowski 205
- Revised seawater strontium isotope curve for the Late Bajocian–Oxfordian (Middle–Late Jurassic)** *by* H. Wierzbowski, R. Anczkiewicz, J. Bazarnik & J. Pawlak 207
- Orbital cyclicity and its environmental response – a case study from the Upper Bathonian of Central Poland** *by* P. Ziólkowski, T. Werner, Z. Dubicka & L. A. Hinnov 209

A sequence stratigraphic interpretation of the contact between the Lathi and Jaisalmer formations, Jaisalmer Basin, Rajasthan, India

ANSHIKA AGARWAL¹, ANAND S. KALE¹ & PRADEEP B. JADHAV²

¹*Bharat Petro Resources Limited, Maker Tower, 'E' Wing, Cuffe Parade, Mumbai 400005, India; E-mail: anshika.agarwal@bharatpetroresources.in*

²*Department of Petroleum Engineering, Maharashtra Institute of Technology, Kothrud, Pune 411038, India*

The Jaisalmer Basin of Rajasthan, India is the stable shelfal part of the larger Indus Basin and preserves a fairly complete record of sea-level changes during the Jurassic to Early Cretaceous times varying from deltaic/transitional to a widespread carbonate platform setting. Lithostratigraphically, Jurassic sediments in the Jaisalmer Basin are divided into Lathi, Jaisalmer, Baisakhi, and Bhadesar formations. Mesozoic sedimentation starts with the siliciclastic-dominated Lathi Formation (Liassic-Bajocian) corresponding with the evolution of the Tethyan passive margin and subsequent initiation the East African rifting. The Jaisalmer Formation (Bathonian-Oxfordian) represents carbonate-dominated sedimentation resulting from the first major long-term marine transgression of the basin.

The contact between the Lathi (Liassic-Bajocian) and Jaisalmer (Bajocian-Oxfordian) formations has been considered in earlier studies to be gradational and intertonguing in surface exposures as well as in subsurface. The present work deals with the documentation of the contact between the two formations and its interpretation in a sequence stratigraphic context. Examination of the transition from a siliciclastic depositional system to a carbonate setting has been done along five transects over a 30 km stretch along the strike from NE to SW of Jaisalmer town, viz. Basanpir, Thaiat, Kheta Sar, Temde Rai, and Narsingo ki dhani.

Conventionally the intertonguing contact between the Thaiat Member of the Lathi Formation and the Hamira Member of the Jaisalmer Formation is recognized at the first appearance of calcareous beds. These are overlain by inter-beds of sandstones and claystones and followed by limestones. The Thaiat Member comprises primarily lower delta plain multi-storey channel sandstones

interspersed with finer overbank facies. These pass upwards into tabular sandstones, typically with relatively flat bases and convex-up tops. Internally these are coarsening-up and hummocky cross-stratified with distinct lateral accretion, representing a more distal facies deposited above the storm wave-base as mouth bars/offshore bars. The sandstones gradually become the dominant facies with decreasing inter-beds of claystone followed by an interval with inter-bedded fine sandstones, bioturbated claystones and arenaceous limestones. The upper part represents a gradual decrease in the siliciclastic supply and the establishment of the carbonate depositional system. Further up in the succession the arenaceous limestones pass into thicker and massive limestones with well developed internal bedding characters suggesting that they are re-distributed by wave and/or currents in a shallow inner shelf setting.

A valley situated west and up-dip of Kheta Sar section shows erosion to cut a level deeper than in the easterly face of the Kheta Sar section. This NNE oriented valley is underlain by limestones, which are thinly bedded flaggy, trough cross-stratified and cherty whereas higher up along the flanks the earlier described succession is exposed. These limestones in the valley are interpreted to be the initial transgressive fill into incisions developed during sea-level lowstand. An angular relationship between the Thaiat Member and overlying Hamira Member is seen in this valley as well as in the area west of Narsingo ki Dhani, where the ripple- and cross-laminated succession of alternating calcareous sand and arenaceous limestones with clay interbeds are progressively overlapped by thick limestone beds.

From a sequence stratigraphic perspective, the uppermost part of the Lathi Formation

(Thaiat Member) is interpreted to be a transgressive systems tract, as evidenced by the appearance of transitional and marine facies overlying the lower deltaic siliciclastics. The paleosol above these represents the sequence boundary between the uppermost Lathi succession and overlying lowermost carbonates of the Jaisalmer Formation. This boundary covers the time span of the highstand to lowstand regressive systems tracts. The

overlying mixed carbonate-siliclastic section represents the subsequent transgressive systems tract of the overlying sequence; the maximum flooding zone of this sequence are the thickly bedded, nearly horizontal limestones of the Hamira Member. The highstand systems tract of the underlying sequence in the Thaiat Member would be present further basinward, concealed beneath the onlapping carbonates.

Ammonites of the family Mayaitidae SPATH, 1928 from the Oxfordian of Kachchh, western India

MATTHIAS ALBERTI¹*, DHIRENDRA K. PANDEY², MANJA HETHKE³ & FRANZ T. FÜRSICH³

¹*Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Ludewig-Meyn-Straße 10, 24118 Kiel, Germany; E-mail: alberti@gpi.uni-kiel.de*

²*Department of Geology, University of Rajasthan, Jaipur 302 004, India; E-mail: dhirendrap@hotmail.com*

³*GeoZentrum Nordbayern, Friedrich-Alexander-Universität Erlangen-Nürnberg, Loewenichstraße 28, 91054 Erlangen, Germany; E-mail: manja.hethke@fau.de, franz.fuersich@gzn.uni-erlangen.de*

*Corresponding author

The geology of the Kachchh Basin in western India has been studied for more than a century beginning with the surveys of GRANT (1840) and WYNNE (1872). Since then several generations of scientists have published articles describing the rich fossil record of the area - especially of the Jurassic strata. In this context, ammonites, in particular, took a prominent position as they allowed biostratigraphic correlations and fairly precise age determinations of the sedimentary rocks. Following the early substantial monographs on Jurassic cephalopods of the Kachchh Basin by WAAGEN (1873-1875) and SPATH (1927-1933), many articles have been published concentrating either on single ammonite groups, fossils of individual localities and time slices, or defining biostratigraphic successions (e.g., SINGH et al. 1982, 1983; PANDEY & AGRAWAL 1984; AGRAWAL & PANDEY 1985; BARDHAN & DATTA 1987; KRISHNA & WESTERMANN 1987; PANDEY & WESTERMANN 1988; KRISHNA & PATHAK 1991; PANDEY et al. 1994; PANDEY & CALLOMON 1995; JAIN et al. 1996; KRISHNA et al. 1996a, b, 2009a, b). In combination with a deeper understanding of the geology of the basin these studies offered a much more detailed view on the development and composition of the ammonite fauna in the area as well as increased the resolution of the biostratigraphic record.

A collection of more than 800 ammonites obtained during four recent field surveys concentrating mainly on the Oxfordian succession of the Kachchh Basin, however, showed that the fossil record is still not fully known. The material was collected with a high stratigraphic resolution and has consequently

been used as the base for a series of articles planned to enlarge our knowledge on the Upper Jurassic ammonite fauna of the Kachchh Basin (see ALBERTI et al. 2011; PANDEY et al. 2012). The current study deals with members of the family Mayaitidae SPATH, 1928. Ammonites of this group are relatively common in Oxfordian rocks of the Indian subcontinent as well as Madagascar (COLLIGNON 1959) and have also been reported from East Africa, Thailand, the Sula Islands, and New Guinea (ENAY & CARIOU 1997), but do not occur in the northwestern Tethys nor in the boreal realm.

Since several of the mayaitids previously described from the Kachchh Basin are long-ranging taxa and since the spatial distribution of the group is restricted, they have generally been regarded as comparatively poor index fossils and rather neglected in taxonomic studies. The present collection includes around 100 mayaitids allowing the first modern and nearly comprehensive study on the taxonomy of the group. Most of the morphospecies originally described by SPATH (1927-1933) could be recognized and confirmed representing the genera *Mayaites* SPATH, 1924 (6 taxa), *Epimayaites* SPATH, 1928 (12 taxa), *Dhosaites* SPATH, 1924 (2 taxa), and *Paryphoceras* SPATH, 1928 (3 taxa). Specimens were prepared, described, as well as photographed and depending on the preservational quality, their ribbing patterns and suture lines have been drawn. Cross-sections allowed the study of their allometric growth (i.e., changes in shape and proportional dimensions of the whorl section from inner to outer whorls), which is characteristic of particular taxa. Since adult

ammonites preserved with complete body chambers are extremely rare in the Kachchh Basin (compare PANDEY et al. 2012), the study of cross-sections through the available large specimens enabled reliable identifications of material representing only inner whorls. The distribution of morphospecies through time and space was evaluated leading to the recognition of taxa indicative of certain ammonite zones in the Kachchh Basin, which in the future might enable correlations within their distribution area (e.g., between India, Africa, and Madagascar). Promising candidates in this context include *Epimayaites falcooides* SPATH, 1928, which is very common in the Plicatilis to Transversarium zones (Middle Oxfordian) and *Epimayaites subtumidus* (WAAGEN, 1875), which has been collected exclusively from the lower Bifurcatus Zone (lower Upper Oxfordian). Other common taxa in the Kachchh Basin include *Mayaites maya* (J. DE C. SOWERBY, 1840), *M. rotundus* SPATH, 1928, *Epimayaites polyphemus* (WAAGEN, 1875), *E. lemoini* (SPATH, 1924), *E. axonoides* SPATH, 1928, and *E. transiens* (WAAGEN, 1875), but their biostratigraphic range is either long or yet undefined. Other taxa, especially the genera *Dhosaites* and *Paryphoceras*, are represented only by solitary specimens.

References

- AGRAWAL, S.K. & PANDEY, D.K. 1985. Biostratigraphy of the Bathonian-Callovian beds of Gora Dongar in Pachchham "Island", District Kachchh (Gujarat). – Proceedings of the Indian National Science Academy, Part A 51: 887–903.
- ALBERTI, M., PANDEY, D.K. & FÜRSICH, F.T. 2011. Ammonites of the genus *Peltoceratoides* SPATH, 1924 from the Oxfordian of Kachchh, western India. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 262: 1–18.
- BARDHAN, S. & DATTA, K. 1987. Biostratigraphy of Jurassic Chari Formation: a study in Keera Dome, Kutch, Gujarat. – Journal of the Geological Society of India 30: 121–131.
- COLLIGNON, M. 1959. Atlas des fossiles caractéristiques de Madagascar. Fascicule III (Oxfordien). 13 pls., Service géologique, République malgache, Tananarive.
- ENAY, R. & CARIU, E. 1997. Ammonite faunas and palaeobiogeography of the Himalayan belt during the Jurassic: Initiation of a Late Jurassic austral ammonite fauna. – Palaeogeography, Palaeoclimatology, Palaeoecology 134: 1–38.
- GRANT, C.W. 1840. Memoir to illustrate a geological map of Cutch. – Transactions of the Geological Society of London, Series 2 (5): 289–326.
- JAIN, S., CALLOMON, J.H. & PANDEY, D.K. 1996. On the earliest known occurrence of the Middle Jurassic ammonite genus *Reineckeia* in the Upper Bathonian of Jumara, Kachchh, western India. – Paläontologische Zeitschrift 70: 129–143.
- KRISHNA, J. & WESTERMANN, G.E.G. 1987. Faunal associations of the Middle Jurassic ammonite genus *Macrocephalites* in Kachchh, western India. – Canadian Journal of Earth Sciences 24: 1570–1582.
- KRISHNA, J. & PATHAK, D.B. 1991. Ammonoid biochronology of the Upper Jurassic Kimmeridgian stage in Kachchh, India. – Journal of the Palaeontological Society of India 36: 1–13.
- KRISHNA, J., PATHAK, D.B. & PANDEY, B. 1996a. Quantum refinement in the Kimmeridgian ammonoid chronology in Kachchh (India). – GeoResearch Forum 1-2: 195–204.
- KRISHNA, J., MELÉNDEZ, G., PANDEY, B. & PATHAK, D.B. 1996b. Middle Oxfordian ammonites (Perisphinctinae) from Kachchh (India): Biostratigraphic and palaeobiogeographic implications. – Revista Española de Paleontología, No. Extraordinario: 140–147.
- KRISHNA, J., PANDEY, B. & OHJA, J.R. 2009a. *Gregoryceras* in the Oxfordian of Kachchh (India): Diverse eventful implications. – Géobios 42: 197–208.
- KRISHNA, J., PANDEY, B. & PATHAK, D.B. 2009b. Characterization of *Dichotomoceras* in the Oxfordian of Kachchh. – Journal of the Geological Society of India 74: 469–479.
- PANDEY, D.K. & AGRAWAL, S.K. 1984. On two new species of the Middle Jurassic ammonite genus *Clydoniceras* Blake from Kachchh, Western India. – Neues Jahrbuch für Geologie und Paläontologie, Monatshefte 6: 321–326.
- PANDEY, D.K. & WESTERMANN, G.E.G. 1988. First record of Bathonian *Bullatimorphites* (Jurassic Ammonitina) from Kachchh, India. – Journal of Paleontology 62: 148–150.
- PANDEY, D.K. & CALLOMON, J.H. 1995. Contribution to the Jurassic of Kachchh, Western India. III. The Middle Bathonian ammonite families Clydoniceratidae and Perisphinctidae from Pachchham Island. – Beringeria 16: 125–145.
- PANDEY, D.K., CALLOMON, J.H. & FÜRSICH, F.T. 1994. On the occurrence of the Callovian ammonite *Parapatoceras tuberculatum* (BAUGIER & SAUZÉ, 1843) in Kachchh, Western India. – Paläontologische Zeitschrift 68: 63–69.
- PANDEY, D.K., ALBERTI, M. & FÜRSICH, F.T. 2012. Ammonites of the genus *Perisphinctes* WAAGEN, 1869 from the Oxfordian of Kachchh, western India. – Revue de Paléobiologie 31: 483–587.
- SINGH, C.S.P., JAITLEY, A.K. & PANDEY, D.K. 1982. First report of some Bajocian-Bathonian (Middle Jurassic) ammonoids and the age of the oldest sediments from Kachchh, W. India. – Newsletters on Stratigraphy 11: 37–40.
- SINGH, C.S.P., PANDEY, D.K. & JAITLEY, A.K. 1983. Discovery of *Clydoniceras* BLAKE and *Gracilisphinctes* BUCKMAN (Bathonian-Middle Jurassic ammonites) in Kachchh, Western India. – Journal of Palaeontology 57: 821–824.
- SPATH, L.F. 1927-1933. Revision of the Jurassic cephalopod

- fauna of Kachh (Cutch). Parts I-VI. - **Memoirs of the Geological Survey of India, Palaeontologia Indica, new series 9, 2: part I, 1-71, pls. 1-7 [1927]; part II, 72-161, pls. 8-19 [1928a]; part III, 162-278, pls. 20-47 [1928b]; part IV, 279-550, pls. 48-102 [1931a]; part V, 551-658, pls. 103-124 [1931b]; part VI, 659-945, pls. 125-130 [1933].**
- WAAGEN, W. 1873-1875. Jurassic fauna of Kutch. The Cephalopoda. - **Memoirs of the Geological Survey of India, Palaeontologia Indica, series 9, 1: part I, 1-22, pls. 1-4 [1873]; part II, 23-76, pls. 5-14 [1875a]; part III, 77-106, pls. 15-24 [1875b]; part IV, 107-247, pls. 25-60 [1875c].**
- WYNNE, A.B. 1872. Memoir of the geology of Kutch to accompany the map compiled by A.B. Wynne and F. Fedden during the seasons of 1867-68 and 1868-69. **Memoirs of the Geological Survey of India 9: 1-293.**

Stratigraphy, facies analysis and reservoir characterization of the Upper Jurassic Arab "C", Qatar, Arabian Gulf

HAMAD AL-SAAD^{1*} & FADHIL SADOONI²

¹*Department of Chemistry and Earth Sciences, Qatar University, P. O. Box 2713, Doha, Qatar; E-mail: Hamadsaad@qu.edu.qa*

²*Environmental Studies Center, Qatar University, P. O. Box 2713, Doha, Qatar*

**Corresponding author*

The Arab C reservoir is an economically significant member of the Upper Jurassic Arab Formation, the most important Jurassic reservoir in the Arabian Basin including Qatar. This unit represents transgressive systems tracts and consists of oolitic-peloidal grainstone, cyanobacterial algal boundstone and lime wackestone and mudstone. Large portions of these rocks underwent significant diagenetic modification including dissolution, cementation, evaporite replacement and

dolomitization. Present-day rock properties reflect both depositional and diagenetic controls. Petrophysical data suggest that the Arab C reservoir may have porosity values up to 30% and permeability values in excess of 450 md. The lithological and diagenetic features of the formation, its widespread distribution and the high porosity and permeability values make the formation an important exploration target in most of Qatar's hydrocarbon fields.

Re-evaluating the Toarcian Oceanic Anoxic Event from the Southern Hemisphere, Neuquén Basin, Argentina

A. H. AL-SUWAIDI¹ *, G. N. ANGELOZZI², F. BAUDIN³, D. CONDON⁴, S. E. DAMBORENEA⁵, S. P. HESSELBO⁶, H. C. JENKYN⁷, M. MANCENIDO⁵ & A. RICCARDI⁵

¹*Petroleum Geoscience Dept., Petroleum Institute, University and Research Centre, PO Box 2533, Abu Dhabi, UAE; E-mail: aalsuwaidi@pi.ac.ae*

²*GEMAS.R.L. Servicios Bioestratigráficos, Avenida Calchaquí Km.23.5, 1888 Florencio Varela, Argentina; E-mail: gemamicro@gmail.com*

³*UPMC- Université de Paris 06 & CNRS, UMR 7193, IStEP, F-75252, Paris Cx 05, France; E-mail: francois.baudin@upmc.fr*

⁴*British Geological Survey, Environmental Science Centre, Nicker Hill, Keyworth, Nottingham, NG12 5GG, UK; E-mail: dcondon@bgs.ac.uk*

⁵*Departamento Paleontología Invertebrados, Museo de Ciencias Naturales La Plata, Argentina, Paseo del Bosque S /N, 1900 La Plata, Argentina; E-mail: riccardi@fcnym.unlp.edu.ar; sdambore@fcnym.unlp.edu.ar; mmanceni@fcnym.unlp.edu.ar*

⁶*Camborne School of Mines, College of Engineering, Mathematics and Physical Sciences, University of Exeter, Penryn Campus, Cornwall, TR10 9EZ, UK; E-mail: S.P.Hesselbo@exeter.ac.uk*

⁷*Department of Earth Sciences, University of Oxford, Parks Road, Oxford, OX1 3PR, UK; E-mail: hugh.jenkyns@earth.ox.ac.uk*

**Corresponding author*

The carbon-isotope composition of organic matter and carbonate in terrestrial and marine sediments from the Early Toarcian (~183 Ma) was subject to abrupt and substantial disturbances of the carbon cycle, recognized as a negative carbon isotope excursion (CIE) disrupting an overall positive excursion. These disturbances are associated with extreme cases of global environmental change and correspond with the formation of the Karoo-Ferrar Large Igneous Province (LIP), possible dissociation of methane hydrate, increases in sea-floor hydrothermal activity, ocean acidification, and widespread deposition of marine black shales linked to intervals of oxygen depletion in large volumes of ocean water, referred to as Oceanic Anoxic Events or OAE (e.g. HESSELBO et al. 2000; PÁLFY & SMITH 2000; JONES & JENKYN 2001; HESSELBO et al. 2007; SVENSEN et al. 2007; KUMP et al. 2009; TRECALI et al. 2012). Recently, two studies have been published concerning the expression of the Toarcian Oceanic Anoxic Event (T-OAE) in the Southern Hemisphere Neuquén Basin, Argentina; one study focused on chemostratigraphic and biostratigraphic identification of the T-OAE at Arroyo Lapa in the Neuquén Province (AL-SUWAIDI et al. 2010),

and the other concerning Arroyo Serrucho in the Mendoza Province (MAZZINI et al. 2010). MAZZINI et al. (2010) provide U-Pb ages determined by ID-TIMS on zircons from two tuff beds that they interpreted to be located within the negative CIE of the T-OAE. These beds gave ages of 181.42 ± 0.24 Ma and 180.59 ± 0.43 Ma, dates were subsequently used to constrain the estimated ages of the limits of the Toarcian Stage (GRADSTEIN et al. 2012). Here we present new data from Arroyo Lapa and Arroyo Serrucho, comprising high-resolution lithostratigraphy, biostratigraphy, organic carbon isotopes (bulk sediment and fossil wood), total organic carbon, hydrogen index and new ages of ash beds from the Early Toarcian. These new data show multiple large-scale negative and positive excursions through the Early–Middle Toarcian interval, with multiple abrupt negative shifts in $\delta^{13}\text{C}_{\text{org}}$ and values falling below -30‰ , followed by abrupt positive shifts with $\delta^{13}\text{C}_{\text{org}}$ values of $>-24\text{‰}$. In addition to this higher resolution organic carbon data, new radio-isotopic ages from volcanic ash layers at Arroyo Lapa confirm synchrony of isotopic perturbations with eruptive and intrusive phases of the Karoo-Ferrar Large Igneous Province (MOULIN

et al. 2011; SVENSON et al. 2012) and the Chon Aike Province (PANKHURST et al. 2000). Re-evaluation of the record from MAZZINI et al. (2010) with our data from Arroyo Serrucho suggests that the carbon isotope stratigraphy and ages correspond to negative CIE's preceding the initial excursion; furthermore the ages determined by MAZZINI et al. (2010) in addition to those determined here provide us with new insights into the duration of the events and will aid in refining the absolute ages of the base of the Toarcian, as well as timing of the onset of the initial negative carbon isotope excursion. These new results also raise questions regarding how well the Toarcian global carbon cycle is described by existing records from the Tethyan–Laurasian Seaway locations and about the actual timing of the event.

References

- AL-SUWAIDI, A.H., ANGELOZZI, G.N., BAUDIN, F., DAMBORENEA, S.E., HESSELBO, S.E., JENKYN, H.C., MANCEÑO, M.O. & RICCARDI, A.C. 2010. First record of the Early Toarcian Oceanic Anoxic Event from the Southern Hemisphere, Neuquén Basin, Argentina. – *Journal of the Geological Society* 167: 633–636.
- GRADSTEIN, F.M., OGG, G.J., SCHMITZ, M.D. & OGG, G.M. 2012. The geological time scale 2012. Vol. 2: 762 pp., Elsevier, Oxford.
- HESSELBO, S.P., GRÖCKE, D.R., JENKYN, H.C., BJERRUM, C.J., FARRIMOND, P., MORGANS BELL, H.S. & GREEN, O.R. 2000. Massive dissociation of gas hydrate during a Jurassic oceanic anoxic event. – *Nature* 406: 392–395.
- HESSELBO, S.P., JENKYN, H.C., DUARTE, L.V. & OLIVEIRA, L.C.V. 2007. Carbon-isotope record of the Early Jurassic (Toarcian) oceanic anoxic event from fossil wood and marine carbonate (Lusitanian Basin, Portugal). – *Earth and Planetary Science Letters* 253: 455–470.
- JONES, C.E. & JENKYN, H.C. 2001. Seawater strontium isotopes, oceanic anoxic events, and seafloor hydrothermal activity in the Jurassic and Cretaceous. – *American Journal of Science* 301: 112–149.
- KUMP, L.R., BRALOWER, T.J. & RIDGWELL, A. 2009. Ocean acidification in deep time. – *Oceanography* 22: 94–107.
- MAZZINI, A., SVENSON, H., LEANZA, H.A., CORFU, F. & PLANKE, S. 2010. Early Jurassic shale chemostratigraphy and U-Pb ages from the Neuquén Basin (Argentina): Implications for the Toarcian Oceanic Anoxic Event. – *Earth and Planetary Science Letters* 297: 633–645. doi:10.1016/j.epsl.2010.07.017.
- MOULIN, M., FLUTEAY, F., COURTILOT, V., MARSH, J., DELPECH, G., QUIDELLEUR, X., GÉRARD, M. & JAY, A.E. 2011. An attempt to constrain the age, duration and eruptive history of the Karoo flood basalt: Naude's Nek section (South Africa). – *Journal of Geophysical Research* 116: B07403, doi:10.1029/2011JB008210.2011.07.
- PÁLFY, J. & SMITH, P.L. 2000. Synchrony between Early Jurassic extinction, oceanic anoxic event, and the Karoo-Ferrar flood basalt volcanism. – *Geology* 28: 747–750.
- PANKHURST, R.J., RILEY, T.R., FANNING, C.M. & KELLEY, S.P. 2000. Episodic silicic volcanism in Patagonia and the Antarctic Peninsula: chronology of magmatism associated with the break-up of Gondwana. – *Journal of Petrology* 41: 605–625.
- SVENSON, H., PLANKE, S., CHEVALLIER, L., MALTHE-SØRENSEN, A., CORFU, F. & JAMTVEIT, B. 2007. Hydrothermal venting of greenhouse gases triggering Early Jurassic global warming. – *Earth and Planetary Science Letters* 256: 554–566. doi:10.1016/j.epsl.2007.02.013.
- SVENSON, H., CORFU, F., POLTEAU, S., HAMMER, Ø. & PLANKE, S. 2012. Rapid magma emplacement in the Karoo Large Igneous Province. – *Earth and Planetary Science Letters* 325–326: 1–9.
- TRECALLI, A., SPANGENBERG, J., ADATTE, T., FÖLLMI, K.N. & PARENTE, M. 2012. Carbonate platform evidence of ocean acidification at the onset of the early Toarcian oceanic anoxic event. – *Earth and Planetary Science Letters* 357–358: 214–225.

Carbon and oxygen isotope record of the Jurassic bulk carbonates and calcareous fossils from the Pieniny Klippen Belt (Carpathians)

AGNIESZKA ARABAS¹ *, JAN SCHLÖGL² & ANDRZEJ WIERZBOWSKI³

¹*Institute of Geological Sciences, Polish Academy of Sciences, 00-818 Warsaw, Poland; E-mail: a.arabas@twarda.pan.pl*

²*Faculty of Natural Sciences, Comenius University in Bratislava, SK-842 15 Bratislava, Slovakia; E-mail: schlogl@nic.fns.uniba.sk*

³*Polish Geological Institute – National Research Institute, 00-975 Warsaw, Poland; E-mail: andrzej.wierzbowski@pgi.gov.pl*

*Corresponding author

Secular variations in carbon isotope composition of marine carbonates are correlated with changes in global ocean productivity. Isotopic composition of carbonate oxygen serves as a basis of seawater temperature reconstructions, which are indicative of environmental and climatic changes. Carbon and oxygen isotope

composition of marine carbonates from the Pieniny Klippen Belt may be used as a proxy for the Jurassic environment of the northern part of the Tethys Ocean.

The main aims of the project are:

- to reconstruct the evolution of sea water temperatures using the oxygen isotope

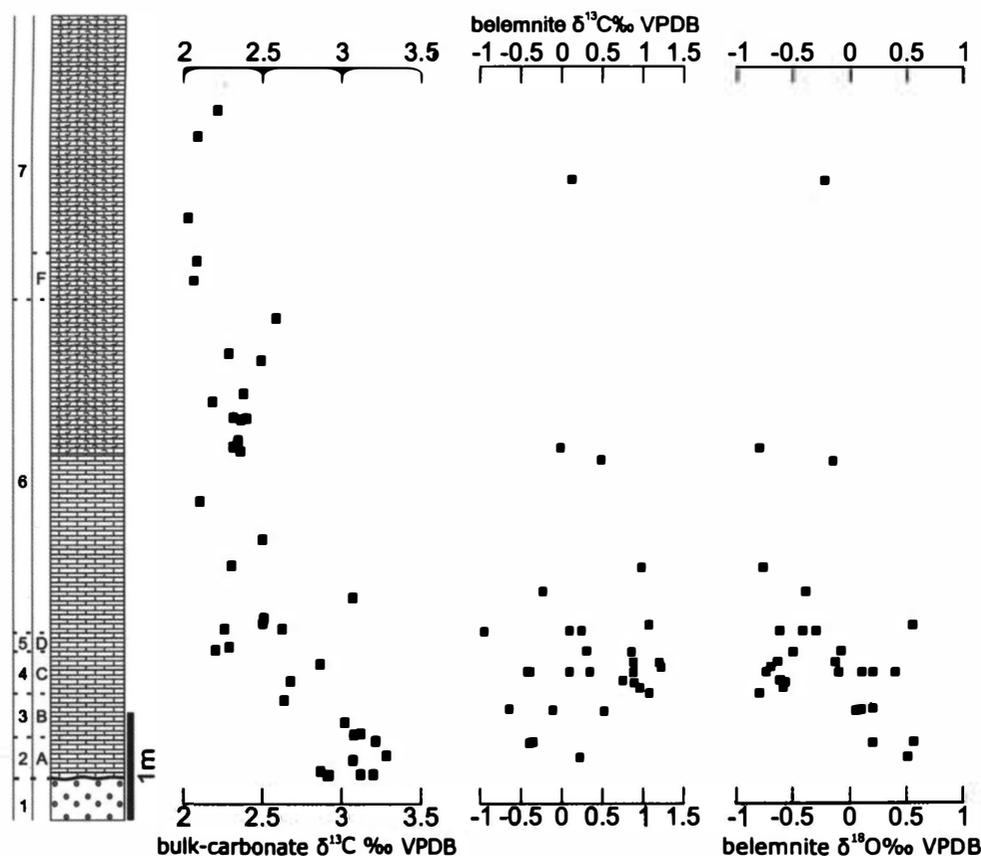


Fig. 1. Carbon and oxygen isotope record of the Middle to Upper Jurassic bulk carbonate and belemnite rostra from the Stankowa Skala sections at Zaskale, Poland (Pieniny Klippen Belt, Carpathians).

Outcrop stratigraphy after A. WIERZBOWSKI (unpublished): 1 – Bajocian, 2 – Middle to Upper Oxfordian, 3 – Upper Oxfordian to Lower Kimmeridgian, 4 – Lower Kimmeridgian, 5 – Lowermost Upper Kimmeridgian, 6 – Upper Kimmeridgian to Lower Tithonian, 7 – Lower Tithonian. Ammonite zones: A – *Transversarium-Bifurcatus*, B – *Bimammatum-Planula-Silenium*, C – *Strombecki-Divisum*, D – *Acanthicum*, F – *Hybonotum*.

composition and Mg/Ca and Sr/Ca ratios of belemnite rostra;

- to trace secular changes in the carbonate carbon isotope composition in order to reconstruct temporal variations in $\delta^{13}\text{C}$ values of dissolved inorganic carbon in Jurassic oceans;
- to compare the obtained $\delta^{13}\text{C}$ curves with the previously reported records of the isotope composition of carbonate carbon.

The sample set includes the stratigraphically well-dated bulk carbonates and belemnite rostra from several outcrops in Polish, Slovakian, and Ukrainian parts of the Pieniny Klippen Belt (PKB). PKB is a long narrow structure separating the Outer and Central Carpathians.

Sample screening for the state of preservation has been conducted using cathodoluminescence microscopy and optical emission spectrometry. Preliminary results of the study show:

- a slow decrease in $\delta^{13}\text{C}$ values of bulk carbonates during the Late Pliensbachian–Toarcian;
- high Middle Oxfordian $\delta^{13}\text{C}$ values of bulk carbonates and calcite fossils correspond to the global positive isotope excursion in carbonate carbon;
- Late Jurassic belemnite $\delta^{18}\text{O}$ values ranging from -0.8 to 0.4 ‰ VPDB which implies palaeotemperatures of 13 ± 2 °C;
- seawater temperature increased for about 6°C between the Middle Oxfordian and Late Kimmeridgian–Early Tithonian.

Micropalaeontological study at the Oxfordian–Kimmeridgian boundary in Central Poland – a preliminary report

MARCIN BARSKI¹ *, MARTA HODBOD², BRONISŁAW A. MATYJA¹ & ANDRZEJ WIERZBOWSKI²

¹*Institute of Geology, University of Warsaw, PL 02-089 Warszawa, ul. Żwirki i Wigury 93, Poland; E-mail: marbar@uw.edu.pl, matyja@uw.edu.pl*

²*Polish Geological Institute-National Research Institute, PL 00-975 Warszawa, ul. Rakowiecka 4, Poland; E-mail: marta.hodbod@pgi.gov.pl, andrzej.wierzbowski@pgi.gov.pl*

*Corresponding author

Recent studies of the sections in Central Poland (Wieluń Upland), rich in Submediterranean ammonites but yielding also Subboreal–Boreal ammonites, supplemented markedly the correlation of the zonal schemes around the Oxfordian–Kimmeridgian boundary. The lower boundary of the Kimmeridgian Stage of the standard (Subboreal) subdivision lies in the stratigraphic interval of the Submediterranean succession ranging from the upper part of the Semiarmatum Subzone up to the Berrense Subzone of the Semiarmatum (= Hypselum) Zone and lowermost part of the Bimammatum Zone, and thus close to the boundary of the Semiarmatum (Hypselum) Zone and the Bimammatum Zone (MATYJA & WIERZBOWSKI 2014).

The section at an abandoned quarry at Katarowa Hill near Łobodno north of Częstochowa is promising for finding the level corresponding to the standard (Subboreal/Boreal) Oxfordian–Kimmeridgian boundary in the Submediterranean succession. It shows a succession of bedded limestones which contain (according to preliminary studies) ammonites of the Submediterranean Hypselum Zone (subzone in older stratigraphic subdivisions) together with Boreal and Subboreal ones. The co-occurrence of ammonites belonging to different faunal provinces makes a correlation with the uppermost Oxfordian of the Boreal/Subboreal primary standard section at Staffin Bay (Isle of Skye, Scotland) possible; the younger deposits of the quarry, which should correspond to the lowermost Kimmeridgian, are very poorly exposed. Organic matter recovered from a chert sample of a limestone bed of these younger deposits that cropped out for a short distance consisted of well preserved spores

and pollen grains as well as of organic-walled dinoflagellate cysts. This finding indicates that formation of the cherts occurred very early on in diagenesis which resulted in preservation of organic matter that is completely absent in the surrounding limestone matrix. The most abundant taxa within the dinoflagellate cyst assemblage include *Systematophora areolata*, *Dingodinium tuberosum*, *Pareodinia ceratophora*, *Barbatocysta* sp., *?Occisucysta balios*, *Cribroperidinium globatum*, *C.* sp., *Glossodinium dimorphum*, *Cribroperidinium granuligerum*, and *Leptodinium subtile*, which strongly indicate a correlation with the Boreal/Subboreal uppermost Oxfordian – lowermost Kimmeridgian, but a single recovery of *Cribroperidinium? longicorne* suggests even correlation with the Lower Kimmeridgian (e.g., RIDING & THOMAS 1992; GRADSTEIN et al. 2004; BARSKI et al. 2005). The spores and pollen taxa are represented by *Baculatisporites* sp., *Cyathidites* sp., *Concavisporites* sp., *Araucariacidites* sp., cf. *Cerebropollenites* sp., and a rich undeterminable bisaccate pollen grain assemblage.

Other palynological samples taken from cherts, however, are characterized by scarce and poorly preserved organic matter. They yielded a few non-age diagnostic terrestrial palynomorph taxa including cf. *Lycopodiumsporites* sp., cf. *Baculatisporites* sp., cf. *Cerebropollenites* sp., cf. *Cyathidites* sp., cf. *Leptolepidites* sp., and several bisaccate pollen grains. These preliminary results, revealing the occurrence of spores and pollen grains as well as of organic-walled dinoflagellate cysts in the cherts of the studied section, may be of great importance for the stratigraphic interpretation of the deposits and the reconstruction of the climatic changes in the area. New studies are planned

to fully characterize the section and to obtain a uniform biostratigraphic interpretation of the deposits at the Oxfordian–Kimmeridgian boundary in relation to the proposed Global Stratotype Section and Point (GSSP) of the base of the Kimmeridgian at Staffin Bay (Isle of Skye), Scotland (MATYJA et al. 2006).

The study was financed by the National Science Centre (grant 2012/05/B/ST 10/02121).

References

- RIDING, J.B. & THOMAS, J.E. 1992. Dinoflagellate cysts of the Jurassic System. In: POWELL, A.J. (ed.), A stratigraphic index of dinoflagellate cysts: 7–57, Chapman & Hall, London.
- BARSKI, M., MATYJA, B.A. & WIERZBOWSKI, A. 2005. Korelacja podziałów amonitowych i dinocystowych przy granicy oksfordu i kimerydu na podstawie wierceń Bartoszyce IG 1 i Kcynia IG 1. – *Tomy Jurajskie* 3: 87–96.
- GRADSTEIN, F.M., OGG, J.G. & SMITH, A.G. 2004. A geologic time scale 2004. 589 pp., Cambridge University Press, Cambridge.
- MATYJA, B.A. & WIERZBOWSKI, A. 2014. On the Oxfordian–Kimmeridgian (Upper Jurassic) boundary - current state of knowledge. 9th International Congress on the Jurassic System, Jaipur. – *Beringeria Special Issue* 8: 103–104.
- MATYJA, B.A., WIERZBOWSKI, A. & WRIGHT J.K. 2006. The Sub-Boreal/Boreal ammonite succession at the Oxfordian/Kimmeridgian boundary at Flodigarry, Staffin bay (Isle of Skye), Scotland. – *Transactions of the Royal Society of Edinburgh: Earth Sciences* 96: 387–405.

Palaeoecological significance of the Callovian-Oxfordian trace fossils of Gangeshwar Dome, southeast of Bhuj, Mainland Kachchh, India

NISHITH Y. BHATT¹* & SATISH J. PATEL²

¹Department of Geology, M. G. Science Institute, Ahmedabad – 380 009, Gujarat, India; E-mail: nybhattmg@yahoo.com

²Department of Geology, M. S. University of Baroda, Vadodara – 390 002, Gujarat, India; E-mail: sjpgeology@gmail.com

*Corresponding author

Kachchh is a peri-cratonic embayed basin, extending from the southwest part of Thar Desert and Nagar-Parkar in the north to Saurashtra in the south, occupying a graben (BISWAS 1991). The Gangeshwar Dome lies between N 23°12'05" to 24°10'38" latitudes and E 69°41'15" to 69°45'32" longitude and is situated southeast of Bhuj in the Khatrod (Charwar) hill range, south of the Katrol Hill Fault (KHF) on Mainland Kachchh. The Gangeshwar Dome forms a big inlier and the core part comprises rocks of the Jumara Formation (BISWAS 1977) ranging in age from Callovian to Oxfordian (BISWAS 1977; BHALLA & ABBAS 1978). The shallow marine deposits of the dome contain diverse groups of well-preserved trace fossils which offer an excellent opportunity to understand the palaeoecological parameters and depositional history of the late Middle Jurassic time slice.

BISWAS (1977) classified lithostratigraphically the Mesozoic sediments in four units – the Jhurio, Jumara, Jhuran, and Bhuj formations. The rocks of the Jumara Formation are classified into four informal members I to IV in ascending order (BISWAS 1977, 1993). The formation is well developed and best exposed in the Gangeshwar Dome, except the lowermost part of Member I, which is only partly exposed. Member I consists of shale with bands of fine-grained greyish to dirty yellow siltstone and sandstone. The siltstone and sandstone contain small bivalves and become cherty towards the upper part. The uppermost boundary of the Member I is fixed above a dark grey carbonaceous shale band. The lower part of Member II is characterised by thick sandstones, whose lower part is mainly massive while its upper part consists

of herringbone cross-bedded, fine- to medium-grained sandstone, marking the upper boundary of Member II. Member III mainly contains shales with thin bands of bioclastic limestones, bioclastic intraformational conglomerates and bioclastic sandstones. Member IV consists of intercalations of shales and oolitic limestone; its uppermost part comprises hard prominent oolitic limestones (Dhosa Oolite) forming a distinct marker horizon which separates the Jumara Formation from the Jhuran Formation (BISWAS 1977).

The Jumara Formation comprises a 247-m-thick succession of shallow marine deposits of clastic and non-clastic sediments divided into seven lithofacies based on distinct lithologic features, composition, textures and structures. These include Laminate Shale–Siltstone (LSS) facies, Sheet Sandstone (SS) facies, Herringbone Sandstone (HS) facies, Bivalve Sandstone (BS) facies, Intraformational Conglomerate (IC) facies, Bioclastic Limestone (BL) facies, and Oolitic Limestone (OL) facies.

Rocks of the Jumara Formation are highly bioturbated and contain abundant identifiable trace fossils. In total 31 ichnospecies of 25 ichnogenera were identified but indistinct forms also occur. The highly diverse trace fossils reveal a wide range of animal behaviour and can be interpreted in terms of ecology, strategy of adaptation and biological parameters, which can directly be related to physical aspects of the palaeoenvironments. The ichnofauna identified in the study area are *Arenicolites carbonarius*, *Bifungites* isp., *Bolonia lata*, *Chondrites* isp., *Cochlichnus kochi*, *Didymaulichnus lyelli*, *Diplocraterion parallelum*, *Granularia* isp., *Gyrochorte comosa*, *Helminthopsis hieroglyphica*, *Isopodichnus problematicus*, *Laevicyclus* isp.,

Monocraterion tentaculatum, *Muensteria* isp., *Ophiomorpha nodosa*, *Palaeophycus sulcatus*, *Phycodes circinatum*, *P. palmatum*, *P. pedum*, *P. isp.*, *Planolites annularis*, *P. isp.*, *Protopalaeodictyon incompositum*, *Rhizocorallium irregulare*, *R. jenense*, *Scolicia* isp., *Skolithos linearis*, *Thalassinoides paradoxicus*, *T. isp.*, *Tisooa siphonalis*, and *Zoophycus brianteus*.

Trace fossils occurring in particular horizons are grouped into ichno-assemblages and named after the dominant ichnogenus. These ichno-assemblages reflect the energy conditions, water depth, nutrients, substrate and bottom water oxygenation.

The *Chondrites* ichno-assemblage is represented by *Chondrites* isp. Associated trace fossils are *Planolites* and *Zoophycus*. It occurs in LSS lithofacies in Member III and OL lithofacies in Member IV. The ichno-assemblage indicates low energy and calm water conditions within oxygen-depleted fine-grained soft and thixotropic sediments. It also signifies protected shoreface environments. It suggests deposit-feeding behaviour of the animals.

The *Diplocraterion* ichno-assemblage is characterised by *Diplocraterion parallelum*. Associated trace fossils are *Diplocraterion*, *Laevicyclus*, *Bifungites*, *Ophiomorpha*, *Skolithos*, *Planolites*, *Palaeophycus*, *Tisooa*, and *Monocraterion*. The ichno-assemblage occurs in SS lithofacies of Member I, II and III and HS lithofacies of Member II. It chiefly represents structures of suspension-feeders produced at the sediment-water interface reflecting high energy conditions, shifting substrates, frequent physical reworking, and high rates of sedimentation. It denotes lower foreshore to upper shoreface environments.

The *Gyrochorte* ichno-assemblage is characterized by *Gyrochorte comosa*. Other trace fossils are *Bolonia*, *Didymaulichnus*, *Isopodichnus*, *Cochlichnus*, *Planolites*, and *Scolicia*. The ichno-assemblage is observed in the LSS and SS lithofacies of members I and III. It represents crawling activity produced at the sediment-water interface in upper and middle shoreface environments. The ichno-assemblage generally shows a high degree of bioturbation indicating relatively low energy, slow sedimentation, and little physical reworking.

The *Muensteria* ichno-assemblage is exemplified by *Muensteria* isp. Other trace

fossils include *Planolites*, *Helminthopsis*, *Protopalaeodictyon*, and *Bolonia*. It is found in the SS lithofacies of Member I. The ichno-assemblage represents predominantly the activity of vagile deposit-feeders where structures are produced within the sediments. The assemblage indicates low energy conditions with low rates of sedimentation in stable and slowly accreting substrates on a well oxygenated middle and lower shoreface zone.

The *Ophiomorpha* ichno-assemblage is represented only by *Ophiomorpha nodosa*. It occurs in LSS and SS lithofacies of Member I and III. The ichno-assemblage indicates moderate or instantaneously high sediment influx in moderate to low energy conditions and shifting sandy substrates mainly in foreshore to upper and middle shoreface environments.

The *Rhizocorallium* ichno-assemblage mainly consists of *R. jenense* and *R. irregulare* with *Laevicyclus*, *Palaeophycus*, *Phycodes*, *Planolites*, *Granularia*, and *Chondrites* in LSS lithofacies of Member I, III and IV. This assemblage is characterized by shallow-burrowing deposit-feeders, found in fine- to medium-grained sandstone-siltstone alternations. It is indicative of a very low rate of deposition in less protected, low energy, middle to lower shoreface environments with intermittent currents sweeping the sea floor.

The *Skolithos* ichno-assemblage is depicted by *Skolithos linearis*. Associated trace fossils are *Arenicolites*, *Diplocraterion*, *Monocraterion*, *Ophiomorpha*, *Tisooa*, *Palaeophycus*, and *Planolites* in SS lithofacies of Member II and III. The ichno-assemblage chiefly represents the activity of suspension-feeders at the sediment-water interface. High-energy hydrodynamic settings or storm-wave influence and shifting substrates subject to abrupt erosion and deposition, which are exploited by opportunistic animals generally populating foreshore and upper shoreface environments, are indicated.

The *Thalassinoides* ichno-assemblage consists of *T. paradoxicus* and *T. isp.* Associated trace fossils are *Phycodes*, *Rhizocorallium*, *Granularia*, *Planolites* etc. in SS and IC of Member I, II and III. The ichno-assemblage is usually prevailing in amalgamated sandstones and intraformational conglomerate facies. The traces are large, semi-permanent mainly horizontal tunnel systems suggesting a deposit-

feeding behaviour and display a very low diversity, indicating extremely quiet water conditions. Because of the low energy level, less abrupt shifting sediments and fluctuating temperature and salinity the bioturbation structures are mainly characterised by feeding and grazing traces. Overall the ichno-assemblage suggests upper to lower shoreface condition with relatively low energy conditions.

The *Zoophycus* ichno-assemblage comprises chiefly *Z. brianteus*. Associated trace fossils are *Chondrites* etc. in OL lithofacies of Member IV. BROMLEY (1990) considered *Zoophycus* as produced by an opportunist, appearing together with *Chondrites* in low resource, inhospitable, oxygen-depleted environments. Further, he considered the ichno-assemblage as representing deposit-feeding structures, which comprise the deepest tier structure. According to PATEL et al (2009) the sediment input remained fairly low and depth did not reach the storm wave base so that the sediments were thoroughly bioturbated by the *Zoophycus* producer. These indicate low energy and probably comparatively deep conditions where the rate of sedimentation is rather slow.

The opportunistic *Diplocraterion* and *Skolithos* ichno-assemblages show a high diversity and typically consist of horizontal ichnospecies, which mark a gradient from foreshore to near-shoreface conditions. The *Gyrochorte*, *Rhizocorallium*, *Muensteria*, and *Thalassinoides* ichno-assemblages indicate typically a lower energy zone of the shoreface-offshore region. The *Chondrites* ichno-

assemblage indicates fluctuations in bottom-water oxygenation, while the *Zoophycus* ichno-assemblage had typically exploited the calm-water niche in offshore regions. These ichno-assemblages recur throughout the succession and belong to SEILACHER'S (1967) archetypical ichnofacies *Skolithos* and *Cruziana* ichnofacies, which relate to energy gradients, substrate stability, water depth, and feeding mode of invertebrate organisms. Sedimentological and ichnological data suggest fluctuating environmental conditions from the upper shoreface to the offshore zone during deposition of the Jurassic sediments of the Gangeshwar Dome.

References

- BHALLA, S.N. & ABBAS, S.M. 1978. Jurassic foraminifera from Kutch, India. – *Micropaleontology* 24: 160–209.
- BISWAS, S.K. 1977. Mesozoic rock-stratigraphy of Kutch, Gujarat. – *Quarterly Journal of the Geological, Mining and Metallurgical Society of India* 49: 1–52.
- BISWAS, S.K. 1991. Stratigraphy and sedimentary evolution of the Mesozoic basin of Kutch, Western India. In: Tandon, S.K., Pant, C.C. & Cusshyap, S.M. (eds.), *Proceeding of Seminar on Sedimentary Basins of India*, Nainital: 74–103, Gyanodaya Prakashan, Nainital.
- BISWAS, S.K. 1993. *Geology of Kutch*: 52–98. K. D. Malaviya Institute of Petroleum Exploration, Dehradun.
- BROMLEY, R.G. 1990. Trace Fossils. Biology and Taphonomy. – *Special Topics in Palaeontology*: 1–280, Unwin Hyman.
- PATEL, S.J., DESAI, B.G. & SHUKLA, R. 2009. Paleoeological significance of the trace fossils of Dhosa Oolite Member (Jumara Formation), Jhura Dome, Mainland Kachchh, Western India. – *Journal of the Geological Society of India* 74: 601–614.
- SEILACHER, A. 1967. Bathymetry of trace fossils. – *Marine Geology* 5: 413–428.

Jurassic basins of India: Tectonic set up and sediment fill

S. K. BISWAS

E-mail: sanjibkbiswas2001@yahoo.co.in

In India Jurassic rocks are present only in a few peri-cratonic basins and in the Central Himalayan orogenic belt. The maximum interval of Jurassic sedimentary succession occurs in the western peri-cratonic basins of Jaisalmer in Rajasthan and Kutch in Gujarat. Jurassic rocks are conspicuously absent in Late Paleozoic-Early Cretaceous intra-cratonic Gondwana basins excepting the Kotah Limestone (?Early/Middle Jurassic) of the Pranhita-Godavari Basin. In the eastern pericratonic basins only continental Late Jurassic rocks are present in the Krishna-Godavari and Kaveri-Palar basins. Jurassic rocks of Tethyan origin in the central Himalayan orogenic belt were caught up in the thrust sheets. In this paper I present a brief overview on the tectonic set up, stratigraphy, and sediment dynamics of the Jurassic deposits of the Rajasthan and Kutch basins.

The maximum Jurassic interval (Lias to Tithonian) is exposed in the Jaisalmer Basin of Rajasthan. In Kutch the Middle (Bajocian) to Late Jurassic (Tithonian) succession is well developed and extensively exposed. Deep borehole data show the presence of (?) Aalenian-Bajocian sediments above the Precambrian basement.

The Jaisalmer Basin is a passive margin shelf basin, whereas Kutch is a rifted basin at the western continental margin of India. Both basins are integral parts of the Indus shelf and received sediments from the transgressive Neo-Tethys during Jurassic times. Sediments in the Jaisalmer Basin were deposited in open marine shallow shelf environments. Sedimentation started with Late Triassic marine transgression (Bhuana Formation) over Precambrian basement covered by patches of Permo-Carboniferous deposits (Bap/Badhaura formations, mostly fluvio-glacial boulder conglomerates and sandstones). Marine sedimentation continued till the Late Jurassic in repeated transgressive-regressive cycles. Jurassic marine sedimentation was terminated during an Early Cretaceous regression when

deltaic sediments (Pariwar, Habur, and Goru formations) prograded over the Late Jurassic sediments (Baisakhi and Bhadasar formations). Drilled well data indicate the continuation of the Jurassic deposits westward in the Indus foreland with progressive thickening below the Tertiary formations.

Rifting of the Kutch Basin in the southern part of the Indus Shelf started in Late Triassic or Early Jurassic when the western part of the Indian plate was undergoing crustal extension due to pre-break up crustal distension in Eastern Gondwanaland. This prolonged crustal distension continued till the Late Cretaceous as India with Madagascar first separated from Africa, followed by separation of Madagascar and Seychelles during the Late Cretaceous. Rift-fill sedimentation in Kutch continued till then in cycles of transgression-regression coeval with the Jaisalmer depositional cycles. Marine transgression over the pericratonic embayment of Kutch started in Early Mid-Jurassic through the narrow channel that opened up between Somalia of the African plate and the Pakistan-Kutch-Saurashtra part of the Greater Indian plate, due to pre-break up fracturing during Bajocian-Bathonian time (167 Ma). The initial transgression started during the early rift stage in the early Mid-Jurassic and continued through the synrift stage in the Middle Jurassic till the early post-rift stage during Late Jurassic-Early Cretaceous time. The Kaladongar, Goradongar, Khadir, and Jhurio formations were deposited during the early synrift stage in Aalenian-Bathonian time. The Jumara and Washtawa formations were deposited during the synrift climax stage in Callovian-Early Oxfordian time, while the Jhuran and Wagad sandstones were deposited during the late synrift stage (Kimmeridgian-Tithonian). During post-rift stage in Neocomian-Albian time marine Jurassic sediments were unconformably covered by prograding delta sediments of the Bhuj Formation. Maximum flooding took place during synrift climax in Late Callovian

– Early Oxfordian time (Jumara Formation). The maximum flooding surface is marked by a conspicuous green oolitic limestone band described as Dhosa Oolite Member on top of the Jumara Formation. Sedimentation in the rifted Kutch Basin was more complex than in the Jurassic shelfal basin of Jaisalmer. A rift basin is differentiated into intra-basin highs and lows: horst-grabens and tilted horst-half grabens. Each half-graben/graben is a sub-basin in the rift profile. Such differentiation into separate domains of sedimentation is responsible for variation in lithofacies and lithologic associations. Further, variation in relative sea levels during sedimentation causes submergence/emergence of intra-basinal highs during sediment accommodation affecting the lithofacies. In Kutch, the Gulf of Kutch half-

graben, Banni half-graben, and Rann graben are the three different domains of sedimentation giving rise to different successions of formations. This resulted in the identifications of three main groups of formations in the Kutch lithostratigraphy namely, Mainland Group, Pachchham Group and Eastern Kutch Group. These groups are well correlated by marker units which include biostratigraphic marker beds also. This made it possible to work out a chronostratigraphic classification which is under finalization. Drilled well data indicate the continuous occurrence of the Jurassic sediments beneath the Deccan Trap and Tertiary deposits in Southern Kutch and beyond into the offshore shelf basin. In Kutch, the Jurassic rocks are intensively intruded by basic igneous rocks as has been noted in other major rift basins.

Early Jurassic (Sinemurian/Pliensbachian) ammonites of the Central Apennines (Monte di Cetona and Acquasparta, Italy)

JOACHIM BLAU¹ & CHRISTIAN MEISTER²

¹Institut für Geowissenschaften Goethe-Universität, 60438 Frankfurt am Main, Germany; E-mail: Joachim.Blau@geolo.uni-giessen.de

²Natural History Museum of Geneva, Department of Geology and Paleontology, CH-1211 Geneva, Switzerland; E-mail: christian.meister@ville-ge.ch

The Central Apennines (Italy) are a classical and historical region for Tethyan Liassic ammonites, especially Monte di Cetona and Acquasparta. The fauna collected in several little quarries around the area of San Casciano dei Bagni was first studied in a series of papers by FUCINI (1901-05). Since most of FUCINI's material had not been collected by horizons, FISCHER (1971, 1972) collected two quarries (Murate and Acquasparta sections) bed-by-bed. The revision of these sections allows to precise the systematics and the biostratigraphy of this area. For Murate, a sequence of six faunal horizons indicating Obtusum, Jamesoni, Ibex, and Davoei zones is established. This sequence is well comparable to already published data from other Tethyan localities. With our revision the systematic and biostratigraphic problems resulting from FISCHER's studies are solved. In the Acquasparta section five faunal horizons

can be distinguished covering a time interval from the Davoei up to the Margaritatus (p.p.) Zone. Since both sections overlap in terms of biochronology a synthetic biostratigraphic scheme can be constructed which ranges from the Upper Sinemurian to the Upper Pliensbachian. A worldwide (Euroboreal, Tethyan, and East Pacific Domains) comparison and correlations of the Lower – Upper Pliensbachian boundary are proposed (Fig. 1).

References

- BLAU, J. & MEISTER, C. 2011. Resolving the Monte di Cetona biostratigraphical enigma – a revision of R. Fischer's Sinemurian and Pliensbachian (Liassic) ammonite collection from Central Apennines (Tuscany, Italy). – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, DOI 10.1127/0077-7749/2011/0151.
- MEISTER, C. 2010. Worldwide ammonite correlation at the Pliensbachian Stage and Substage boundaries (Lower Jurassic). – Stratigraphy 7: 83–101.

	NORTH AMERICA		SOUTH AMERICA		NW EUROPE			WESTERN TETHYS		
	Biozones	Biozones	Biohorizons	Chrono-Zones	Subchronozones	potential Zonules	Bioevents (= biohorizons)	Bio-zones Ap.	Bio-zones Be.	
Upper PLIENSACHIAN	F. kunae (pars)	F. fannini (pars)	F. fannini	Margaritatus	Stokesi	Celebratum	F. celebratum	F. lavinianum	F. lavinianum	
			F. leptodiscus			Nitescens	F. marianii			
Lower PLIENSACHIAN	D. freboldi	A. behrendseni	A. behrendseni	Davoei	Figulinum	Figulinum	F. costicillatum	F. costicillatum sensu Braga	B. columbriforme dilectum sensu Braga	
			A. carinatus			Angulatum				
			A. prorsiflexus			Crescens				
			A. volkheimeri			Capricornus				
			E. arayaensis			Lataecosta				
	E. meridianus	E. meridianus	E. ovatoides		Maculatum	Maculatum?				
			E. multicostatus		Sparsicosta	Sparsicosta?				
			E. meridianus		Luridum	Luridum?				
			D. latidorsale		Crassum	Crassum?				
					Rotundum	Rotundum?				
A. whitea-vesi (pars)	M. ex-terminum (pars)	D. latidorsale	Ibex (pars)	Luridum	Luridum	F. dilectum	M. gem. (pars) = F. dilectum sensu Braga	F. dilectum		
						F. aff. dilectum				

Fig. 1. Biohorizons present in Monte di Cetona and Acquasparta around the Lower and Upper Pliensbachian boundary, and correlations with the zonations of Western Tethys, NW Europe, and the Americas (MEISTER 2010).

Life in a Late Jurassic Subboreal Sea and on its coast: a new taphonomic window of exceptionally preserved fauna at Owadów-Brzezinki (Central Poland)

BŁAŻEJ BŁAŻEJOWSKI¹ *, BRONISŁAW A. MATYJA², ANDRZEJ WIERZBOWSKI³ & HUBERT WIERZBOWSKI⁴

¹*Institute of Paleobiology, Polish Academy of Sciences, ul. Twarda 51/55, PL 00-818 Warsaw, Poland; E-mail: bblazej@twarda.pan.pl*

²*Institute of Geology, University of Warsaw, ul. Żwirki i Wigury 93, PL 02-089 Warsaw, Poland; E-mail: matyja@uw.edu.pl*

³*Polish Geological Institute – National Research Institute, ul. Rakowiecka 4, PL 00-975 Warsaw; E-mail: andrzej.wierzbowski@uw.edu.pl*

⁴*Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, PL 00-818 Warszawa, Poland; E-mail: hwierzbo@twarda.pan.pl*

*Corresponding author

The recently discovered paleontological site of the Sławno limestones in the Owadów-Brzezinki Quarry, about 19 km southeast of Tomaszów Mazowiecki (central Poland), has yielded unusually well preserved fossils of latest Jurassic terrestrial and marine organisms. At the moment, the Owadów-Brzezinki quarry is the only place in extra-Carpathian Poland where the Scythicus Zone (Middle Volgian) strata corresponding to some lower parts of the Upper Tithonian are available for study (the classic locality Brzostówka is now within the Tomaszów Mazowiecki town limits; quarries in Pomerania are flooded). The exposed carbonate succession belongs to the Kcynia Formation (KUTEK 1994), and can be divided into the following four successive units (Fig. 1).

The lowermost part of the unit (III) is highly fossiliferous. Numerous specimens of horseshoe crabs (*Limulus* sp. n. and *Crenatolimulus* sp. n.) were found in association with an enormously rich assemblage of the bivalves *Corbulomima obscura* and *Mesosaccella* sp., remains of various fishes and marine reptiles, rare ammonites, crustaceans, land insects (dragonflies, beetles, grasshoppers), and pterosaurs. The uniqueness of this new locality lies in its very close stratigraphic relationship to the famous *Fossil-Lagerstätte* localities Solnhofen and Nusplingen in southern Germany, with approximately 5 and 7 Ma, respectively separating them (KIN et al. 2013). Marine and terrestrial organisms lived and died during the Late Jurassic at Solnhofen (Lower Tithonian, Hybonotum

Zone), Nusplingen (uppermost Kimmeridgian, Beckeri Zone) and at newly discovered locality (Owadów-Brzezinki Quarry, Zarajskensis Subzone of the Scythicus Zone), under closely related environmental conditions.

The fossils identified in all localities indicate a similar geological age and environment. Both marine and terrestrial organisms are very similar and allow comparative paleontological studies at a previously unattainable level of taxonomic resolution. The recent identification of a new species of dragonfly (family Eumorbaeschnidae) and grasshopper (family Prophalangopsidae), families previously known from the Solnhofen area, is an example. Clearly, the Owadów-Brzezinki Quarry may be regarded as a new 'taphonomic window' into the living world of the latest Jurassic and it represents the first near-contemporary palaeontological 'supplement' to the previously known *Fossil-Lagerstätten*. The small palaeochronological distance (5-7 Ma) separating all central European Late Jurassic localities may enable us to trace lineages, with different stages of evolutionary advancement recorded by fossils from different locations.

The study was supported by the Polish National Science Centre (grant no.2012/07/B/ST10/04175).

References

- KIN, A., GRUSZCZYŃSKI, M., MARTILL, D., MARSHALL J. & BŁAŻEJOWSKI B. 2013. Palaeoenvironment and taphonomy of a Late Jurassic (Late Tithonian) Lagerstätte from central Poland. – *Lethaia* 46: 71–81.
- KUTEK, J. 1994. The *Scythicus* Zone (Middle Volgian) in Poland: its ammonites and biostratigraphic subdivisions. – *Acta Geologica Polonica* 44: 1–33.

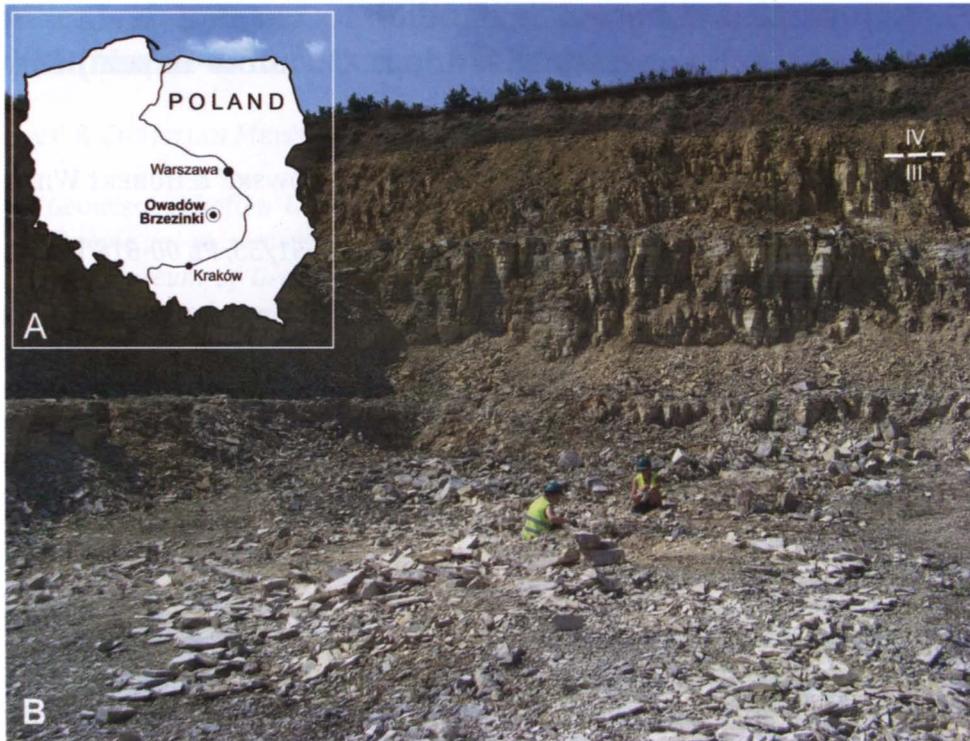


Fig. 1. A. Location of the Owadów-Brzezinki Quarry in Poland. B. Stratigraphic units: Unit I is composed of indistinctly laminated massive fine-grained limestone (total thickness ~6.6 m) with *Deltoideum delta*, which forms a few beds 40–80 cm in thickness. The overlying c. 2-m-thick unit II is represented by thinly bedded, fine-grained limestones with occasional distinct parallel lamination and mass occurrence of calcareous polychaete tubes in one horizon. Unit III, c. 15.6 m thick, is highly fossiliferous and has yielded the fossils that are the subject of proposed research. Unit IV, c. 2.3 m thick, the top not being exposed, is developed as organo-detrital limestone rich in the oyster *Nanogyra*, bryozoans, and serpulids, the latter often forming small bioherms. In general, units I, II, and III probably represent a transition from an offshore to nearshore, perhaps lagoonal, setting, whereas Unit IV bears evidence of a return to more open marine conditions. Below the Kcynia Fm. yellowish marls and marly clays of the Pałuki Formation occur. .



Fig. 2. Part and counterpart of an articulated horseshoe crab exoskeleton – *Crenatolimulus* sp.

Geodynamic events and the drowning history of a Jurassic carbonate platform: a case study from the Aurès area (NE Algeria)

EL HADJ YUCEF BRAHIM¹ * & MOHAMED CHADI²

¹University of Batna BP 25, Merouana-Batna 05013, Algeria; E-mail: wahidyb@yahoo.fr

²Normal Superior School, Zouaghi Faculty, Constantine zip: 25000, Algeria

**Corresponding author*

This study focuses on an area located at the southern fringe of the Alpine Belt external zones. The objective of this work is to reconstruct the drowning history of the Jurassic carbonate platform and to discuss its relationship with the geodynamic evolution of the southern Tethyan margin. The identification and interpretation of drowning events of platforms can help significantly to reconstruct the depositional, tectonic and eustatic history of these platforms.

The drowning of carbonate platforms was the subject of stratigraphic and sedimentological research in different places of our planet and at different periods of the Phanerozoic. The

stratigraphic interpretation and correlation of the Jurassic succession of the study area, based on a few cross-sections, have allowed to highlight the platform physiography during this geological period and to recognise three stratigraphic units.

The synthesis of bio-sedimentological data reveals diversified facies, involving various depositional environments ranging from supratidal to deep pelagic. These facies have evolved on the subsiding carbonate ramp. The ramp experienced a drowning phase (Toarcian) and filling phases (Tithonian, Berriasian), related to eustatic sea-level changes and regional tectonics.

The Upper Bajocian *Cranocephalites*-succession in East Greenland: achieving the highest possible biostratigraphic resolution

JOHN H. CALLOMON, PETER ALSEN¹ * & FINN SURLYK²

¹Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, DK-1350 Copenhagen K, Denmark; E-mail: PAL@GEUS.DK

²Department of Geosciences and Natural Resource Management, University of Copenhagen, Øster Voldgade 10, Dk-1350 Copenhagen K, Denmark; E-mail: finns@geo.ku.dk

*Corresponding author

Professor JOHN H. CALLOMON died April 1st 2010. The last two decades before his death he had been working on establishing the faunal succession of the Middle Jurassic *Cranocephalites* beds in East Greenland. He left an unfinished manuscript, which his family entrusted the co-authors to complete. We here present the main results of CALLOMONS work - post-humously- and intend to publish it in a monograph-format in the Geological Survey of Denmark and Greenland Bulletin.

In compiling the faunal succession of the existing Middle Jurassic ammonite zonation (CALLOMON 1993), the greatest difficulty lay in the lower part, in the Indistinctus-Pompeckji zones of the *Cranocephalites* beds. The *Arctocephalites* and *Arcticoceras* beds appeared to be widely represented in Jameson Land and elsewhere in the Arctic, and their ammonite faunas well sampled in the collections from Hurry Fjord made by A. ROSENKRANTZ in 1926-7 and H. ALDINGER and others in later years. What was known of the *Cranocephalites* beds was, in contrast, largely based on a single collection made by T. HARRIS during an excursion in 1927 up the valley of Ugleelv, west of inner Hurry Fjord, to its headwaters around Katedralen (ROSENKRANTZ 1934). This is also the type area of the oldest named species of this genus, *Cranocephalites pompeckji*, brought back in 1900 (MADSEN 1904).

Opportunities arose in 1994 and 1996 to revisit the area of Ugleelv and to concentrate on the ammonite biostratigraphy of the *Cranocephalites* beds. The results obtained exceeded all expectations. Some 750 ammonites were collected bed by bed from 17 sections. The number of faunal horizons that could be distinguished grew from the nine previously

recognized (CALLOMON 1993) to 34 today.

The zonal stratigraphy of the *Cranocephalites* beds up to 1993 was encompassed by three zones, the Borealis, Indistinctus and Pompeckji zones, based on the then recognized succession of just eight faunal horizons. Of these, five were in an undifferentiated Pompeckji Zone. These zones form part of the secondary standard zonation for the Boreal Province of the biogeographic Boreal Realm of the Middle Jurassic and were classed into the so-called Boreal Bathonian Stage (CALLOMON 1959, 1993). With the refinement available today, it is possible and useful to subdivide the Pompeckji Zone with its 23 faunal horizons into four subzones. They reflect four successive basic morphologies of *Cranocephalites* that should be recognizable more widely, making possible correlations – and hence age determinations – at subzonal level of precision even when assignment to individual horizons is not possible.

The evolutionary tempo of the *Cranocephalites* lineage allows us to follow the microevolution of the ammonites at a level of time-resolution with few biostratigraphic rivals in the geological record. If the 34 transients represent evolution over the duration of the Late Bajocian, whose rocks make up the three standard zones of the European primary scale (Subfurcatum – Parkinsoni zones), the time-resolution achieved here is close to the achievable limit, set by the ability to recognize morphological changes in successive assemblages. Hence, on this time-scale, evolution appears to be continuous. Yet the observed record in the rocks continues to be highly discontinuous. This punctuation of the record is determined not by punctuation – discontinuities in the sense of ELDREDGE & GOULD 1972) – in the phyletic development of

the ammonoid genome but by the environment in which the ammonites lived and died. The sedimentary record is incomplete, both vertically and horizontally. The present account shown by the ammonites has revealed the existence of non-sequences in the Middle Jurassic sediments of Jameson Land whose presence in the rocks is reflected in nothing more than a simple bed parting. As noted by BUCKMANN (1881), the more the complete the biostratigraphical record becomes, the less complete the lithostratigraphic record turns out to be.

References

- BUCKMANN, S.S. 1881. A descriptive catalogue of some species of ammonites from the Inferior Oolite of Dorset. – Quarterly Journal of the Geological Society of London 37: 588–608.
- CALLOMON, J.H. 1959. The ammonite zones of the Middle Jurassic beds of East Greenland. – Geological Magazine 96: 505–13.
- CALLOMON, J.H. 1993. The ammonite succession in the Middle Jurassic of East Greenland. – Bulletin of the Geological Society of Denmark 40: 83–113.
- ELDREDGE, N. & GOULD, S.J. 1972. Punctuated equilibria: an alternative to phyletic gradualism. In SCHOPF, T.J.M (ed.), Models in Paleobiology: 82–115, Freeman Cooper, San Francisco.
- MADSEN, V. 1904. On Jurassic fossils from East Greenland. – Meddelelser om Grønland 29: 157–211.
- ROSENKRANTZ, A. 1934. The Lower Jurassic rocks of East Greenland. Part 1. – Meddelelser om Grønland 110 (1): 1–122.

The Early Toarcian Oceanic Anoxic Event in Western North America: Testing regional vs. global controlling mechanisms

ANDREW H. CARUTHERS¹ *, DARREN R. GRÖCKE², PAUL L. SMITH¹, BEN C. GILL³, SARAH J. PORTER¹ & PENGFEI HOU¹

¹*Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver V6T 1Z4, Canada; E-mail: caruthers.andrew@gmail.com, psmith@eos.ubc.ca, sporter@eos.ubc.ca, phou@eos.ubc.ca*

²*Department of Earth Sciences, Durham University, Sciences Laboratories, Durham DH1 3LE, UK; E-mail: d.r.grocke@durham.ac.uk*

³*Department of Geosciences, Virginia Tech University, Blacksburg 24061, USA; E-mail: bcgill@vt.edu*

*Corresponding author

Currently it is understood that volcanogenic outgassing of CO₂ during the Karoo–Ferrar igneous province eruption initiated a period of prolonged global warming and mass extinction during the Pliensbachian–Toarcian interval of the Early Jurassic (PÁLFY & SMITH 2000). Warmer water temperatures are thought to have caused a series of environmental changes during the Early Toarcian that include methane hydrate release (HESSELBO et al. 2000) and a period of global marine anoxia dubbed the Toarcian Oceanic Anoxic Event or T–OAE (JENKYN 1988; 2010 and references therein). This is evidenced in the Tethys Ocean area by deposition of organic-rich black shale and coeval perturbations in a variety of geochemical systems that include carbon (JENKYN 1988; 2010; HESSELBO et al. 2000), nitrogen (JENKYN et al. 2001), manganese (SABATINO et al. 2011), sulfur (MCARTHUR et al. 2008; GILL et al. 2011), and molybdenum (PEARCE et al. 2008; MCARTHUR et al. 2008). It is believed that disruption of these geochemical systems is evidence for the rapid injection and oxidation of methane which reduced oceanic O₂ levels and increased organic carbon burial leading to marine euxinic conditions on a global scale (JENKYN et al. 2010 and references therein).

However, recent studies have questioned the timing, evidence for, and geographic extent of the T–OAE (WIGNALL et al. 2005; VAN DE SCHOOTBRUGGE et al. 2005; MCARTHUR et al. 2008 and references therein). An alternative, regional hypothesis invokes local controls within several silled basins developed across the epicontinental seaway of NW Europe

(MCARTHUR et al. 2008). Black shale deposition and coeval geochemical perturbations reflect euxinic conditions resulting from local upwelling together with increased freshwater input that caused a salinity driven pycnocline to develop (MCARTHUR et al. 2008 and references therein). It is possible that both hypotheses are applicable and that simultaneous regional and global controls reinforced each other during this event.

In our poster we report preliminary geochemical data from the Sonoma Basin of Nevada (USA) in order to assess whether anoxic water mass conditions developed in a restricted basin on the eastern edge of the northeast paleo-Pacific Ocean that may have been analogous to the European basins. Preliminary results are also compared with geochemical data from the Haida Gwaii region of British Columbia, Canada, which was located in an open paleo-Pacific Ocean setting during the Early Toarcian and shows no evidence of the T–OAE. Results generated in our study will therefore test the controlling mechanisms for the T–OAE and shed light on the debated ‘global’ vs. ‘restricted basin’ models for marine anoxia.

References

- GILL, B.C., LYONS, T.W., & JENKYN, H.C. 2011. A global perturbation to the sulfur cycle during the Toarcian Oceanic Anoxic Event. – *Earth and Planetary Science Letters* 312: 484–496.
- HESSELBO, S.P., GRÖCKE, D.R., JENKYN, H.C., BJERRUM, C.J., FARRIMOND, P., MORGANS BELL, H.S. & GREEN, O.R. 2000. Massive dissociation of gas hydrate during a Jurassic oceanic anoxic event. – *Nature* 406: 392–395.
- JENKYN, H.C. 1988. The Early Toarcian (Jurassic) event: stratigraphy, sedimentary and geochemical evidence.

- American Journal of Science 288: 101–151.
- JENKYN, H.C. 2010. Geochemistry of oceanic anoxic events. – *Geochemistry, Geophysics, Geosystems* 11: Q03004, doi:10.1029/2009GC002788.
- JENKYN, H.C., GRÖCKE, D.R. & HESSELBO, S.P. 2001. Nitrogen isotope evidence for water mass denitrification during the early Toarcian (Jurassic) ocean anoxic event. – *Paleoceanography* 16: 593–603.
- MCARTHUR, J.M., ALGEO, T.J., VAN DE SCHOOTBRUGGE, B., LI, Q. & HOWARTH, R.J. 2008. Basinal restriction, black shales, Re-Os dating, and the Early Toarcian (Jurassic) oceanic anoxic event. – *Paleoceanography*, 23: 1–22.
- PÁLFY, J. & SMITH, P.L. 2000. Synchrony between Early Jurassic extinction, oceanic anoxic event, and the Karoo–Ferrar flood basalt volcanism. – *Geology* 28: 747–750.
- PEARCE, C.R., COHEN, A.S., COE, A.L. & BURTON, K.W. 2008. Molybdenum isotope evidence for global ocean anoxia coupled with perturbations to the carbon cycle during the Early Jurassic. – *Geology* 36: 231–234. doi: 10.1130/G24446A.1.
- SABATINO, N., NERI, R., BELLANCA, A., JENKYN, H.C., MASETTI, D. & SCOPELLITI, G. 2011. Petrography and high-resolution geochemical records of Lower Jurassic manganese-rich deposits from Monte Mangart, Julian Alps. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 299: 97–109.
- VAN DE SCHOOTBRUGGE, B., BAILEY, T.R., ROSENTHAL, Y., KATZ, M.E., WRIGHT, J.D., MILLER, K.G., FEIST-BURKHARDT, S. & FALOWSKI, P. 2005. Early Jurassic climate change and the radiation of organic-walled phytoplankton in the Tethys Ocean. – *Paleobiology* 31: 73–97.
- WIGNALL, P.B., NEWTON, R.J. & LITTLE, C.T.S. 2005. The timing of paleoenvironmental change and cause-and-effect relationships during the Early Jurassic mass extinction Europe. – *American Journal of Science* 305: 1014–1032.

The impacts of palaeoenvironmental change on benthic and pelagic fauna during the Toarcian Oceanic Anoxic Event

BRYONY A. CASWELL^{1*} & ANGELA L. COE²

¹*School of Environmental Sciences, University of Liverpool, Nicholson Building, Brownlow Street, Liverpool, L69 3GP, UK; E-mail: b.a.caswell@liverpool.ac.uk*

²*Department of Environment, Earth and Ecosystems, Centre for Earth, Planetary, Space and Astronomical Research, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK; E-mail: a.l.coe@open.ac.uk*

*Corresponding author

The Toarcian (Early Jurassic) Oceanic Anoxic Event (OAE) was a period of severe global palaeoenvironmental change. It was characterised by global deposition of organic-rich mudrocks (JENKYN 2003), a negative $\delta^{13}\text{C}$ excursion (e.g. KEMP et al. 2005; HESSELBO et al. 2007; AL-SUWAIDI et al. 2010), increased weathering (COHEN et al. 2004), higher seawater temperatures (BAILEY et al. 2003), ocean de-oxygenation (PEARCE et al. 2008), and a marine mass extinction (LITTLE 1996; CASWELL et al. 2009).

We present a new, large high temporal resolution dataset (~4.5–11 cm) for species ranges, and body-size and abundance changes ($n \approx 36,000$) for the two bivalve species that dominate the benthos (*Bositra radiata* and *Pseudomytiloides dubius*; CASWELL et al. 2009) during the Toarcian OAE in the Cleveland Basin, Yorkshire, UK. Our results show quantitative relationships, at a thousand year resolution, between geochemical proxies for environmental change and changes in the size and abundance of benthic fauna during the Toarcian OAE. A comparison and correlation of the bivalve size and abundance data with geochemical proxies, published data on the pelagic macrofauna, and new data on the abundance of fish debris from the Cleveland Basin sections suggest there were two phases of persistent de-oxygenation that extended into the photic zone.

Our study of the Holwell Quarry, Leicestershire that represents a shallower water area (East Midland Shelf) adjacent to the Cleveland Basin shows that the benthic fauna was more diverse and abundant. This area is interpreted to have been more hospitable and a possible source of new invertebrate recruits

for the basinal areas. Ammonite species ranges and high-resolution $\delta^{13}\text{C}_{\text{org}}$ measurements from Holwell Quarry show that the lowermost part of $\delta^{13}\text{C}_{\text{org}}$ negative excursion is not represented in this area (CASWELL & COE 2012).

The Early Toarcian OAE represents a good analogue for anthropogenically induced climatic change because the rates of $p\text{CO}_2$ increase and warming during the Toarcian are comparable with those at present day. The palaeontological changes that occurred during the Toarcian OAE are directly comparable with the ecological changes being observed in present day systems facing increasing marine hypoxia (LEVIN 2009). Therefore, understanding how the biota responded during the Toarcian OAE can show how organisms within present day oceans might respond to increasing hypoxia on millennial timescales.

References

- AL-SUWAIDI, A.H., ANGELOZZI, G.N., BAUDIN, F., DAMBORENEA, S.E., HESSELBO, S.P., JENKYN, H.C., MANCENIDO, M.O. & RICCARDI, A.C. 2010. First record of the Early Toarcian Oceanic Anoxic Event from the Southern Hemisphere, Neuquén Basin, Argentina. – *Journal of the Geological Society*, London 167: 633–636.
- BAILEY, T.R., ROSENTHAL, Y., MCARTHUR, J.M., VAN DE SCHOOTBRUGGE, B. & THIRLWALL, M.F. 2003. Paleocyanographic changes of the Late Pliensbachian–Early Toarcian interval: a possible link to the genesis of an Oceanic Anoxic Event. – *Earth and Planetary Science Letters* 212: 307–320.
- CASWELL, B.A., COE, A.L. & COHEN, A.S. 2009. New range data for marine invertebrate species across the early Toarcian (Early Jurassic) mass extinction. – *Journal of the Geological Society*, London 166: 859–872.
- CASWELL, B.A. & COE, A.L. 2012. A high-resolution shallow marine record of the Toarcian (Early Jurassic) Oceanic Anoxic Event from the East Midlands Shelf, UK. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 365–366: 124–135.

- COHEN, A.S., COE, A.L., HARDING, S.M. & SCHWARTZ, L. 2004. Osmium isotope evidence for the regulation of atmospheric CO₂ by continental weathering. – *Geology* 32: 157–167.
- HESSELBO, S.P., JENKYN, H.C., DUARTE, L.V. & OLIVEIRA, L.C.V. 2007. Carbon-isotope record of the Early Jurassic (Toarcian) Oceanic Anoxic Event from fossil wood and marine carbonate (Lusitanian Basin, Portugal). – *Earth and Planetary Science Letters* 253: 455–470.
- JENKYN, H.C. 2003. Evidence for rapid climate change in the Mesozoic-Palaeogene greenhouse world. – *Philosophical Transactions of the Royal Society of London A* 361: 1885–1916.
- KEMP, D.B., COE, A.L., COHEN, A.S. & SCHWARTZ, L. 2005. Astronomical pacing of methane release in the Early Jurassic period. – *Nature* 437: 396–399.
- LEVIN, L.A., EKAU, W., GOODAY, A.J., JORISSEN, F., MIDDELBURG, J.J., NAQVI, S.W.A., NEIRA, C., RABALAIS, N.N. & ZHANG, J. 2009. Effects of natural and human-induced hypoxia on coastal benthos. – *Biogeosciences* 6: 2063–2098.
- LITTLE, C.T.S. 1996. The Pliensbachian-Toarcian (Lower Jurassic) extinction event. In: RYDER, G., FASTOVSKY, D. & GARTNER, S. (eds.), *The Cretaceous-Tertiary event and other catastrophes in Earth history*. – Geological Society of America, Special Papers 307: 505–512.
- PEARCE, C.R., COHEN, A.S., COE, A.L. & BURTON, K.W. 2008. Molybdenum isotope evidence for global ocean anoxia coupled with perturbations to the carbon cycle during the early Jurassic. – *Geology* 36: 231–234.

Center of gravity and shell volume calculations for some Jurassic ammonoids from Kachchh, India

ALOK CHAUDHARI

Center of Advanced Study in Geology, Banaras Hindu University, Varanasi 221001, India; E-mail: alok.hhh@gmail.com

Ammonoids constitute the most diverse fossil invertebrates during the Mesozoic Era. One of the most striking features of ammonoids is its chambered shell, which aided them to remain buoyant at different depths. This significant attainment may partly explain their dominance in the Mesozoic. Earlier workers have elaborated mathematical models to explain the parameters associated with ammonoid buoyancy, which accounts for the center of gravity and shell volume.

MOSELEY (1938) in his pioneering paper on molluscan geometry derived the equations for shell volume and surface area for planispirally coiled shells, which incorporated several intrinsic shell parameters. TRUEMAN (1941) gave a modified equation for the shell volume assuming the ammonoid shell to be a right cone wrapped about around an axis. Both TRUEMAN and MOSELEY laid the foundation for the ammonoid hydrostatics calculations. RAUP & CHAMBERLAIN (1967), with slight modification of TRUEMAN's and MOSELEY's works, applied these equations to actual ammonoid specimens and compared the calculated volume with the actual volume obtained by water displacement

method.

The Jurassic succession of Kachchh is well known for its diverse fossil record particularly its richness in ammonoids. In view of the above, an attempt has been made to apply the modified equations given by RAUP and CHAMBERLAIN to calculate the shell volume and center of gravity of about 20 Jurassic ammonoid specimens from Kachchh, India. Such calculations will allow me to comment on their mode of life and swimming capabilities. To minimize the complexities, I use here MatLab (Mathematical Software) for all kinds of desired calculations. It is a preliminary work in context of Indian Jurassic ammonoids, which has never been attempted before.

References

- MOSELEY, H. 1938. On the geometrical forms of turbinated and discoid shells. – *Philosophical Transactions of the Royal Society London* 1838: 351–370.
- RAUP, D.M. & CHAMBERLAIN, J.A., Jr. 1967. Equations for volume and center of gravity in ammonoid shells. – *Journal of Paleontology* 41: 566–574.
- TRUEMAN, A.E. 1941. The ammonite body chamber, with special reference to the buoyancy and mode of life of the living ammonite. – *Quarterly Journal Geological Society, London* 96: 339–383.

Ductile deformation in Jurassic sequence of Kachchh rift basin: A clue to Median High tectonics, Western India

GAURAV CHAUHAN & M. G. THAKKAR

Department of Earth and Environmental Science, K.S.K.V. Kachchh University, Bhuj-Kachchh-370001

The Kachchh peri-cratonic rift basin originated during break-up of the eastern Gondwanaland and superposed by the Tertiary sag basin. During post-collision compressive regime of the Indian plate, the basin became a shear zone with strike-slip movements along sub-parallel rift faults. The major uplifts along the basal faults trending E-W in Kachchh expose Mesozoic sediments. The most striking feature of the basin is the structural high or ridge in the basement which cuts across the mainland uplift, Banni graben and Pachchham uplift. It is known as Median High (MH) that separates the higher eastern part of the basement from the gradually dipping western part. In post-Oxfordian time the MH arch was rejuvenated affecting the facies of upper Jurassic to Cretaceous viz. Jhuran and Bhuj formations.

The present work focuses on the flexure zone of the MH in the core of Katrol Hill Range (KHR) of mainland Kachchh. The flexures are found near the Katrol Hill Fault – KHF and associated transverse faults. KHF is a secondary

intra-basinal fault located in the central part of the basin and formed in a reverse tectonic environment. The fault is neotectonically and seismically active, forming a prominent escarpment facing due north. It separates the Bhuj Formation to the North and the Jhuran and Jumara formations to the south. The ductile deformation in the Jurassic sequences in the core region of the KHR indicates early activities along the MH during the reverse tectonics of the basin. The flexure zone is identified by the complex foldings, faults and shearings south of Bhuj in the Katrol hill range. The sheared rocks are sandstones and shales of the Jumara Formation, while some shearings are also observed in the Cretaceous sandstones. The ductile condition is only possible when the rocks are at considerable depth and when they are not consolidated. The sheared zone is confined to a small area where transverse faults are dominating and dissecting the KHF. The whole study implies the pre- and post-collision tectonic activities along the MH region.

Integrated stratigraphy of the Oxfordian succession on the Isle of Skye, Scotland

ANGELA L. COE

Department of Environment, Earth and Ecosystems, Centre for Earth, Planetary, Space and Astronomical Research, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK; Email: a.l.coe@open.ac.uk

The Oxfordian at Staffin Bay in the northern part of the Isle of Skye, Scotland is represented by about 100 m of interbedded mudstones and siltstones rich in ammonites. The succession is stratigraphically fairly complete but the outcrop is composed of a complex series of fault blocks exposed in the foreshore making correlation challenging and the amount of exposure variable depending on the position of the overlying storm beach. Detailed examination shows the succession is composed of many, centimetre- to decimetre-sized, fining upward cycles. The base of each cycle is composed of a dark-grey silty mudstone with abundant plant debris and this rapidly fines upward into medium- and pale-grey mudstones. These cycles are most likely to represent changes in sediment supply driven by climatic fluctuation. Changes in the stacking pattern of these small-scale cycles allows a sequence stratigraphical interpretation to be made which shows eight depositional sequences similar to other sections in NW Europe (HESSELBO & COE 2000). What is unusual about this particular Oxfordian succession is that most of the key sequence stratigraphical surfaces are gradational, in common with some other Mesozoic mudrock successions.

Palaeomagnetic analysis on samples taken about every 50 cm through the lower and upper part of the succession was successful in all but the occasional sideritic carbonate bands and shows a detailed pattern of normal and reversed polarity (OGG et al. 2010; PRZYBYLSKI et al. 2010; WIERZBOWSKI et al. 2006) The palaeomagnetic results provide further key constraints on the biostratigraphic and sequence stratigraphic correlation between the different ammonite provinces and sections. The succession is important because it is the most stratigraphically complete Oxfordian section in the UK, was deposited in comparatively deep water, is suitable for a wide range of stratigraphic techniques and a key reference section for the Boreal/Sub-Boreal ammonite province. The top

of the succession is the proposed site for the base Kimmeridgian GSSP at Flodigarry on the north side of Staffin Bay (MATYJA et al. 2006; WIERZBOWSKI et al. 2006).

A further Oxfordian succession is exposed on the south side of the Isle of Skye but this is much coarser-grained, not well constrained biostratigraphically and is likely to be fairly incomplete. Low grade thermal metamorphism of the succession due to the proximity of the Cullin Igneous Complex prevent construction of a palaeomagnetic or chemostratigraphic stratigraphy. The succession, however, provides large-scale sedimentological patterns that are interesting sequence stratigraphically.

A high resolution integrated graphic log of the Staffin Bay succession showing the facies, biostratigraphy, sequence stratigraphy and magnetostratigraphy will be presented. The succession will be compared and correlated with other Oxfordian records.

References

- HESSELBO S.P. & COE, A.L. 2000. Jurassic sequences of the Hebrides Basin, Isle of Skye, Scotland. In: GRAHAM, J.R. & RYAN, A. (eds) International Association of Sedimentologists. Field Trip Guidebook, Dublin 2000: 41–58, Department of Geology, Trinity College, Dublin.
- MATYJA, B.A., WIERZBOWSKI A. & WRIGHT, J.K. 2006. The Sub-Boreal/Boreal ammonite succession at the Oxfordian/Kimmeridgian boundary at Flodigarry, Staffin Bay (Isle of Skye), Scotland. – *Transactions of the Royal Society of Edinburgh, Earth Sciences*, 96: 387–405.
- OGG, J.G., COE, A.L., PRZYBYLSKI, P.A. & WRIGHT, J.K. 2010. Oxfordian magnetostratigraphy of Britain and its correlation to Tethyan regions and Pacific marine magnetic anomalies. – *Earth and Planetary Science Letters* 289: 433–448.
- WIERZBOWSKI, A., COE, A.L., HOUNSLOW, M.W., MATYJA, B.A., OGG, J.G., PAGE, K.N., WIERZBOWSKI, H. & WRIGHT, J.K. 2006. A potential stratotype for the Oxfordian/Kimmeridgian boundary: Staffin Bay, Isle of Skye, UK. – *Volumina Jurassica* 4: 17–33.
- PRZYBYLSKI, P.A., OGG, J.G., WIERZBOWSKI, A., COE, A.L., HOUNSLOW, M.W., WRIGHT, J.K., ATROPS, F., SETTLES, E. 2010. Magnetostratigraphic correlation of the Oxfordian-Kimmeridgian Boundary. – *Earth and Planetary Science Letters* 289: 256–272.

Nodularity vs. geochemistry in Ammonitico Rosso: a preliminary report from the Upper Jurassic (Betic Cordillera, SE Spain)

RUTE COIMBRA & FEDERICO OLÓRIZ

Departamento de Estratigrafía y Paleontología, Universidad de Granada, 18071 Granada, Spain; E-mail: rcoimbra@ugr.es, foloriz@ugr.es

Ammonitico Rosso facies (AR) provides some of the most typical rocks from the Tethyan Jurassic. Variations in colour, nodularity, and fossil content are common, and the wide array of features in which this facies occurs complicates attempts for descriptive rather than genetic classifications of identified AR variability (HOLLMANN 1962; JENKYNs 1974; FARINACCI & ELMi 1981; CLARI et al. 1984; NICOSIA 1991; CLARI & MARTIRE 1996; MARTIRE 1996; COIMBRA et al. 2009). This contribution focuses on testing the descriptive concept of “nodularity” and its wide use to designate the result of distinct processes. Although composition, shape, boundaries and size of AR

in situ and intraformational components are often suitable criteria, other aspects as textural fabrics and potential distinct origins must also be discussed.

The term *nodule* is here restricted to within-sediment nuclei of comparatively accelerated lithification regarding the surrounding matrix. Since *nodule* differentiation is an *in situ*, progressive and very early diagenetic process, *nodule* boundaries will depend on the degree to which differential lithification, and synsedimentary and subsequent compaction/dissolution (stylolitic contacts), operate with respect to the surrounding matrix (dissolution seams, matrix adaption). *Nodules*

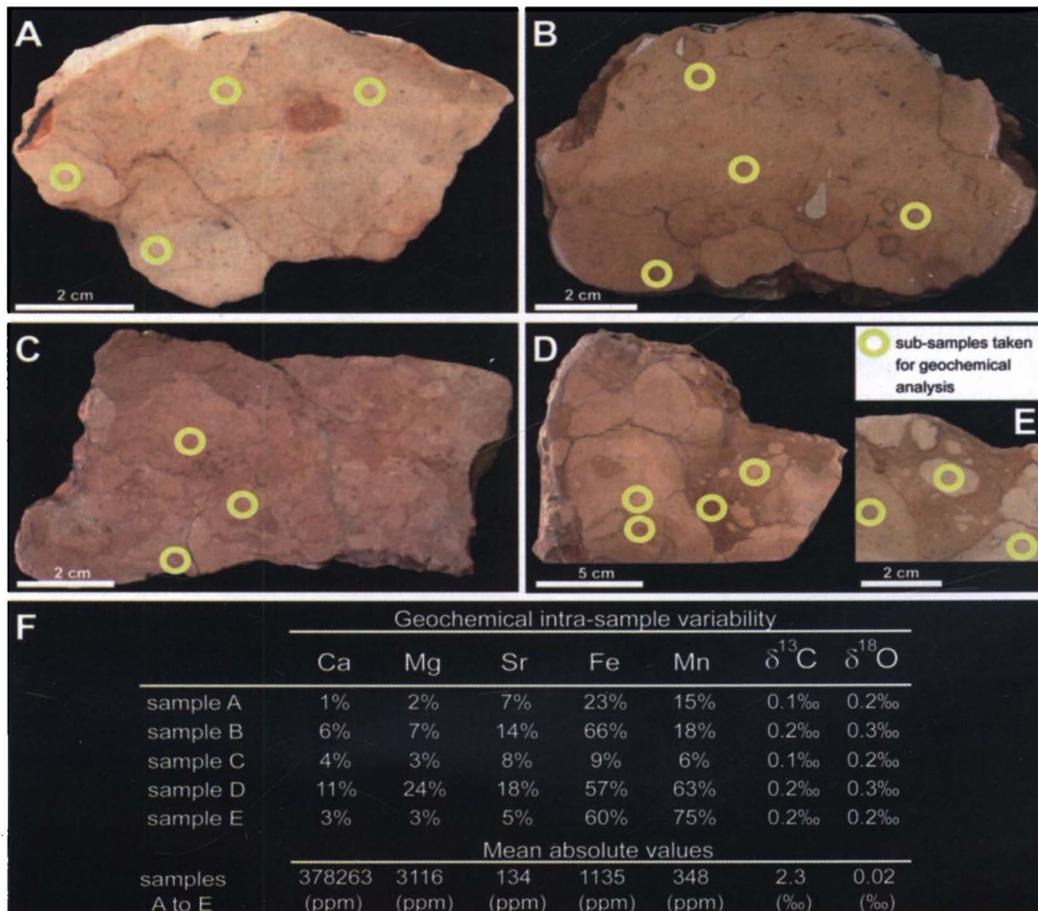


Fig. 1. Examples of analyzed Ammonitico Rosso samples. A to E: Variable degree of nodularity. F: Average intra-sample geochemical variability and mean absolute values obtained for samples A to E.

can be reworked with resulting boundary reinforcement. However, uncertainty is evident when dealing with sub-rounded to more angular lithoclasts in AR, and their interpretation as *nodules* under the assumption of reworking cannot be conclusive. Sea-bottom surface and biogenically mediated processes such as biogenic (oncooids, oncolites) and mixed (aggregate grains, cortoids) growths precede lithification processes *s.str.* and therefore are not interpreted as *nodules* in the genetic sense here chosen. *Nodule* recognition was conducted on macroscopic observation of polished slabs of hand-samples, hence accounting only for formation of centimetre-sized nodules. Petrographic analysis complemented *nodule* inspection.

In a context of high variable nodularity in more or less calcareous horizons of the investigated AR and related facies, the geochemical signature of different macroscopic sedimentary components is compared in order to evaluate homogeneity/heterogeneity in their geochemical signatures. Representative cases of intra-sample variability were chosen among samples selected from six sections belonging to the S-E Iberian paleomargin. The studied material, obtained under strict biostratigraphic control, corresponds to Late Jurassic epiocceanic settings, from the middle Oxfordian to the latest Tithonian.

Petrographic analysis was performed through microfacies, cathodoluminescence and scanning electron microscopy (SEM) analyses, allowing the evaluation of the degree of diagenetic alteration of the studied carbonates. Three to six powder sub-samples were drilled from each rock slab for analysis of C and O stable isotopes and major and trace elements (Ca, Mg, Sr, Fe, and Mn).

In a context of fair preservation of the studied material and negligible degree of diagenetic imprint (COIMBRA et al. 2009), it seems of relevance that very early diagenesis produced a wide spectrum of nodularity. Regarding intra-sample variability (Fig. 1), a very stable C isotope record is observed, with mean value of 2.3‰ (maximum scattering 0.2‰), accompanied with only slight variations in oxygen isotope values, with a mean value of 0.03‰ (maximum scattering 0.3‰). The elemental abundance distribution shows

a slightly more variable record, with intra-sample abundance variability <24% for Mg and Sr, and higher for Fe and Mn, showing intra-sample scattering from 6% up to 75% (mean values in Fig. 1). Interestingly, a high visual differentiation does not always correspond to high variability in elemental abundance (Fig. 1A-C), and no strict relationships seem to be recorded between elemental and $\delta^{18}\text{O}$ records. The highest intra-sample variability obtained for samples containing lithoclasts (Fig. 1D, E) could be expected. These preliminary data indicates that incipient lithification during very early diagenesis of AR sediments promoted the preservation of both its isotope and elemental signature. This occurs in all macroscopically differentiated patches of incipient nodule formation, *nodules* and investigated reworked lithoclasts – the latter being a particular sub-sample of intraformational components.

References

- CLARI, P.A. & MARTIRE, L. 1996. Interplay of cementation, mechanical compaction and chemical compaction in nodular limestones of the Rosso Ammonitico Veronese (middle - upper Jurassic, northeastern Italy). – *Journal of Sedimentary Research* 66: 447–458.
- CLARI, P.A., MARINI, P., PASTORINI, M., & PAVIA, G. 1984. Il Rosso Ammonitico Inferiore (Baiociano-Calloviano) nei monti lessini settentrionali (Verona). – *Rivista Italiana di Paleontologia e Stratigrafia* 90: 15–86.
- COIMBRA, R., IMMENHAUSER, A. & OLÓRIZ, F. 2009. Matrix micrite $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ reveals synsedimentary marine lithification in Upper Jurassic Ammonitico Rosso limestones (Betic Cordillera, SE Spain). – *Sedimentary Geology* 219: 332–348.
- FARINACCI, A & ELMI, S. (eds.) 1981. Rosso Ammonitico Symposium, Roma, Proceedings: 602 pp., Tecnoscienza, Roma.
- HOLLMANN, R. 1962. Über Subsollution und die "Knollenkalke" des Calcare Ammonitico Rosso Superiore im Monte Baldo (Malm, Norditalien). – *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte* 1962: 163–179.
- JENKYN, H.C. 1974. Origin of red nodular limestones (Ammonitico Rosso, Knollenkalke) in the Mediterranean Jurassic: A diagenetic model. In: Hsü, K.J. & JENKYN, H.C. (eds.), *Pelagic sediments: on Land and under the Sea*. – International Association of Sedimentologists, Special Publication 1: 249–271.
- MARTIRE, L. 1996. Stratigraphy, facies and synsedimentary tectonics in the Jurassic Rosso Ammonitico Veronese (Altopiano di Asiago, NE Italy). – *Facies* 35: 209–236.
- NICOSIA, U., CONTI, M.A., FARINACCI, A., ALTINER, D. & KOÇYİĞİT, A. 1991. Western Anatolia Ammonitico Rosso type sediments. Depositional history and geodynamic meaning. – *Geologica Romana* 27: 101–112.

Palaeolatitudinal patterns of diversity and distribution in Early Jurassic South American bivalves

SUSANA E. DAMBORENEA* & JAVIER ECHEVARRÍA

Consejo Nacional de Investigaciones Científicas y Técnicas. Departamento Paleontología Invertebrados, Museo de Ciencias Naturales La Plata, 1900 La Plata, Argentina; E-mail: sdambore@fcnym.unlp.edu.ar

**Corresponding author*

One of the global-scale relationships between biogeography and ecology is the existence of latitudinal gradients in species diversity, known both in past and living faunas (CRAME 2000; VALENTINE & JABLONSKI 2010). Although it is generally acknowledged that the global pattern of decreasing diversity towards higher latitudes may be altered locally due to several factors, these are not well-known. In this contribution we present an integrated study taking into account several aspects of the latitudinal patterns of distribution and diversity of marine bivalves during the Early Jurassic along the western South American margin of the Palaeopacific and their changes through time. Presence-absence bivalve species data were compiled from about 200 localities in Chile and Argentina, grouped into 2° units between 20° and 46° present-day latitude, and recorded separately for each of the four Early Jurassic stages. Data and methods were updated from previous reports (DAMBORENEA 1996; DAMBORENEA et al. 2012). A set of analytical methods was applied to the study of the latitudinal ranges of species thus obtained. The first approach was cluster analysis, but this method, although useful, imposes a hierarchical structure on the data. Since a gradation along latitudinal range is expected, the distribution of species was then analysed using techniques similar to those considered for origination/extinction analysis (HAMMER & HARPER 2006), counting the number of species per 2° unit, and substituting first and last appearances by northernmost and southernmost geographical occurrences. The results do not show the expected decrease in species diversity towards higher latitudes in the geographic range considered here, but instead a consistent local diversity increase between 30° and 40°, which

is especially evident for Pliensbachian and Toarcian times. This local break may be due to an abrupt change in geographic settings at that latitude, with the establishment of favourable conditions and an increased variety of habitats within the extensive Neuquén Basin, which at that time was a quasi-isolated shallow-epeiric sea, very different from the coasts and environments to the north of that latitude. The analysis of southernmost and northernmost geographic occurrences also shows a somewhat bounded range of major change in species distribution instead of the expected gradient. In order to statistically check for gradational patterns, the changes in the proportional values of systematic- and palaeobiogeographic-kinship species categories were evaluated by means of generalized linear models (CRAWLEY 2007). The analysis revealed a significant trend of decreasing relative diversity at higher latitudes for the superfamily Trigonioidea in the four considered stages. During the Pliensbachian, the superfamilies Arcoidea, Nuculanoidea, and Inoceramoidea showed a southward increasing trend in proportion of species, while Pholadomyoidea showed an opposite trend. For the Toarcian the superfamilies Limoidea and Lucinoidea decreased southwards in relative number of species, while Monotoidea, Pectinoidea, and Crassatelloidea tended to increase their relative diversity in that same direction. The analysis of the distribution produces a break when palaeobiogeographic affinity groups are considered. This suggests the existence of two main biogeographic units, a northern (or Tethyan) and a southern (or Austral) one, with a boundary zone within the study area (DAMBORENEA 2002). Some other general trends through time, which are consistent with Northern Hemisphere

bivalve data (HALLAM 1977; HAYAMI 1990; LIU 1995), include: a slight decrease in the percentage of "local" species through time from the Hettangian to the Toarcian; a diversity maximum in the Pliensbachian; and a shift (for about eight degrees of latitude) towards higher latitudes of the boundary zone between southern and northern faunas for the time involved (DAMBORENEA 2002). This last result is here interpreted as due to a combination of factors involving both climatic change and continental latitudinal drift. The present study indicates that large-scale geographic conditions are important factors to be taken into account for the analysis of latitudinal diversity trends of benthic faunas, confirming similar conclusions based on living faunas along the same latitudinal range (VALDOVINOS et al. 2003). In contrast, the coeval changes in relative proportions of different bivalve superfamilies towards either higher or lower latitudes are probably not so heavily dependent on geography but reflect instead latitudinal trends most probably related to temperature gradients.

References

- CROME, J.A. 2000. The nature and origin of taxonomic diversity gradients in marine bivalves. In: HARPER, E.M., TAYLOR, J.D. & CROME, J.A. (eds.), *The evolutionary biology of the Bivalvia*. - Geological Society Special Publication 177: 347-360.
- CRAWLEY, M.J. 2007. *The R Book*. John Wiley and Sons, Ltd.
- DAMBORENEA, S.E. 1996. Palaeobiogeography of Early Jurassic bivalves along the southeastern Pacific margin. - 13^o Congreso Geológico Argentino y 3^o Congreso de Exploración de Hidrocarburos (Buenos Aires) Actas 5: 151-167.
- DAMBORENEA, S.E. 2002. Jurassic evolution of Southern Hemisphere marine palaeobiogeographic units based on benthonic bivalves. - *Geobios* 35, MS24: 51-71.
- DAMBORENEA, S.E., ECHEVARRÍA, J. & ROS-FRANCH, S. 2012. Southern Hemisphere palaeobiogeography of Triassic-Jurassic marine bivalves. *Springer Briefs in Earth System Sciences*, 141, Springer, Dordrecht.
- HALLAM, A. 1977. Jurassic bivalve biogeography. - *Paleobiology* 3: 58-73.
- HAMMER, Ø. & HARPER, D.A.T. 2006. *Paleontological data analysis*. Blackwell Publishing.
- HAYAMI, I. 1990. Geographic distribution of Jurassic faunas in Eastern Asia. In: ICHIKAWA, K., MIZUTANI, S., HARA, I. HADA, S. & YAO, A. (eds.), *Pre-Cretaceous terranes of Japan*. - Publication of IGCP Project 224, Osaka.
- LIU, C. 1995. Jurassic bivalve palaeobiogeography of the Proto-Atlantic and the application of multivariate analysis methods in palaeobiogeography. - *Beringeria* 16: 3-123.
- VALDOVINOS, C., NAVARRETE, S.A. & MARQUET, P.A. 2003. Mollusk species diversity in the Southern Pacific: Why are there more species towards the pole? - *Ecography* 26: 139-144.
- VALENTINE, J.W. & JABLONSKI, D. 2010. Origins of marine patterns of biodiversity: some correlates and applications. - *Palaeontology* 53: 1203-1210.

The terrestrial Triassic–Jurassic boundary in China

SHENGHUI DENG*, YUANZHENG LU, RU FAN & XIN LI

Research Institute of Petroleum Exploration & Development PetroChina, Beijing 100083, China; E-mail: dsh63@petrochina.com.cn; luyz@petrochina.com.cn; rufan@petrochina.com.cn; lixin@petrochina.com.cn

*Corresponding author

The Late Triassic and Jurassic strata in China are dominated by terrestrial rocks except those in Tibet and the Pacific Ocean marginal areas (Guangdong Province of South China for example). Thus, the Triassic–Jurassic (Tr–J) boundary in China is represented by continental beds. Due to lack of marine fossils and any other definite evidence, the Tr–J boundary in China is still controversial.

In 2010, the GSSP for the base of the Hettangian Stage, namely the Tr–J boundary, had been ratified by the IUGS. The Tr–J boundary GSSP was placed at the Kuhjoch section, Northern Calcareous Alps, Austria. It coincides with the first appearance of the ammonite *Psiloceras spelae* GUÉZENNEC subsp. *tirolicum* HILLEBRANDT & KRISTYAN and with an approximately simultaneous brief negative excursion in organic carbon isotopes and a palynological assemblage of *Cerebropollenites thiergartii* (RHUL et al. 2009). Both the isotopic event and palynological assemblage are very valuable for determining the continental Tr–J boundary.

In order to correlate the Mesozoic oil-bearing terrestrial strata in China, the authors have investigated the Upper Triassic Series and Jurassic System of the major oil-bearing basins, such as the Tarim, Junggar, and Turpan-Hami basins of Xinjiang, Northwest China, and the Sichuan Basin of Southwest China during the recent years. The Tr–J boundary is one of the issues of the studies.

The Tr–J boundary in northern China

During the Late Triassic and Early Jurassic Epochs in northern China, namely north of the Kunlun Mountains, Qinling Mountains, and Dabie Mountains, the climate was predominantly temperate-humid and the strata are characterized by coal-bearing formations. The Upper Triassic and the Lower Jurassic

stratigraphic successions are represented by the succession in the Junggar Basin of Northwest China, which is composed of the Haojiaguo, Badaowan, and Sangonghe formations, in ascending order. These strata yield abundant plants, spore-pollen, megaspores, bivalves, and conchostracans (DENG et al. 2003, 2010). The Tr–J boundary should be placed at the base of the Badaowan Formation based on the palaeontological evidence and isotopic excursion.

Lithological features. – The lower part of the Badaowan Formation is characterized lithologically by grey or whitish grey sandstones, siltstones, mudstones, and conglomerates with coal interbeds; while the underlying beds, the upper part of the Haojiaguo Formation, is characterized by greyish green and yellowish green rocks intercalated by coal-bearing beds. This general colour difference reflects somewhat the change of sedimentary environments through the Late Triassic to the Early Jurassic age.

Palaeontological evidence. – There are two different floral assemblages in the Haojiaguo Formation. One is the *Danaeopsis-Cladophlebis ichunensis* Assemblage from the lower and middle part of the formation, which has been assigned to the Late Triassic as it consists chiefly of Late Triassic elements, such as *Danaeopsis*. The assemblage from the upper part of the formation is named *Hausmannia-Clathropteris minoria* Assemblage, which lacks typical Jurassic elements but is composed of some taxa that are usually recorded in the Late Triassic, such as *Thinnfeldia?* sp., *Cladophlebis kaoiana*, *Sphenopteris chowkiawanensis*, and *Cycadocarpidium* sp.. It is, therefore considered as possibly Late Triassic in age. The Badaowan Formation yields two palaeobotanical assemblages. The upper one is definitely

of Early Jurassic age containing *Coniopteris gaojiatianensis* and numerous species that are commonly encountered in Jurassic floras. The Lower one, in contrast, should be of Early Jurassic age containing abundant *Todites princes* and *Clathropteris elegans*, which are the major species of the early Early Jurassic *Thaumatopteris* Zone of Greenland. So, the Tr-J boundary can be placed at the base of the Badaowan Formation.

The spore-pollen from the Haojiaguo Formation indicates a Triassic age due to numerous Triassic or older elements, including *Aratrisporites*, *Chordasporites*, *Lueckisporites tatoensis*, *Hamiapollenites bullaeformis*, *Remysporites* and *Endosporites ornatus*. A sharp peak of fern spores, including *Densosporites scanicus*, *Densosporites crassus*, and *Cyathidites*, occurs near the base of the Badaowan Formation, indicating a major change in floral evolution. Besides, the major taxa of the megaspore *Hughesporites gibbosus* – *Calamospora rhaeticus* assemblage from the Haojiaguo Formation and the *Horstisporites harrisii* – *Trileites murrayi* – *Echitriletes hispidus* assemblage from the Badaowan Formation show they can be assigned to the Late Triassic and Early Jurassic respectively.

Organic carbon isotope excursion. – Organic carbon isotope analyses of rock and charcoal samples from the Middle to Upper Haojiaguo Formation and Lower Badaowan Formation demonstrate that there is a major negative excursion (-2‰ PDB in whole rock samples and -4.0‰ PDB as the maximum value in charcoal samples) in the topmost beds of the Haojiaguo Formation and through the lowermost beds of the Badaowan Formation. It is correlated with the main negative excursion event at the GSSP of Kuhjoch section of Austria (RHUL et al. 2009), Nevada (WARD et al. 2007; McROBERTS et al. 2007), East Greenland, and England (HESSELBO et al. 2002). This implicates that the Tr-J biostratigraphic boundary coincides with the Tr-J chronostratigraphic boundary at the Haojiaguo section of the Junggar Basin.

The Tr-J boundary in South China

The well exposed continental Tr-J boundary sections in South China are located in the Sichuan and Yunnan provinces of Southwest China. In the Sichuan Basin, the Upper Triassic

and Lower Jurassic are usually continuous and well exposed. The Tr-J boundary was previously determined at the base of the Zhengzhuchong Formation, marked by first appearance of red beds or by a quartzitic sandstone bed (WANG et al. 2010). However, as a result of our investigations of a dozen outcrop sections and numerous well sections in recent years, the Tr-J chronostratigraphic boundary in the northern Sichuan Basin should be placed in the black shales of the upper part of the Xujiache Formation, which is generally assigned to the Upper Triassic. This boundary has been determined chiefly by palynological and palaeobotanical evidence and an organic carbon isotopic excursion. Below the boundary the palynological assemblage is characterized by Late Triassic spores, such as *Dictyophyllidites*, *Kyrtomisporsis*, *Lunzisporites*, and *Taeniaesporites*, whereas; above the boundary the content of the pollen *Classopollis* sharply and that of the fern spore *Cyathidites* greatly increases and that of Triassic spores greatly decline. The macro-plant fossils from the rocks close to and below the boundary are dominated by dipteridaceous ferns and Cycadopsida, indicating a Late Triassic age; the dicksoniaceae fern *Coniopteris* appears at about 10 m above the boundary. A negative organic carbon isotopic excursion of -3‰ PDB and ~-4‰ PDB value is found in the rocks close to the biostratigraphic Tr-J boundary.

References

- DENG, S., LU, Y., FAN, R. et al. 2010. The Jurassic of Northern Xinjiang. 279 pp., University of Science and Technology of China Press. Hefei (in Chinese).
- DENG, S., YAO, Y., YE, D. et al. 2003. Jurassic System in the North of China (I), Stratum. 399 pp., Petroleum Industry Press, Beijing (in Chinese with English abstract).
- McROBERTS, C.A., WARD, P.D. & HESSELBO, S. 2007. A proposal for the base Hettangian Stage (= base Jurassic System) GSSP at New York Canyon (Nevada, USA) using carbon isotopes. – ISJS Newsletter 34: 43–49.
- HESSELBO S.P., ROBINSON, S.A., SURLYK, F. & PIASECKI, S. 2002. Terrestrial and marine extinction at the Triassic-Jurassic boundary synchronized with major carbon-cycle perturbation: A link to initiation of massive volcanism? – *Geology* 30: 251–254.
- RHUL, M., KUSCHNER, W.M. & KRZYSTYN, L. 2009. Triassic-Jurassic organic carbon isotope stratigraphy of key sections in the western Tethys realm (Austria). – *Earth and Planetary Science Letters* 281: 169–187.
- WANG, Y., FU, B., XIE, X. et al. 2010. The terrestrial Triassic and Jurassic System in the Sichuan Basin, China. 160

pp., University of Science and Technology of China Press, Hefei.

WARD, P.D., GARRISON, G.H., WILLIFORD, K.H., KRINGS, D., GOODWIN, D., BEATTIE, M. & MCROBERTS, C. 2007. The organic carbon isotopic and paleontological record

across the Triassic-Jurassic boundary at the candidate GSSP section at Ferguson Hill, Muller Canyon, Nevada, USA. - *Palaeogeography, Palaeoclimatology, Palaeoecology* 244: 281-289.

Continental drainage and oceanic circulation during the Jurassic inferred from the Nd isotope composition of biogenic phosphates and sediments

GUILLAUME DERA¹, JONATHAN PRUNIER¹, PAUL L. SMITH², JIM HAGGART^{2,3}, EVGENY POPOV⁴, ALEXANDER GUZHOV⁵, MIKHAIL A. ROGOV⁶, DOMINIQUE DELSATE⁷, DETLEV THIES⁸, GILLES CUNY⁹, EMMANUELLE PUCÉAT¹⁰, GUILLAUME CHARBONNIER¹¹ & GERMAIN BAYON¹²

¹Laboratoire GET, University of Toulouse, 14 avenue Edouard Belin, 31400 Toulouse, France; E-mail: guillaume.dera@get.obs-mip.fr

²Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, 2207 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada

³Geological Survey of Canada, 101-605 Robson Street, Vancouver, British Columbia V6B 5J3, Canada

⁴Department of Palaeontology, Geological Faculty, Saratov State University, 83 Astrakhanskaya Str., 40012 Saratov, Russia

⁵Paleontological Institute, Russian Academy of Sciences, 123 Profsoyuznaya ul., 117997 Moscow, Russia

⁶Geological Institute, Russian Academy of Sciences, 7 Pyzhevsky lane, 119017 Moscow, Russia

⁷Muséum National d'Histoire Naturelle, 25 rue Munster, 2160 Luxembourg, Luxemburg

⁸Institut für Geologie, Leibniz Universität Hannover, Callinstr. 30, D-30167 Hannover, Germany

⁹The Natural History Museum of Denmark, Øster Voldgade 5-7, 1350 Copenhagen, Denmark

¹⁰Laboratoire Biogéosciences, Université de Bourgogne, 6 Bd Gabriel, 21000 Dijon, France

¹¹Laboratoire IDES, Université Paris Sud XI, Bâtiment 504, 91405 Orsay, France

¹²Ifremer, Unité de Recherche Géosciences Marines, 29280 Plouzané, France

The Jurassic period marked the onset of Pangean dislocation that led to our modern geography. The initiation of this major continental reorganisation involved numerous geodynamic processes whose timing, interaction and feedback had important paleoclimatic and geochemical consequences. Among them, the opening of the northern Atlantic Ocean and the development of transcontinental seaways across the Laurasian and Gondwanan cratons caused major modifications to global oceanic circulation which significantly affected heat and moisture transport (DONNADIEU et al. 2006). At the same time, the incipient growth of the Pacific plate triggered increases in plate subduction rates, terrane accretion, and volcanism all around the Panthalassan ocean (BARTOLINI & LARSON 2001). Similarly, many subduction and accretion events occurred in other domains, leading to progressive closures of the Paleotethyan and Mongol-Okhotsk oceans. This global reorganisation of both continental masses and oceanic circulation patterns likely affected the Jurassic climate by shifting the climatic belts, changing albedo, and modulating atmospheric $p\text{CO}_2$ through volcanic degassing or changes in silicate weathering rates (DERA et

al. 2011).

In this study, we attempt to better constrain oceanic connections as well as the modifications in continental drainage that resulted from the Jurassic paleogeographic reorganisation. For this purpose, we present 53 new neodymium isotope values (noted $\epsilon\text{Nd}_{(t)}$) measured on fossil fish teeth, ichthyosaur bones, phosphate ooids, and sediments from Europe, European Russia, and North America. Application of this geochemical proxy is based on the principle that rocks weathered on continents have different Nd isotope compositions according to their origin (volcanic vs. cratonic) and age (Precambrian to recent). Through fluvial discharge, seawater acquires its ϵNd signal (recorded by phosphate during early diagenesis) reflecting all potential sources in the drainage area (TACHIKAWA et al. 2003). As the Nd residence time is relatively short compared with the global oceanic mixing rate, this geochemical proxy is deemed conservative and very suitable for tracking exchanges of water masses with different isotopic signatures (MARTIN & SCHER 2004). For example, STILLE et al. (1996) showed that during the Triassic period, Panthalassan and Tethyan ocean waters were very radiogenic

owing to extensive volcanic sources. During the Pangean dislocation, climate changes caused stronger weathering of the cratons, leading to less radiogenic Tethyan seawaters. Here we reappraise the evolution of circulation patterns at high stratigraphic resolution (ammonite biozone) by specifying both the potential sources and the drainage pathways that influenced seawater signatures throughout the Jurassic period.

Combined with an exhaustive compilation of worldwide $\epsilon\text{Nd}_{(t)}$ data from the literature, our new results show that the sources of Nd were very different according to oceanic domains. In contrast to current patterns showing that all circum-Pacific volcanic areas of the ring fire contribute to the radiogenic signal of the Pacific Ocean (JEANDEL et al. 2007), the radiogenic signature of Panthalassan waters (≈ -3.9) was mainly dependant on North-American and southern Gondwanan volcanic arc inputs. Indeed, the sediments of Asian Panthalassan margins show very low $\epsilon\text{Nd}_{(t)}$ values presumably resulting from the dilution of local volcanic sources by massive Precambrian cratonic input from rising Amurian relief. In the Tethyan domain, the tropical seawater $\epsilon\text{Nd}_{(t)}$ values are comparatively less radiogenic (≈ -6.3). This probably reflects a mixing of radiogenic sources such as Panthalassan waters or volcanic Cimmerian inputs and non-radiogenic influxes from former Laurasian and Gondwanan crust. Toward higher latitudes, the Nd isotope composition of Tethyan waters strongly decreases in the Euro-boreal domain (-8.6) but remains higher in the Russian seaway (-7.4). This difference could result from the respective influences of non-radiogenic

Precambrian Fenno-Scandian sources to the north and radiogenic Cimmerian volcanic inputs to the east. Finally, we note that the $\epsilon\text{Nd}_{(t)}$ values of Euro-boreal and Russian seawaters strongly fluctuate through time and reflect short-term changes in water mass circulation patterns and/or sporadic modifications of drainage areas during the Jurassic.

References

- BARTOLINI, A. & LARSON, R. 2001. Pacific microplate and the Pangea supercontinent in the Early to Middle Jurassic. – *Geology* 29: 735–738.
- DERA, G., BRIGAUD, B., MONNA, F., LAFFONT, R., PUCÉAT, E., DECONINCK, J.F., PELLENARD, P., JOACHIMSKI, M. & DURLET, C. 2011. Climatic ups and downs in a disturbed Jurassic world. – *Geology* 39: 215–218.
- DERA, G., PUCÉAT, E., PELLENARD, P., NEIGE, P., DELSATE, D., JOACHIMSKI, M.M., REISBERG, L. & MARTINEZ, M. 2009. Water mass exchange and variations in seawater temperature in the NW Tethys during the Early Jurassic: Evidence from neodymium and oxygen isotopes of fish teeth and belemnites. – *EPSL* 286: 198–207.
- DONNADIEU, Y., GODDÉRI, Y., PIERREHUMBERT, R., DROMART, G., FLUTEAU, F. & JACOB, R. 2006. A GEOCLIM simulation of climatic and biogeochemical consequences of Pangea breakup. – *Geochemistry, Geophysics, Geosystems* 7(11): Q11019, doi:10.1029/2006GC001278
- JEANDEL, C., ARSOUZE, T., LACAN, F., TÉCHINÉ, P. & DUTAY, J.-C. 2007. Isotopic Nd compositions and concentrations of the lithogenic inputs into the ocean: A compilation, with an emphasis on the margins. – *Chemical Geology* 239: 156–164.
- MARTIN, E.E. & SCHER, H.D. 2004. Preservation of seawater Sr and Nd isotopes in fossil fish teeth: bad news and good news. – *EPSL* 220: 25–39.
- STILLE, P., STEINMANN, M. & RIGGS, S.R. 1996. Nd isotope evidence for the evolution of the paleocurrents in the Atlantic and Tethys Oceans during the past 180 Ma. – *EPSL* 144: 9–19.
- TACHIKAWA, K., ATHIAS, V. & JEANDEL, C. 2003. Neodymium budget in the modern ocean and paleo-oceanographic implications. – *Journal of Geophysical Research* 108: 10/1–10/3.

Palynology of Missão Velha and Brejo Santo formations (Jurassic) of the Araripe Basin, Northeastern Brazil

SARAH DUARTE¹, MITSURU ARAI² & NEERJA JHA³

¹Laboratory of Nannofossils, Geoscience Institute, Department of Geology, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil; Email: Sarahpalino@yahoo.com.br

²Petrobras/CENPES/PDGeo/BPA, Biostratigraphy & Palaeoecology, Rio de Janeiro, Brazil; Email: arai@petrobras.com.br

³Birbal Sahni Institute of Palaeobotany, Lucknow, India; E-mail: neerjajha@yahoo.co.uk

The present communication records spores and pollen grains recovered from Jurassic sediments of the Araripe Basin (northeastern Brazil). Five samples belonging to the Missão Velha and Brejo Santo formations in borehole 2-AP-1-CE between a depth of 923.65 m and 1,450.50 m were processed with traditional palynological methodology for recovery of palynomorphs. The recovered assemblage contains 72 taxa, out of which 44 belong to spores and 28 to pollen, which are listed below.

Spores: *Baculatisporites comaumensis* (COOKSON) POTONIÉ, *B. aff. comaumensis* (*), *Cicatricosisporites australiensis* (COOKSON) POTONIÉ, *C. crassistriatus* BURGER (*), *C. imbricatus* (MARKOVA) SINGH, *C. magnus* DÖRING (*), *C. purbeckensis* NORRIS (*), *C. shalmaricus* Srivastava (*), *C. sternum* VAN AMERON (*), *Clavatisporites hammenii* (HERBST) DE JERSEY, *Converrucosisporites pricei* MCKELLAR, *C. saskatchewanensis* POCOCK, *C. variverrucatus* (COUPER) NORRIS (*), *Deltoidospora australis* (COUPER) POCOCK (*), *D. germanica* DÖRHÖFER, *D. sp.* (*), *Densoisporites perinatus* COUPER (*), *D. velatus* WEYLAND & KRIEGER, *D. sp.* (*), *Dictyophyllidites equixinus* (COUPER) DETTMANN, *D. harrisii* COUPER (*), *Dictyotriletes southeyensis* POCOCK, *Gemmatriletes clavatus* BRENNER, *Impardispora apiverrucata* (COUPER) VENKATACHALA, *Ischyosporites crateris* BALME, *I. punctatus* COOKSON & DETTMANN, *I. scaberis* COOKSON & DETTMANN, *Januasporites spinosireticulatus* MCKELLAR, *Klukisporites sp.* (*), *Laevigatosporites sp.* (*), *Leptolepidites argenteaeformis* (BOLKHOVITINA) MORBEY, *L. major* COUPER, *L. sp.* (*), *Lycopodiacidites eminulus* DETTMANN, *Pilosisporites ingramii* BACKHOUSE, *P. trichopapillosus* (THIERGART) DELCOURT & SPRUMONT (*), *P. aff. trichopapillosus*, *P. sp.* (*), *Retitriletes clavatoide*

(COUPER) DÖRING et al., *R. tenuis* (BALME) BACKHOUSE, *Sestrosporites pseudoalveolatus* (COUPER) DETTMANN, *Stereisporites bujargiensis* (BOLKHOVITINA) SCHULZ, *Verrucosisporites asymmetricus* (COOKSON & DETTMANN) POCOCK, *V. jonkeri* (JANSONIUS) OUYANG & NORRIS, and *V. sp.* (*).

Pollen grains (gymnosperms): *Alisporites australis* DE JERSEY, *A. bilateralis* ROUSE, *A. grandis* (COOKSON) DETTMANN, *Araucariacites australis* COOKSON (*), *A. sp.* (*), *Callialasporites dampieri* (BALME) DEV (*), *C. triangularis* (LEVET-CARETTE) REYRE, *C. aff. triangularis*, *C. trilobatus* (BALME) DEV (*), *C. turbatus* (BALME) SCHULZ, *Cedripites sp.* (*), *Cerebropollenites mesozoicus* (COUPER) NILSSON (*), *Classopollis sp.* (*), *Cycadopites sp.* (*), *Dicheiopollis sp. A* (in COIMBRA et al. 2002); *Equisetosporites sp.* (*), *Eucomiidites spp.* (*), *Exesipollenites tumulus* BALME (*), *Inaperturopollenites dettmanniae* POCOCK, *Monosulcites sp.* (*), *Parvisaccites sp.* (*), *Perinopollenites elatoides* COUPER, *Podocarpidites multesimus* (BOLKHOVITINA) POCOCK, *P. ornatus* POCOCK, *P. sp.* (*), *Sergipea spp.* (*), *Vitreisporites contectus* DE JERSEY, *V. jurassicus* POCOCK, and *V. pallidus* (REISSENGER) NILSSON (*).

The presence of *Ischyosporites crateris*, *I. punctatus*, *I. scaberis*, *Januasporites spinosireticulatus*, *Retitriletes clavatoide*, *Retitriletes tenuis*, etc. indicates a Jurassic affinity. The taxa marked by asterisks (*) are known also from Cretaceous strata of Brazil. A preliminary study, including Cretaceous well sections, was performed by ARAI et al. (2001). *Laevigatosporites sp.* is a long-ranging taxon and is also reported from Palaeozoic and Cenozoic strata of Brazil and India. It has no stratigraphic significance.

The palynofloristic spectrum indicates

a humid tropical palaeoclimate during the deposition of the Missão Velha and Brejo Santo formations. The palynoflora is similar to that of the San Cayetano formation (Jurassic of Cuba) (BLANCO-GONZÁLEZ 1998; DUEÑAS-JIMÉNEZ et al. 2003), suggesting that these localities belonged to same palaeoclimatic zone. The palaeoclimate at the time of deposition of these formations was more humid than is interpreted traditionally for Brazilian Jurassic and earliest Cretaceous times (e.g., FREITAS et al. 2008; PIRES & GUERRA-SOMMER 2009). The relatively humid climate is suggested also by the scarcity of the ephedroid pollen and *Classopollis* grains.

References

- ARAI, M., COIMBRA, J.C. & SILVA-TELLES JR, A.C. 2001. Síntese Bioestratigráfica da Bacia do Araripe (Nordeste do Brasil). In: Simpósio sobre a Bacia a Araripe et Bacias interiores do nordeste, 2., 1997, Crato. Atas... Crato: DNPM-URCA-SBP: 109–117, 122–124 (Coleção Chapada do Araripe, No. 1).
- BLANCO-GONZÁLEZ, M. 1998. Palinología del Jurásico Superior en Cuba Central. In: Geología y Minería'98 Memorias 2: 271-273, Centro Nacional de Información Geológica, La Habana.
- COIMBRA, J.C., ARAI, M. & CARREÑO, A.L. 2002. Biostratigraphy of Lower Cretaceous microfossils from the Araripe Basin, northeastern Brazil. – *Geobios* 35: 687–698.
- DUEÑAS-JIMÉNEZ, H., LINARES-CALA, E. & GARCÍA-SÁNCHEZ, R. 2003. Palinomorfos em las rocas de La Formación SanCayetano, Pinar Del Rio, Cuba. – *Minería y Geología* 19: 59–70.
- FREITAS, F.I. DE, HESSEL, M.H. & NOGUEIRA NETO, J. DE A. 2008. Troncos fósseis da Formação Missão Velha na porção leste da Bacia do Araripe, Ceará. – *Revista de Geologia* 21: 193–206.
- PIRES, E. F. & GUERRA-SOMMER, M. 2009. Plant-arthropod interaction in the Early Cretaceous (Berriasian) of the Araripe Basin, Brazil. – *Journal of South American Earth Sciences* 27: 50–59.

Correlation of the Boreal Jurassic–Cretaceous boundary strata by means of belemnites

OXANA S. DZYUBA

Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of RAS, Acad. Koptug av., 3, Novosibirsk 630090, Russia; E-mail: dzyubaos@ipgg.sbras.ru

Belemnites (mainly *Cylindroteuthidae*) are well known from the Boreal Jurassic–Cretaceous (J–K) boundary sediments, which are widely distributed in northern Eurasia, northern North America and the Arctic islands. *Cylindroteuthid* belemnites were also recorded from J–K boundary sections containing mixed Boreal and Tethyan faunas, being found in Northern California, Western Canada, Russian Platform; recently they have been reported from Central Japan (SANO et al. 2012). These belemnites can abound where such biostratigraphically important macrofossils as ammonites and buchias are absent or rare. Therefore, belemnite zonal scales based on *cylindroteuthids* have been developed intensely over the last few decades.

The J–K boundary in the Boreal regions is not characterised by a sharp change in belemnite assemblages (SAKS & NALNYAEVA 1973; DZYUBA 2013). Many genera and species occurring in the Jurassic pass into the Lower Cretaceous. Taxonomic composition and especially the quantitative relationships of certain genera in belemnite communities were not identical for different biogeographic realms during the terminal Jurassic–initial Cretaceous. Thus, in the Boreal–Atlantic Realm the representatives of the genera *Acroteuthis* and *Liobelus* have become dominant in belemnite communities since the latest Middle Volgian. In the Arctic Realm (including the Boreal–Pacific Province) these genera together with *Boreioteuthis* have become dominant since the latest Ryazanian. Of course, the geographic differentiation of *cylindroteuthids* complicates the construction of a belemnite-based Panboreal correlation scheme for the J–K boundary interval, but this task is not absolutely unsolvable.

The most detailed belemnite zonation of the Volgian and Ryazanian stages has been suggested for Siberian sections (SHENFIL' 1992, 1995; DZYUBA 2004, 2012, 2013). The

East Siberian high-resolution succession of belemnite zones and beds is recorded in the West Siberian sections almost completely, excluding the Tehamaensis Zone. In the eastern foothills of the Northern and Subpolar Urals (northwestern margin of Western Siberia) within the Volgian and Ryazanian stages, the following East Siberian biostratons have been documented: Mamillaris Zone, Napaensis Zone, Knoxvillensis Zone, Russiensis Zone, and Curvulus Zone, Explanata Beds, and Gustomesovi and Porrectiformis Beds (DZYUBA 2004, 2012, 2013). In addition, the local Explorata Beds and Compactus Beds have been established here. Some Siberian zones (in the beds' rank) and beds are traceable to the Pechora Basin (Mamillaris Beds, Explorata Beds, and Curvulus Beds), northwestern Europe (Explanata Beds) and northern California (Tehamaensis Beds, and Knoxvillensis Beds).

Cylindroteuthid belemnite zonations of the J–K boundary strata were also suggested for northwestern Europe (PINCKNEY & RAWSON 1974; MUTTERLOSE 1990) and East European (Russian) Platform (MESEZHNIKOV 1993a, b; MITTA et al. 2012). Species abundance and stratigraphic distribution of some European index species are topics of discussion (DZYUBA 2004) that complicates the use of the existing northwest European schemes. Therefore, the author is working on the development of new belemnite zonal schemes for the European territories. As the investigation showed, in addition to Lateralis Beds, almost all biostratons determined in the J–K boundary interval of the European Russia can be traced also to northwestern Europe, namely the Magnificus Beds, Volgensis Beds, Russiensis and Mosquensis Beds.

In terms of biostratigraphic units, the *cylindroteuthid* belemnite zones are mainly interval zones, or assemblage zones and encompass from 1–2 ammonite zones to a

substage or slightly more. Making a phylozone scale is now possible, but less necessary, because belemnites in individual lineages do not evolve rapidly enough to ensure a detailed subdivision of the sediments, whereas using transformations in different lineages makes it possible.

This is a contribution to the RAS Programs 23 and 28 and the RFBR project 12-05-00453.

References

- DZYUBA, O.S. 2004. Belemnites (Cylindroteuthidae) and biostratigraphy of the Middle and Upper Jurassic of Siberia. Novosibirsk, Publishing House of SB RAS, Department "GEO". [in Russian]
- DZYUBA, O.S. 2012. Belemnites and biostratigraphy of the Jurassic–Cretaceous boundary deposits of northern East Siberia: new data on the Nordvik Peninsula. – *Stratigraphy and Geological Correlation* 20: 53–72.
- DZYUBA, O.S. 2013. Belemnites in the Jurassic–Cretaceous boundary interval of the Maurynya and Yatriya River sections, Western Siberia: biostratigraphic significance and dynamics of taxonomic diversity. – *Stratigraphy and Geological Correlation* 21: 189–214.
- MESEZHNIKOV, M.S. (ed.) 1993a. Unified stratigraphic scheme of Jurassic deposits of the Russian Platform. St. Petersburg, VNIGRI. [in Russian]
- MESEZHNIKOV, M.S. (ed.) 1993b. Unified stratigraphic scheme of Lower Cretaceous deposits of the East European Platform. St. Petersburg, VNIGRI. [in Russian]
- MITTA, V.V., ALEKSEEV, A.S. & SHIK, S.M. (eds.). 2012. Unified regional stratigraphic scheme of the Jurassic of East European Platform. Explanatory note. Moscow, PIN RAS–VNIGNI. [in Russian]
- MUTTERLOSE, J. 1990. A belemnites scale for the Lower Cretaceous. – *Cretaceous Research* 11: 1–15.
- PINCKNEY, G. & RAWSON, P.F. 1974. *Acroteuthis* assemblages in the Upper Jurassic and Lower Cretaceous of northwest Europe. – *Newsletters on Stratigraphy* 3: 193–204.
- SAKS, V.N. & NALNYAEVA, T.I. 1973. Belemnite assemblages from the Jurassic–Cretaceous boundary beds in the Boreal Realm. In: CASEY, R. & RAWSON, P.F. (eds.), *The Boreal Lower Cretaceous*. – *Geological Journal Special Issue* 5: 393–400.
- SANO, S., DZYUBA, O.S., IBA, Y., et al. 2012. An earliest Cretaceous belemnite from the Mitarai Formation in the Shokawa area, Central Japan. In: *The 2012 Annual Meeting of the Palaeontological Society of Japan* (June 29–July 1, 2012, Nagoya, Aichi Prefecture), Abstracts with Programs: 63, Nagoya. [in Japanese]
- SHENFIL', O.V. 1992. Belemnites and stratigraphy of Neocomian deposits in the north of Central Siberia. In: *Geological history of the Arctic in the Mesozoic and Cenozoic*: 65–70. VNII Okeangeologiya, St. Petersburg. [in Russian]
- SHENFIL', O.V. 1995. Belemnite zonal scale of the Upper Jurassic sediments of the Anabar–Khatanga area (northern Middle Siberia). In: LEBEDEVA, N.K. & NIKITENKO, B.L. (eds.), *Geology and geochemistry of the sedimentary rock basins of Siberia*: 30–38, NITs OIGGM, Novosibirsk. [in Russian]

Bajocian ammonoids and depositional events of the Arequipa Basin (southern Peru): evidence from Rio Pumani area (Ayacucho)

SIXTO R. FERNANDEZ-LOPEZ¹ *, VICTOR C. CAILLAUX², EDWIN G. SALDIVAR² & CESAR C. BUDIEL²

¹Departamento Paleontología, Facultad Ciencias Geológicas, calle José Antonio Novais,2, Universidad Complutense de Madrid, 28040-Madrid, Spain; E-mail: sixto@ucm.es

²Instituto Geológico Minero y Metalúrgico (INGEMMET), Av. Canadá 1470, San Borja, Lima, Peru; E-mail: vcarlotto@ingemmet.gob.pe, geo_egiraldo@hotmail.com; cchacaltana@ingemmet.gob.pe

*Corresponding author

Bajocian ammonoids are scarce in the central Andes, although marine deposits are well developed in the southern areas of Peru. The Rio Pumani area, 300 km SE of Lima, displays an unusual Bajocian succession mainly because its high biostratigraphic completeness within the southern Peruvian outcrops (WESTERMANN et al. 1980; RICCARDI et al. 1992).

During the Early Jurassic, the Pucara Basin in the North and the Arequipa Basin in the South were separated from each other by structural highs with distinctive depositional areas. The Totos-Paras structural high, meridionally delimited by the Abancay-Andahuaylas-Totos fault system (AAT in Fig. 1A), was a prolongation of the Cusco-Puno High, defined by the Cusco-Lagunillas-Mañazo and the Urcos-Sicuani-Ayaviri fault systems (CLM and USA in Fig. 1A, CARLOTTO et al. 2011), due to sinistral transtensive tectonics.

In the septentrional area of Totos and Paras, the Chunumayo Formation is composed of Toarcian-Bajocian marine deposits, 200-500 m

thick, and overlies volcanic rocks of the Permo-Triassic Mitu Group. Above the Chunumayo Formation, there are 300 m of the Yura Group (Middle-Upper Jurassic) corresponding to fluvial-deltaic deposits. Southward of the Arequipa Basin, these deposits reach thicknesses greater than 2000 m and developed in deeper depositional environments going from turbidites to slope and shelf deposits with the development of olistoliths.

In the area of the Rio Pumani and Quebrada Pucayacu, 17 km S of Totos, at the boundary between the Sarhua and Lucanamarca districts, grey and brown limestones with microfilaments (*Bositra* sp.) of the Socosani Formation represent Aalenian and Bajocian open marine platform and ridge deposits, equivalent to the Chunumayo Formation. However, they display microbial laminae and centimetric, domal structures in the uppermost levels, indicative of sedimentary starvation (Fig. 1B). Above, two well differentiated lutaceous stratigraphic intervals surpass 700 m in thickness. The lower

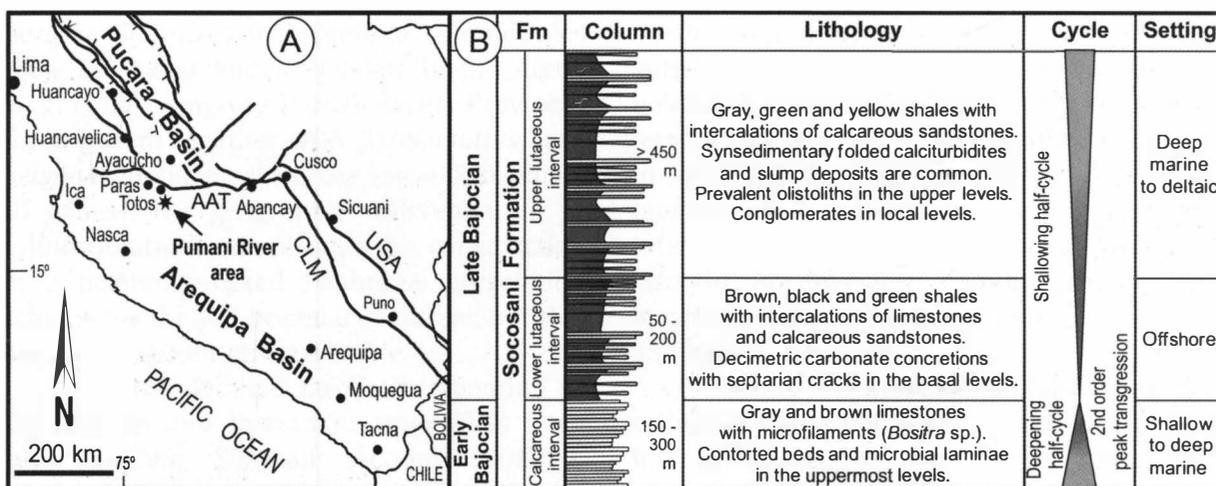


Fig. 1. Location, age, column, lithology, depositional cycle, and setting of the Rio Pumani section.

lutaceous interval consists of brown, black and green shales with intercalations of limestones and calcareous sandstones. The upper lutaceous interval is composed of grey and green shales with intercalations of calcareous sandstones, where isolated blocks of lowermost Upper Bajocian marine deposits, tens of metres in thickness, are surrounded by at least middle Upper Bajocian marine deposits. These blocks, observable for a distance of several kilometres and interpreted as olistoliths, correspond to Late Bajocian and Bathonian deep-water slope and basal deposits. Associated with extensive and thick beds, locally arkosic sandstones with rounded detrital quartz grains and angular pebbles of Jurassic limestones occur, identified as olistostromes. These metric olistostromes and the decametric olistoliths composed of, and included within, deep-water slope and basal deposits probably are the result of synsedimentary regional tectonics.

Bajocian ammonites are scarce in the calcareous interval, but Upper Bajocian ammonites are locally common in the two lutaceous intervals. The uppermost Aalenian Malarguensis Biozone and lowermost Bajocian levels have been identified by the occurrence of *Puchenquia* (*Gerthiceras*) cf. *mendoza* WESTERMANN [Macroconch] and *Tmetoceras* cf. *flexicostatum* WESTERMANN [M] in the lower part of the calcareous interval. At the upper levels of this lithologic subdivision, two fragmentary specimens of *Dorsetensia* sp. [M] allow to recognize the Lower Bajocian Humphriesianum Zone. In the lutaceous intervals, several successive ammonite assemblages characterize the Upper Bajocian Magnum Biozone. The identified taxa indicate a time span from the latest Niortense Zone to the Garantiana Zone. The uppermost Niortense Zone is characterized by the occurrence of *Megasphaeroceras* cf. *magnum* RICCARDI & WESTERMANN [M & m], *Spiroceras orbigny* (BAUGIER & SAUZE) and *Leptosphinctes* spp. [M & m]. The Garantiana Zone is recognized in the upper lutaceous interval with *Megasphaeroceras* cf. *magnum*, *Spiroceras orbigny*, *S. cf. annulatum* (DESHAYES), and *Vermisphinctes* spp. [m & M]. The finding of a single *Iniskinites* suggests the first Bathonian deposits including the uppermost olistoliths at the top of the upper lutaceous interval.

Late Bajocian Eurycephalitinae are

dominant, and *Megasphaeroceras* [M & m] is the most common ammonoid genus (45%) with a species endemic to the southeastern Pacific borderlands. This monospecific group is recorded by shells with unimodal size-frequency distribution of positive asymmetry, dominant juveniles, and well displayed dimorphism. Also locally common are Leptosphinctinae (26%) and Spiroceratinae (15%). *Leptosphinctes* [M] – *Cleistosphinctes* [m] display juvenile and pre-adult individuals in the lower lutaceous interval, whereas *Vermisphinctes* [m] – *Prorsisphinctes* [M] are mainly represented by pre-adult individuals within the upper lutaceous interval. *Spiroceras orbigny* is represented by dominant juveniles in the lower lutaceous interval, but *S. annulatum* is very scarce and restricted to the upper lutaceous interval. Cadomitinae (6%), Lissoceratinae (4%), Phylloceratinae (2%), Oppeliinae (1%), and Strigoceratinae (1%) are very scarce. Consequently, most of these Bajocian ammonoid genera correspond to adult individuals and were the result of regional nekrokinosis and/or local immigration, without evidence of sustained colonization, from more open marine or exotic oceanic areas. In contrast, Late Bajocian, monospecific populations dominated by juvenile individuals and indicative of sustained-colonization bioevents by eudemic taxa (i.e., in their breeding area) were abundant in the case of *Megasphaeroceras* [M & m] and *Spiroceras* [M & m]. These populations inhabiting the Arequipa Basin belong to species endemic to the Andean Province of the Eastern Pacific Subrealm and to pandemic species of the Tethys-Panthalassa Realm, respectively.

In conclusion, these Late Bajocian bioevents of regional appearance of immigrant ammonite taxa and even sustained colonization should be associated with an episode of maximum deepening, maximum relative sea-level rise, and highest oceanic accessibility of a second-order, transgressive–regressive facies cycle in the Arequipa Basin during the Upper Bajocian Niortense Zone, although disturbed by regional tectonics.

The research was supported by the scientific projects CGL2011-23947 (MICINN) and GR-6 INGEMMET.

References

CARLOTTO, V., RODRÍGUEZ, R., ACOSTA, H., CÁRDENAS, J. & JAILLARD, E. 2009. Alto estructural Totos-Paras

(Ayacucho): límite Paleogeográfico en la evolución mesozoica de las cuencas Pucará (Triásico Superior-Liásico) y Arequipa (Jurásico-Cretácico). – Sociedad Geológica del Perú 7: 1–46.

RICCARDI, A.C., GULISANO, C.A., MOJICA, J., PALACIOS, O. & SCHUBERT, C. 1992. Western South America and

Antartica. In: WESTERMANN, G.E.G. (ed.), *The Jurassic of the Circum Pacific*: 122–161, Cambridge University Press, London.

WESTERMANN, G.E.G., RICCARDI, A., PALACIOS, O. & RANGEL, C. 1980. Jurásico medio en el Perú. – *Boletín Instituto Geológico Minero y Metalúrgico* 9: 1–47.

The ecological role of the Jurassic seafloor: benthic ecological functioning during the Kimmeridgian OAE

CHRIS L. J. FRID¹ * & BRYONY A. CASWELL²

¹*School of Environmental Sciences, University of Liverpool, Liverpool L69 3GP, UK; E-mail: c.l.j.frid@liv.ac.uk*

²*School of Environmental Sciences, University of Liverpool, Liverpool L69 3GP, UK; E-mail: b.a.caswell@liv.ac.uk*

**Corresponding author*

The Late Jurassic Kimmeridge Clay Formation (KCF; ~148–155 Ma) was deposited in a shallow semi-restricted basin, the Wessex Basin, in the UK. The KCF represents the longest period (~8 million years; Weedon et al. 2004) of organic carbon accumulation during the Mesozoic (TYSON 2004), and it was deposited under fluctuating levels of oxygenation that ranged from dysoxic to anoxic (PEARCE et al. 2010). The presence of isorenieratane biomarkers (breakdown products of photosynthetic sulphur reducing bacteria) in the KCF indicates that at times the water column was euxinic (SINNINGHE DAMSTÉ et al. 2001).

At present day oceanic hypoxia is rapidly increasing globally due to anthropogenic activities such as climate change and eutrophication. We know that deoxygenation has profound effects on the marine biota and potentially therefore also on the delivery of ecological functions in benthic systems. The ecological functions that could be impacted include nutrient regeneration, carbon sequestration, and provision of food to higher trophic levels. However, we know little about how marine ecosystems will respond to deoxygenation over long timescales or the consequences it will have for ecological functioning. Periods of ancient environmental change provide an opportunity to learn lessons and apply them to the current environmental challenges that we face.

The areal extent of anoxia during the Kimmeridgian of the UK was greater than today but less than during the oceanic anoxic events of the past (PEARCE et al. 2010) and thus represents regional hypoxia–anoxia. Therefore the KCF is a more appropriate analogue for present-day hypoxia in eutrophic shelf seas and

marginal basins than the more extreme periods of global oceanic anoxia. This study uses a contemporary multi-disciplinary approach Biological Traits Analysis (BTA) to explore the impacts of fluctuating regional hypoxia on the composition and functioning of 21 benthic palaeocommunities from the KCF in the Wessex Basin, Dorset, UK (data from WIGNALL 1990). We could not find any prior application of BTA with palaeontological data. However, it is particularly well suited to palaeoecological data as it can be used to compare spatially and temporally separated communities that may significantly differ in terms of their species composition.

The KCF palaeocommunities contained gastropods, brachiopods, scaphopods, bryozoans, serpulids, hydroids, and crustaceans, but were dominated by bivalves. Significant changes in species composition are shown within periods of less intense hypoxia (CASWELL & FRID 2013), but during these periods trait composition did not significantly differ implying conservation of ecological function. However, significant changes in palaeoecological functioning occurred between periods of extremely different palaeo-redox states. Proportionally more surface living or shallow burrowing species with traits suggestive of opportunists occurred during periods of low oxygen availability. The hypoxic communities had a higher relative abundance of organisms with thinner skeletons (<0.5 mm) composed of less soluble forms of calcite that may be linked to acidity. These changes observed from the KCF are similar to those for modern benthos exposed to hypoxia (e.g. WU 2002).

The functional changes that occurred during ancient hypoxic events can be used to infer the

magnitude, thresholds, and rates of long-term functional change in modern communities. Results from this study suggest that during deoxygenation benthic functioning will initially be maintained, but will collapse once thresholds are reached. This is consistent with the patterns emerging for contemporary systems where functional collapse is associated with hysteresis and threshold effects (CONLEY et al. 2009).

References

- CASWELL, B.A. & FRID, C.L.J. 2013. Learning from the past: functional ecology of marine benthos during eight million years of aperiodic hypoxia, lessons from the Late Jurassic. – *Oikos*, in press.
- CONLEY, D.J. et al. 2009. Ecosystem thresholds with hypoxia. – *Hydrobiologia* 629: 2129.
- PEARCE, C.R. et al. 2010. Seawater redox variations during the deposition of the Kimmeridge Clay Formation, United Kingdom (Upper Jurassic): Evidence from molybdenum isotopes and trace metal ratios. – *Paleoceanography* 25: 1–15.
- SAELEN, G. et al. 2000. Contrasting watermass conditions during deposition of the Whitby Mudstone (Lower Jurassic) and Kimmeridge Clay (Upper Jurassic) formations, UK. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 163: 163–196.
- SINNINGHE DAMSTÉ J.S. et al. 2001. Isorenieratene derivatives in sediments: Possible controls on their distribution. – *Geochimica Cosmochimica Acta* 65: 1557–1571.
- TYSON, R.V. 2004. Variation in marine total organic carbon through the type Kimmeridge Clay Formation (Late Jurassic), Dorset, UK. – *Journal of the Geological Society, London* 161: 667–673.
- WEEDON, G.P. et al. 2004. Cyclostratigraphy, orbital tuning and inferred productivity for the type Kimmeridge Clay (Late Jurassic), Southern England. – *Journal of the Geological Society, London* 161: 655–666.
- WIGNALL, P.B. 1990. Benthic palaeoecology of the Late Jurassic Kimmeridge Clay of England. – *Special Papers in Palaeontology* 43: 1–74.
- WU, R.S. 2002. Hypoxia: from molecular responses to ecosystem responses. – *Marine Pollution Bulletin* 45: 3545.

Facies patterns and environmental evolution of the Amu Darya Basin and associated basins in central Asia during the Jurassic

FRANZ T. FÜRSICH¹ *, MARKUS WILMSEN² & HERMANN MUNSCH³

¹*FG Paläoumwelt, GeoZentrum Nordbayern, FAU Erlangen-Nürnberg, Loewenichstrasse 28, D-91054 Erlangen, Germany; E-mail: franz.fuersich@fau.de*

²*Senckenberg Naturhistorische Sammlungen Dresden, Königsbrücker Landstraße 159, 01109 Dresden, Germany*

³*Total E&P, 2 place de la coupole, 92078 Paris la Défense cedex, France*

**Corresponding author*

In the Amu Darya Basin of southern Uzbekistan (Kugitang Mts., Ghissar Mts.), Mesozoic sedimentation started in the Early Jurassic. Late Palaeozoic basement rocks (granites, metamorphics) are covered by paleosol and followed by conglomerates and coarse-grained sandstones of braided river origin. General fining of the sediments up-section is related to levelling of the topography and the development of an extensive peneplain. Due to the warm, humid climate, meandering rivers and lakes prevailed, the latter characterized by organic-rich muds and coal layers. This 400-460 m thick succession is late Early Jurassic to Early Bajocian in age. Subsequently, the sea transgressed across the coastal plain and until the Early Bathonian storm-influenced siliciclastic shelf sedimentation prevailed. Sedimentation rate decreased up-section and culminated in a highly fossiliferous "condensed" unit of Early Bathonian age. This deepening trend continued in the Early Callovian with a 200-m-thick marl unit which represents offshore, low-energy shelf conditions. During the Callovian–Oxfordian these strata grade into a several 100-m-thick unit of thick-bedded carbonates of a generally low-energy carbonate ramp and are replaced in the Kimmeridgian up to the end of the Jurassic by evaporites.

This sedimentary succession shows some similarities with those of the Alborz Mts and Koppeh Dagh of northern Iran (WILMSEN et al. 2009): In the Alborz Mts, an overfilled foreland basin represented by non-marine siliciclastic sediments (alluvial, fluvial and lacustrine systems with widespread coal swamps) developed during the Early Jurassic

and was followed by a rapidly subsiding rift basin filled with marine shales in the Aalenian. Uplift in connection with the Early Bajocian Mid-Cimmerian tectonic event was followed by a conspicuous transgression starting in the Late Bajocian. Concomitantly, sedimentation changed from a siliciclastic setting to a mixed carbonate-siliciclastic setting and finally to a carbonate-dominated system in the Callovian to Tithonian. The latter consisted of large carbonate platforms (Lar Formation) and associated slope and basinal sediments (Dalichai Formation). In the Koppeh Dagh, sedimentation started with the marine Kashafrud Formation in the Late Bajocian, which accumulated in a rapidly subsiding rift basin. Similar to the situation in the Alborz region, a carbonate system (Chaman Bid Formation, Mozduran Formation) became established from the Callovian onwards.

In SW Kyrgyzstan, in contrast, non-marine conditions persisted throughout the Jurassic characterized by rapid subsidence and high rates of sedimentation. Prevailing environments were floodplains swamps and lakes.

Sedimentation in all these basins was controlled by extensional tectonics up to the Middle Jurassic. In addition, climate also exerted a major control: Humid conditions in the Early Jurassic changed to increasingly arid conditions towards the end of the Jurassic and replaced siliciclastic sediments by carbonates and, finally, by evaporites.

References

- WILMSEN, M., FÜRSICH, F.T., SEYED-EMAMI, K., MAJIDIFARD, M.R. & TAHERI, J. 2009. The Cimmerian orogeny in northern Iran: tectono-stratigraphic evidence from the foreland. – *Terra Nova* 21: 211–218.

Palaeobiogeography and evolutionary trends in the Oxfordian subfamily Prososphinctinae GŁOWNIAK, 2012 (Ammonoidea, Perisphinctidae)

EWA GŁOWNIAK

Faculty of Geology, University of Warsaw, ul. Żwirki i Wigury 93, 02-089 Warsaw, Poland; E-mail: eglownia@uw.edu.pl

The phenomenon of palaeobiogeographic differentiation of Late Jurassic ammonite faunas has been noticed as early as in the 19th century (ZITTEL 1870; NEUMAYR 1873) and soon has become the basis for the modern concept of provinces (e.g., WESTERMANN 2000; PAGE 2008). Two main ammonite domains (provinces) have been distinguished in the Jurassic marine basins in Europe: the Mediterranean Province with the Submediterranean (Sub) Province, and the Boreal Province with the Subboreal (Sub) Province. While much attention has been paid to the Late Oxfordian and Early Kimmeridgian ammonite biogeography due to its impact on the inter-provincial biostratigraphic correlations (e.g., MATYJA et al. 2006), we know still relatively little about the early stages of palaeobiogeographic ammonite differentiation in the Early Oxfordian. Our studies are intended to supplement this gap. The research is aimed at the Submediterranean ammonites broadly assigned to the Oxfordian perisphinctids, with special attention to the Early Oxfordian genus *Prososphinctes* SCHINDEWOLF. The purpose of this study is to characterise the stratigraphic and palaeobiogeographic significance of the recently erected subfamily Prososphinctinae GŁOWNIAK, 2012, based on *Prososphinctes*. The subfamily embraces a lineage of some Early to early Late Oxfordian species. Taxonomically, they are assigned to the following successive genera: *Prososphinctes* – *Liosphinctes*, *Platysphinctes* – and *Larcheria*, plus a few less known taxa whose usefulness for taxonomy of Oxfordian ammonites is disputable (e.g., GYGI 1998; GŁOWNIAK & WIERZBOWSKI 2007). The distinctive character of this lineage lies in the discontinuous palaeobiogeographic spread of its species and their recurrent stratigraphic ranges, with a tendency to form bioevent-horizons (GŁOWNIAK 2000, 2006a, b, 2012). The lineage of Prososphinctinae persisted in seas of southern Europe adjoining the northern

margin of the Tethys Ocean from Early to early Late Oxfordian. Later it disappeared. Offshoots of this lineage should be sought outside the area of Submediterranean Europe (see e.g., KRISHNA et al. 1995). We propose a new interpretation of the evolutionary diversification of the Oxfordian perisphinctid stock with emphasis on the Prososphinctinae lineage. Based on some new biostratigraphic and taxonomic evidence (e.g. GŁOWNIAK et al. 2010), and taking into account some older contributions (WIERZBOWSKI 1976; MELÉNDEZ et al. 1988; OLÓRIZ et al. 2008) we regard that the Prososphinctinae lineage splits in the Middle Oxfordian into two branches: The first is the Subboreal branch, which gave rise to the species of *Decipia* ARKELL and its successors in the lineage of the family Aulacostephanidae SPATH, in the areas of northern Europe. The second is the Mediterranean-Submediterranean branch which, for example, gave rise to the genus *Vinalesphinctes* and its allies in the perisphinctid subfamily Vinalesphinctinae MELÉNDEZ & MYCZYŃSKI, in Cuba. Both new lineages, Aulacostephanidae and Vinalesphinctinae, emerged in the late Middle Oxfordian. Stratigraphic horizons of their appearance roughly correlate with, but are slightly younger than, the level of early Middle Oxfordian maximum of sea-level rise (e.g., WIERZBOWSKI 2002). The latter is marked by occurrence of the *Platysphinctes* bioevent-horizon as evidenced in the neritic carbonate facies of southern Poland (GŁOWNIAK 2000, 2006a). This, and also a lower bioevent-horizon (*Prososphinctes* Acme Horizon in the Lower Oxfordian of southern Poland) point to the species of the subfamily Prososphinctinae as a useful potential tool for multi-proxy marine palaeoenvironmental studies.

References

- GŁOWNIAK, E. 2000. The *Platysphinctes* immigration event in the Middle Oxfordian of the Polish Jura Chain (Central Poland). – *Acta Geologica Polonica* 50:

- 143–160.
- GŁOWNIAK, E. 2006a. The *Platysphinctes* immigration event: biostratigraphic and paleobiogeographic implications for the Middle Oxfordian (Late Jurassic) seas of central Europe (NW Germany and Poland). – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 241: 155–201.
- GŁOWNIAK, E. 2006b. The correlation of the zonal schemes at the late Middle to early Late Oxfordian boundary (Jurassic) in the Submediterranean Province: Poland and Switzerland. – Acta Geologica Polonica 56: 33–50.
- GŁOWNIAK, E. 2012. The perisphinctid genus *Prososphinctes* SCHINDEWOLF (Ammonoidea, subfamily Prososphinctinae nov.): an indicator of palaeoecological changes in the Early Oxfordian Submediterranean sea of southern Poland. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 264: 117–179.
- GŁOWNIAK, E. & WIERZBOWSKI, A. 2007. Taxonomical revision of the perisphinctid ammonites of the Upper Jurassic (Plicatilis to Planula zones) described by Józef Siemiradzki (1891) from the Kraków Upland. – Volumina Jurassica 5: 27–137.
- GŁOWNIAK, E., KISELEV, D.N., ROGOV, M., WIERZBOWSKI, A. & WRIGHT, J.K. 2010. The Middle Oxfordian to lowermost Kimmeridgian ammonite succession at Mikhalenino (Kostroma District) of Russian Platform, and its stratigraphical and palaeobiogeographical importance. – Volumina Jurassica 8: 5–48.
- GYGI, R. 1998. Taxonomy of perisphinctid ammonites of the Early Oxfordian (Late Jurassic) from near Herznach, Canton Aargau, Switzerland. – Palaeontographica A 251: 1–37.
- KRISHNA, J., MELÉNDEZ, G., PANDEY, B. & PATHAK, D.B. 1995. Characterisation of the ammonite genus *Larcheria* (Middle Oxfordian) in Kachchh (India): biostratigraphy and palaeobiogeographic evaluation in the context of Tethyan occurrences. – Comptes Rendus de l'Académie des Sciences de Paris, sér. 2a, 321: 1187–1193.
- MATYJA, B.A., WIERZBOWSKI, A. & WRIGHT, J.K. 2006. The Sub-Boreal/Boreal ammonite succession at the Oxfordian/Kimmeridgian boundary at Flodigarry, Staffin Bay (Isle of Skye), Scotland. – Transactions of the Royal Society of Edinburgh, Earth Sciences 96: 387–405.
- MELÉNDEZ, G., SEQUEIROS, L., BROCHWICZ-LEWIŃSKI, W., MYCZYŃSKI, R. & CHONG, G. 1988. Paleobiogeographic relationship between Oxfordian ammonite faunas from the Mediterranean, Caribbean, and Andean provinces. In: WIEDMANN, J. & KULLMANN, J. (eds.), Cephalopods Present and Past. 425–436, Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
- NEUMAYR, M. 1873. Die Fauna der Schichten mit *Aspidoceras acanthicum*. – Abhandlungen der kaiserlich-königlichen Geologischen Reichsanstalt 5: 141–257
- OLÓRIZ, F., VILLASEÑOR, A.B. & LÓPEZ-PALOMINO, I. 2008. Middle Oxfordian ammonite biostratigraphy of the Lower Santiago Formation at Tamán, San Luis Potosí, Mexico, with notes on Mexico-Caribbean ochetoceratins. – Revista Mexicana de Ciencias Geológicas 25: 261–283.
- PAGE, K.N. 2008. The evolution and geography of Jurassic ammonoids. – Proceedings of the Geologist's Association 119: 35–57.
- WESTERMANN, G.E.G. 2000. Marine faunal realms of the Mesozoic: review and revision under the new guidelines for biogeographic classification and nomenclature. – Palaeogeography, Palaeoclimatology, Palaeoecology 163: 49–68.
- WIERZBOWSKI, A. 1976. Oxfordian ammonites of the Pinar del Río province (western Cuba), their revision and stratigraphical significance. – Acta Geologica Polonica 26: 137–260.
- WIERZBOWSKI, H. JR. 2002. Detailed oxygen and isotope stratigraphy of the Oxfordian in Central Poland. – Geologische Rundschau 91: 304–314.
- ZITTEL, K.A. 1870. Die Fauna der älteren Cephalopodenführenden Tithonbildungen. – Palaeontographica, Supplement 2: i–vii, 1–373.

Jurassic geology and biostratigraphy of the Early Callovian in the Kanev district area (Cherkassy region, Ukraine)

DENIS GULYAEV¹ *, ALEXEI IPPOLITOV² & DMITRY KISELEV³

¹Interdepartmental Stratigraphic Committee (ISC) of Russia, 25-7 Chekhov St., 150054 Yaroslavl, Russia; E-mail: dgulyaev@rambler.ru

²Geological Institute of Russian Academy of Sciences, 7 Pyzhevski Lane, 119017 Moscow, Russia; E-mail: ippolitov.ap@gmail.com

³Yaroslavl State Pedagogical University, Respublikanskaya st., 150000 Yaroslavl, Russia; E-mail: dnkiselev@mail.ru

*Corresponding author

The Jurassic deposits of the Kanev district area (Fig. 1) are known since the first half of the 19th century, but yet studied poorly. Biostratigraphic schemes, available for the area, are still far from satisfying considering the modern level of knowledge in ammonite biostratigraphy with its detailed infrazonal subdivisions, and contains several inconsistencies. However, Jurassic rocks of the Kanev area potentially should provide a key to interregional correlations due to the location near the Pripyat strait connecting East European epicontinental seas with West European ones.

During the field seasons of 2011 and 2012 ten Jurassic sections, together forming the full succession, were studied by the authors in the Kanev area, accompanied with careful bed-by-bed sampling of ammonites and belemnites. Collection of studied fossils totally counts about 300 ammonites and over 750 belemnites. Some preliminary biostratigraphic results have already been published (KISELEV & IPPOLITOV 2011).

The Jurassic of the Kanev district is strongly tectonically disturbed and split into numerous tectonic slivers during the Pleistocene glacial epochs. The deposits are composed of a thick series of coastal terrigenous rocks (clays and sands) of mostly Bathonian age with no marine macrofossils, overlain by silt to clay deposits with abundant carbonate matter and numerous marine macrofossils of Early Callovian age. Contrary to old literature data, younger Jurassic rocks were not found in the district. Middle Jurassic strata are covered everywhere by sands of Cretaceous and Paleogene age, tectonically disturbed in the same way.

Biostratigraphic analysis of the ammonite record of the Lower Callovian succession allowed to distinguish the presence of 13 biohorizons (Fig. 2), 12 of which are known from NW Europe and European Russia, and one is new, with the index species transitional between typical *Paracadoceras elatmae* and *Cadochamoussetia tchernyschewi* and yet to be described. The sequence of biohorizons characterize four ammonite zones, the lower two of which (Elatmae and Subpatruus zones) are part of the regional succession of European Russia, and the upper two (Koenigi Zone including Gowerianus, Curtilobus, Galilaei subzones and Calloviense Zone, including Calloviense and Enodatum subzones) are part of the Euporean Subboreal zonal standard.

Early Callovian ammonite successions of

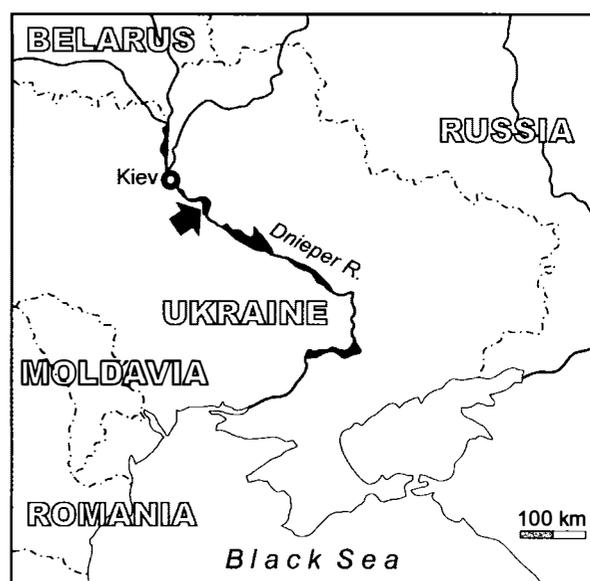


Fig. 1. Location of the Kanev district area (arrowed).

the Kanev district also have a good potential to provide further detailed infrazonal subdivision in the interval of the subgenus *Keplerites* (*Gowericeras*) range (biohorizons *K. toricelli* to *K. galilaeii*), as it was proposed for Central Europe and England by MÖNNIG (2010).

Belemnite data can also provide detailed subdivision of the succession, in particularly, in the interval of the Elatmae Zone to *K. gowerianus* biohorizon of the Gowerianus Zone, where the

solely boreal forms belonging to the family *Cylindroteuthidae* occur. In this interval 4 or 5 biohorizons can be established, and this is close to the resolution of the ammonite infrazonal scale. However, Boreal belemnite assemblages from this interval are almost not known in the adjacent regions (E and W Europe, European Russia) either due to the rarity of finds or to poor preservation. Thus, tracing this unit outside the Kanev area is a challenge for the future.

North-West Europe (modified after Callomon et al., 1988, 1989; Cariou & Hantzpergue (eds.), 1997; Cox, Sumbler, 2002; Dietze et al., 2007 etc.)				Eastern Europe				
ZONE	Sub-zone	England	Germany	European Russia (by Gulyaev, 2001, 2005; Gulyaev et al., 2002 etc.)		Kanev district area (present work)	Subzone	ZONE
		Biohorizons						
CALLOVIENSE	Enodatum	<i>Lacune</i>	<i>Lacune</i>	<i>C. enodatum aeeta</i>		<i>C. enodatum aeeta</i>	Enodatum	CALLOVIENSE
		<i>C. enodatum enodatum</i> [=enodat. γ] (' <i>S. anterior</i> ')	<i>C. enodatum enodatum</i> [=enodatum γ]	<i>C. enodatum enodatum</i>		<i>C. enodatum enodatum</i>		
		<i>C. enodatum planicerclus</i> [=enodat. β] (<i>A. difficilis</i>)	<i>C. enodatum planicerclus</i> [=enodatum β]	<i>C. enodatum planicerclus</i>	<i>A. difficilis</i>	<i>C. enodatum planicerclus</i>		
	Calloviense	<i>C. pagei</i> [=enodatum α]	<i>?Lacune</i>	<i>C. pagei</i>	<i>Pr. cracoviensis</i>	<i>C. pagei</i>	Calloviense	
		<i>S. micans</i>		<i>S. micans</i>		<i>S. micans</i>		
		<i>S. calloviense</i>	<i>S. calloviense</i>	<i>S. calloviense</i>		<i>S. calloviense</i>		
		<i>S. precalloviense</i> MS <i>K. 'copernici'</i> MS	<i>K. 'copernici'</i> MS					
KOENIGI	Galilaeii	<i>K. galilaeii</i>	<i>?Lacune</i>	<i>K. galilaeii</i>		<i>K. galilaeii</i>	Galilaeii	KOENIGI
	Curtiobus	<i>K. trichophorus</i>		<i>K. curtiiobus</i>		<i>K. curtiiobus</i>		
		<i>K. indigestus</i> (sensu Page) <i>Cad. tolype</i> ('gregarium' MS)	<i>O. subcostarius</i>					
		<i>K. curtiiobus</i> (sensu Page)	<i>M. macrocephalus</i>	<i>K. densicostatus</i>		<i>K. densicostatus</i>		
	Gowerianus	<i>K. gowerianus</i>	<i>M. megaloccephalus</i> β <i>M. megaloccephalus</i> α	<i>K. gowerianus</i>		<i>K. gowerianus</i>		
		<i>K. metorchus</i>						
HERVEYI	Kamptus	<i>K. toricelli</i>	<i>K. toricelli</i>	<i>Ch. croblyoides</i> (<i>K. toricelli</i>)		<i>Ch. croblyoides</i> (<i>K. toricelli</i>)	SUBPATRUUS	
		<i>M. polyptychus</i> (<i>M. kamptus</i> γ)	<i>?Lacune</i>	<i>C-ch. uzhovkensis</i>		<i>Lacune</i>		
		<i>M. kamptus</i> β	<i>M. kamptus</i>	<i>C-ch. subpatruus</i>				
		<i>M. kamptus</i> α (<i>M. herveyi</i>)	<i>Lacune</i>	<i>C-ch. surensis</i> II				
	Terebratus	<i>M. terebratus</i> γ	<i>M. terebratus</i>	<i>C-ch. surensis</i> I		<i>P. sp. nov.</i> (aff. <i>elatmae</i>)		
		<i>M. terebratus</i> β	<i>Lacune</i>	<i>C-ch. tschernyschewi</i>				
		<i>M. terebratus</i> α	<i>Lacune</i>	<i>?</i>				
	Kepleri	<i>M. verus</i>	<i>'Cad. suevicum</i> β' <i>'Cad. suevicum</i> α'	<i>P. elatmae</i>		<i>P. elatmae</i>	ELATMAE	
			<i>Cad. quenstedti</i>	<i>P. chvadukasyense</i> MS (<i>Cad. quenstedti</i>)		<i>Ammonites not found</i>		
		<i>K. kepleri</i> (<i>M. jacquoti</i>)	<i>K. kepleri</i> (<i>M. jacquoti</i>) <i>K. kepleri</i> II <i>K. kepleri</i> I	<i>M. jacquoti</i>	<i>P. primaevum</i> <i>P. poultoni</i>			

Fig. 2. Infrazonal ammonite scale for the Early Callovian of the Kanev district area (grey column) and its correlation with infrazonal scales for European Russia and NW Europe. Abbreviations: A. – *Anaplanulites*, C. – *Catasigaloceras*, Cad. – *Cadoceras*, Ch. – *Chamousetia*, C-ch. – *Cadochamousetia*, K. – *Keplerites*, M. – *Macrocephalites*, O. – *Oxycerites*, P. – *Paracadoceras*, Pr. – *Proplanulites*, S. – *Sigaloceras*.

The study was supported by RFBR grant №12-05-00380-a.

References

- CARIOU, E. & HANTZPERGUE, H. (eds.) 1997. Biostratigraphie du Jurassique ouest-européen et méditerranéen: zonations parallèles et distribution des invertébrés et microfossiles. – Bulletin des centres des recherches Elf, Exploration et Production, mémoire 17: 1–440.
- CALLOMON, J.H., DIETL, G. & PAGE, K.N. 1988. On the ammonite faunal horizons and standard zonations of the Lower Callovian Stage in Europe. – 2nd International Symposium on Jurassic Stratigraphy, Lisboa: 359–376.
- CALLOMON, J.H., DIETL, G. & NIEDERHOFER, H.-J. 1989. Die Ammonitenfaunen-Horizonte im Grenzbereich Bathonium/Callovium des Schwäbischen Juras und deren Korrelation mit W-Frankreich und England. – Stuttgarter Beiträge zur Naturkunde B 148: 1–13.
- COX, B.M. & SUMBLER, M.G. 2002. British Middle Jurassic Stratigraphy. – Geological Conservation Review 26: 508 p.
- DIETZE, V., SCHWEIGERT, G., CALLOMON, J.H., DIETL, G. & KAPITZKE, M. 2007. Der Mitteljura des Ipf-Gebiets (östliche Schwäbische Alb, Süddeutschland). Korrelation der süddeutschen Ammoniten-Faunenhorizonte vom Ober-Bajocium bis zum Unter-Callovium mit Südengland und Frankreich. – Zitteliana A47: 105–125.
- GULYAEV, D.B. 2001. Infrazonal ammonite scale for the Upper Bathonian–Lower Callovian of Central Russia. – Stratigraphy and Geological Correlation 9: 65–92.
- GULYAEV, D.B. 2005. Infrazonal subdivision of the Upper Bathonian and Lower Callovian of the East-European Platform by ammonites. Jurassic System of Russia: Problems of stratigraphy and paleogeography. First All-Russian meeting. – Scientific materials: 64–70. [in Russian]
- GULYAEV, D.B., KISELEV, D.N. & ROGOV, M.A. 2002. Biostratigraphy of the Upper Boreal Bathonian and Callovian of European Russia. – 6th Intern. Symposium on the Jurassic System, Mondello, September 16-19, 2002. Abstracts and Program: 81–82.
- KISELEV, D.N. & IPPOLITOV, A.P. 2011. New data on Callovian biostratigraphy of Kanev Dislocation area. – Jurassic System of Russia: Problems of stratigraphy and paleogeography. Fourth All-Russian meeting. Scientific materials: 103–106. [in Russian]
- MÖNNIG, E. 2010. On the systematic of the ammonite genus *Keplerites* and its occurrence in the Koenigi Zone (Callovian, Middle Jurassic) of Central Europe and England. – Earth Science Frontiers 17, Special Issue: 117–119.

Morphological variations in the ichnogenus *Hillichnus*: a record from the Jaisalmer Formation, Rajasthan, India

SHWETA S. GURAV¹ & KANTIMATI G. KULKARNI² *

Agharkar Research Institute, G G Agarkar Road, Pune 411 004, India; ¹E-mail: shwtgrv@gmail.com; ²E-mail: kgkulkarni@aripune.org; kantimatik@gmail.com

*Corresponding author

The compound bivalve trace fossil *Hillichnus lobosensis* has been discovered on the upper surface of a yellow, cross-bedded, gently dipping calcarenite of the Hamira Member, Jaisalmer Formation (Bajocian) exposed southeast of Jaisalmer city. Four morphological levels described by BROMLEY et al. (2003), viz. A, B, C, and D are very well represented. Signatures of Level E are hardly present but can be unequivocally established when its expression in 3D becomes available. The dominance of a deposit-feeding strategy of the organism is indicated by the maximum development of level B and C. The trace fossils *Gyrochorte*, *Taenidium*, *Rosselia*, and *Rhizocorallium* are also present in the *Hillichnus*-bearing calcarenite unit. The alternation of argillaceous and sandy sediments and low-angle cross-bedding in the upper part

of the succession point towards a fluctuating rate of sedimentation. Towards the top, the sediments became rich in organic matter as is indicated by the presence of abundant repichnia and fodinichnia.

The Level C is indicated by a feather-like meandering structure formed due to a cluster of lateral lamellae arranged on both side of a central line. The basal tube, in contrast, giving rise to thick-lined oval to bean-shaped structures arranged in zigzag fashion points towards the level D morphology of *Hillichnus*.

References

BROMLEY, R.G., UCHMAN, A., GREGORY, M.R. & MARTIN, A.J. 2003. *Hillichnus lobosensis* igen. et isp. nov., a complex trace fossil produced by tellinacean bivalves, Paleocene, Monterey, California, USA. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 192: 157–186.

Early–Middle Jurassic chemostratigraphy, black shale, and sea-level change: evidence for cyclically repeated global change events

STEPHEN P. HESSELBO¹ *, CHRISTOPH KORTE² & CLEMENS V. ULLMANN³

¹*Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK; E-mail: stephen.hesselbo@earth.ox.ac.uk*

²*Department of Geography and Geology & Nordic Center for Earth Evolution (NordCEE), University of Copenhagen, Copenhagen, Denmark; E-mail:korte@geo.ku.dk*

³*Department of Geography and Geology & Nordic Center for Earth Evolution (NordCEE), University of Copenhagen, Copenhagen, Denmark; E-mail:cu@geo.ku.dk*

**Corresponding author*

Of Jurassic palaeoenvironmental change events, the Toarcian Oceanic Anoxic Event (T-OAE) stands out as being potentially the premier ‘supergreenhouse’ episode. In addition to clear carbon-isotope signatures, a range of other isotopic, elemental, sedimentological and palaeontological anomalies have been described by multiple authors over the last three decades. The T-OAE palaeoenvironmental changes clearly affected both marine and non-marine settings and recent studies confirm both the global impact of the T-OAE on a multitude of Earth systems and also the unique magnitude of change represented by the event. On the other hand it is also becoming clear that several other times in the Jurassic are likewise characterised by repeated global carbon-cycle perturbations and associated palaeoenvironmental changes, these greater in magnitude than anything experienced by the planet during the Cenozoic. Of particular significance are a major black shale event at the Sinemurian–Pliensbachian

boundary (KORTE & HESSELBO 2011) and also another within the Sinemurian (RIDING et al. 2013). More uncertain are putative ‘ice house’ interludes in the Late Pliensbachian and during the Aalenian and Bajocian. New high-resolution and stratigraphically extensive elemental and isotopic datasets are now allowing us to place all these warm and cold events firmly in a chronological context, and to determine relationships to other Earth system events such as LIPs more accurately.

References

- KORTE, C. & HESSELBO, S.P. 2011. Shallow-marine carbon- and oxygen-isotope and elemental records indicate icehouse-greenhouse cycles during the Early Jurassic. – *Paleoceanography* 26: PA4219, doi:10.1029/2011PA002160.
- RIDING, J.B., LENG, M.J., KENDER, S., HESSELBO, S.P., & FEIST-BURKHARDT S. 2013. Isotopic and palynological evidence for a new Early Jurassic environmental perturbation. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 374: 16–27.

Refined palaeoenvironmental analysis based on changes in macrobenthic communities – A case study from the Kimmeridgian of Normandy

MANJA HETHKE*, TOBIAS FELSCH & FRANZ T. FÜRSICH

GeoZentrum Nordbayern, FG Paläoumwelt, Universität Erlangen-Nürnberg, Loewenichstraße 28, D-91054 Erlangen, Germany; Email: manja.hethke@fau.de

*Corresponding author

The reconstruction of past ecosystems involves the identification of abiotic components and the biotic response, documented particularly in ecological communities. Here, we use community relicts from marine Kimmeridgian deposits of the Normandy coast, France, to reconstruct subtle changes in environmental parameters, comparing sedimentological evidence with biogenic signals.

Kimmeridgian deposits in NW-Europe are widely regarded as having been deposited under a range of environmental regimes from oxic to oxygen-depleted conditions (e.g., WIGNALL & NEWTON 1998). Major controls on the faunal distribution in the English Kimmeridge Clay Formation are oxygen levels, substrate, and the dispersal rate of organisms (WIGNALL 1990). Kimmeridgian rocks of the Normandy coast crop out between Cap de la Hève (Le Havre) and Ecqueville with a northward regional dip and a generally argillaceous lithology, displaying more calcareous levels near the base (SAMSON et al. 1996). Three short sections (~49°30'43.5"N,

0°03'57.5"E; 49°33'15.51"N, 0°05'14.5"E; 49°34'34.12"N; 0°6'9.06"E) were considered in this study. Section 1 was measured in Lower Kimmeridgian strata near Cap de La Hève; sections 2 and 3 belong to different members of the Upper Kimmeridgian Argiles d'Octeville. The base of Section 2 extends downwards into the upper members of the Lower Kimmeridgian, represented by Assemblage 2 in Fig. 1. Lithologies range from calcareous mudstones to siliciclastic mudstones, both often featureless. The environment represented by sections 2 and 3, drawn from the rather uniform lithological evidence, is characterized by soft substrates below the storm wave-base. In contrast, Section 1 can easily be distinguished from the other two by its sedimentary features. Carbonate contents were higher and substrates more compacted and firm. Soft substrates alternated with firm- and hardgrounds, which are indicated by glauconite-impregnated, bored, and encrusted surfaces, implying strongly reduced sedimentation rates at times.

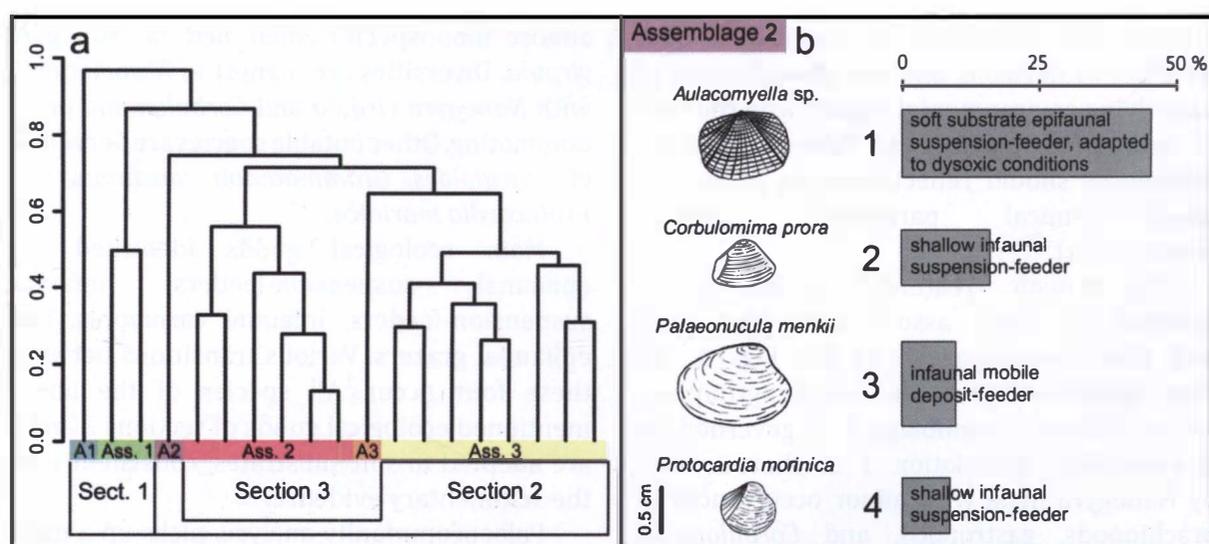


Fig. 1. Hierarchical cluster analysis (a) and guild distribution in assemblage 2 of section 2 (b). Sample groupings delineate the three studied sections very well.

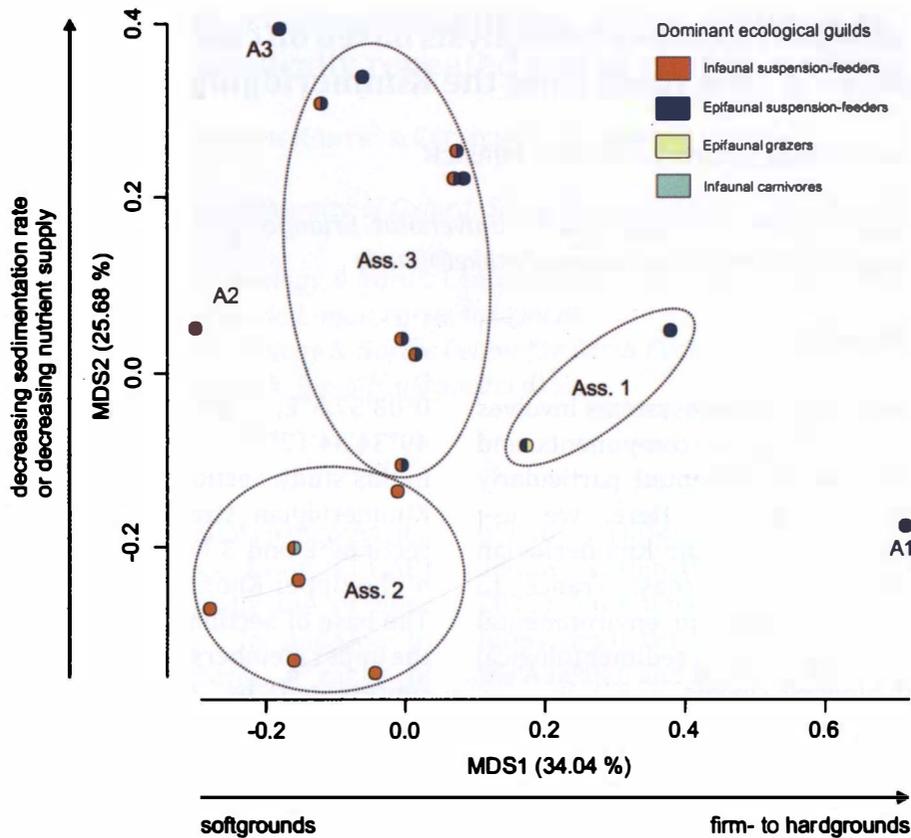


Fig. 2. Principal coordinates analysis. The first three PCO axes explain 34.04 %, 25.68 % and 14.84 % of the total variance in the dissimilarity matrix. Ecological guilds of the most abundant faunal elements within each sample are colour-coded. Mixed guild compositions were signified, when the most abundant taxon was below 50 % and the ecological guild of the second most abundant taxon different from the former.

Qualitative biogenic evidence in Section 1 came from trace fossils, such as scratch marks preserved on the walls and fills of *Thalassinoides* burrows, implying firm substrates. *Podichnus* traces on brachiopod shells show that secondary hardgrounds were exploited by brachiopods. Quantitative biogenic evidence involved the collection of abundance data for a set of horizons and the identification of underlying environmental signals with the help of ordination techniques. Palaeocommunity differences should reflect changes in ancient physico-chemical parameters (abiotic components).

The statistic treatment of the dataset resulted in three associations (Ass. 1-3) and three assemblages (A1-A3; Figs 1, 2). Taxa responsible for the sample groupings are as follows. Assemblage 1 is governed by terebratulids. Association 1 is characterized by *Nanogyra nana* with minor occurrences of brachiopods, gastropods, and *Corbulomima prora*. Assemblage 2 is dominated by *Aulacomyella*, with less abundant occurrences

of *Corbulomima*, *Protocardia*, and *Palaeonucula*. Association 2 is entirely made up of Section 2 samples, which are characterized by the shallow infaunal, suspension-feeder *Corbulomima prora*. Notable other taxa are *Nicaniella extensa*, *Nanogyra virgula*, and the gastropod *Tornatellaea*. Assemblage 3 is an almost monospecific shell bed of *Nanogyra virgula*. Diversities are highest in Association 3 with *Nanogyra virgula* and *Corbulomima prora* dominating. Other notable species are *Gervillella* cf. *aviculoides*, *Grammatodon concinnus*, and *Protocardia morinica*.

Main ecological guilds identified are epifaunal suspension-feeders, infaunal suspension-feeders, infaunal carnivores, and epifaunal grazers. Various transitions between these four occur. All species of the above mentioned ecological guilds of sections 2 and 3 are adapted to soft substrates, consistent with the sedimentary evidence.

Palaeocommunity analysis picks up a more refined signal than the sedimentary evidence does, clearly separating section 2 from section 3,

which are dominated by epifaunal and infaunal suspension-feeders, respectively. However, single assemblages may represent episodic fluctuations in environmental parameters. Assemblage 2 (Fig. 1b), for example, reveals an oxygen-restricted, soft substrate environment. In addition, the biotope must have been similar in sections 2 and 3 during the time the epifaunal reclining oyster *Nanogyra virgula* colonized the Kimmeridgian sea floor (A3 and Ass. 3). The ordination picks up a substrate signal ranging from softgrounds to firm- and hardgrounds on MDS1, and possibly increasing sedimentation rates and nutrient supply towards Association 2 on MDS2. In summary, palaeocommunity analysis unravels the physico-chemical

parameters that shape the distribution pattern of the benthic macrofauna, often much better than sedimentary analysis does.

References

- SAMSON, Y., LEPAGE, G., HANTZPERGUE, P., GUYADER, J., SAINT-GERMÈS, M., BAUDIN, F. & BIGNOT, G. 1996. Révision lithostratigraphique et biostratigraphique du Kimméridgien de la région havraise (Normandie). – *Géologie de la France* 3: 3–19.
- WIGNALL, P.B. 1990. Benthic palaeoecology of the Late Jurassic Kimmeridge Clay of England. – *Special Papers in Palaeontology* 43: 1–74.
- WIGNALL, P.B. & NEWTON, R. 1998. Pyrite framboid diameter as a measure of oxygen deficiency in ancient mudrocks. – *American Journal of Science* 298: 537–552.

Foraminifera and the end-Triassic biotic crisis at the T-J boundary in the Northern Calcareous Alps

AXEL VON HILLEBRANDT

Institut für Angewandte Geowissenschaften, Technische Universität Berlin, Ernst-Reuter-Platz 1, 10587 Berlin; E-mail: axel.vonhillebrandt@campus.tu-berlin.de

Sections with continuous sedimentation across the T-J boundary are found in the Northern Calcareous Alps in three basins, which extend in west-east direction. In the North, in the area of the Lechtal and Allgäu nappes, existed a carbonate platform with intraplatform depressions, the (1) Allgäu Basins, and sedimentary sections across the T-J boundary. South of that area the (2) Eiberg Basin is located, an intraplatform depression with Triassic and Jurassic sediments, which can be traced over 200 km from the Salzkammergut (Upper Austria) in the East to the Lahnewiesgraben Gorge (Bavaria) in the West. Many T-J boundary sections of this basin have been studied. In the western part of this basin the Karwendel Syncline contains the GSSP of the T-J boundary (HILLEBRANDT et al. 2007). In its south-eastern part the Eiberg Basin is bordered by a Rhaetian platform with locally fringing reefs and, further to the South, with an outer shelf, the (3) Hallstatt Basin, which is transitional to the Tethys Ocean.

The T-J boundary sediments mostly consist of washable marls and clays containing more or less rich and well preserved microfaunas of foraminifers, ostracods, and additional microfossils (HILLEBRANDT et al. 2007). Changes in sedimentation and palaeoecological conditions in time and space are reflected by the microfaunas. The three basins are characterized by different foraminiferal assemblages.

The probably more than 150-m-thick Rhaetian Zlambach marls of the Hallstatt Basin yield a high-diverse fauna of foraminifers. KRISTAN-TOLLMANN (1964) described 54 genera with 245 species. Nodosarioidea predominate with 14 genera and 136 species, but they are taxonomically oversplit. Textulariina are represented in this monograph by 19 genera and 39 species, and some additional genera and species have been recorded. Large-sized species of *Annulina*, *Ammodiscus*, and *Glomospira* can be abundant. Miliolina, eight genera and 13

species of which are described, are rare in all samples. Allochthonous and autochthonous foraminifers mainly occur in the upper part of the Zlambach Beds. The allochthonous foraminifers are derived from shallower areas and can make up a considerable part of the assemblages. On top of the Zlambach Beds follow some meters of mm-bedded, silty to fine-sandy, weakly calcareous beds, which mostly lack foraminifers or contain only tiny and probably reworked Nodosarioidea. One sample (probably from the lower part) yields a low diverse foraminiferal assemblage (e.g. *Annulina*, compressed *Trochammina*, *Marginulinopsis*), which also occurs in the Eiberg Basin in a similar stratigraphic position (Fig. 1). Above these beds there exist outcrops with more or less argillaceous and micaceous marls (=Dürrenberg Formation), which are at least 10 to 20 m thick, containing the earliest Jurassic ammonites (*Psiloceras spelae tirolicum* in the middle and *P. cf. tilmanni* in the upper part). These marls yield a diverse and normal-sized foraminiferal fauna. Nodosarioidea predominate but agglutinated foraminifers may also be abundant. Apart from *Dentalina*, *Ichthyolaria mesoliassica* n. spp. sensu KRISTAN-TOLLMANN (1964) and *Lingulina tenera collenoti* are abundant. The latter both rarely occur in the Zlambach marls. *L. tenera collenoti* is most common in the Pre-Planorbis Beds and Planorbis Zone of Britain. Within a lumachelle of the upper part of the section some foraminifers reappear that already existed in the Zlambach Beds. Oberhauserellidae are more or less abundant.

The most complete boundary sections of the Eiberg Basin are found in the Karwendel Syncline. Marly interlayers of the Upper Rhaetian Oxycolpella Beds contain a diverse microfauna of Nodosarioidea (Fig. 1). The Koessen Formation ends with a bed (T Bed, Fig. 1), which contains high-diverse Nodosarioidea at its marly base. Within this bed the diversity

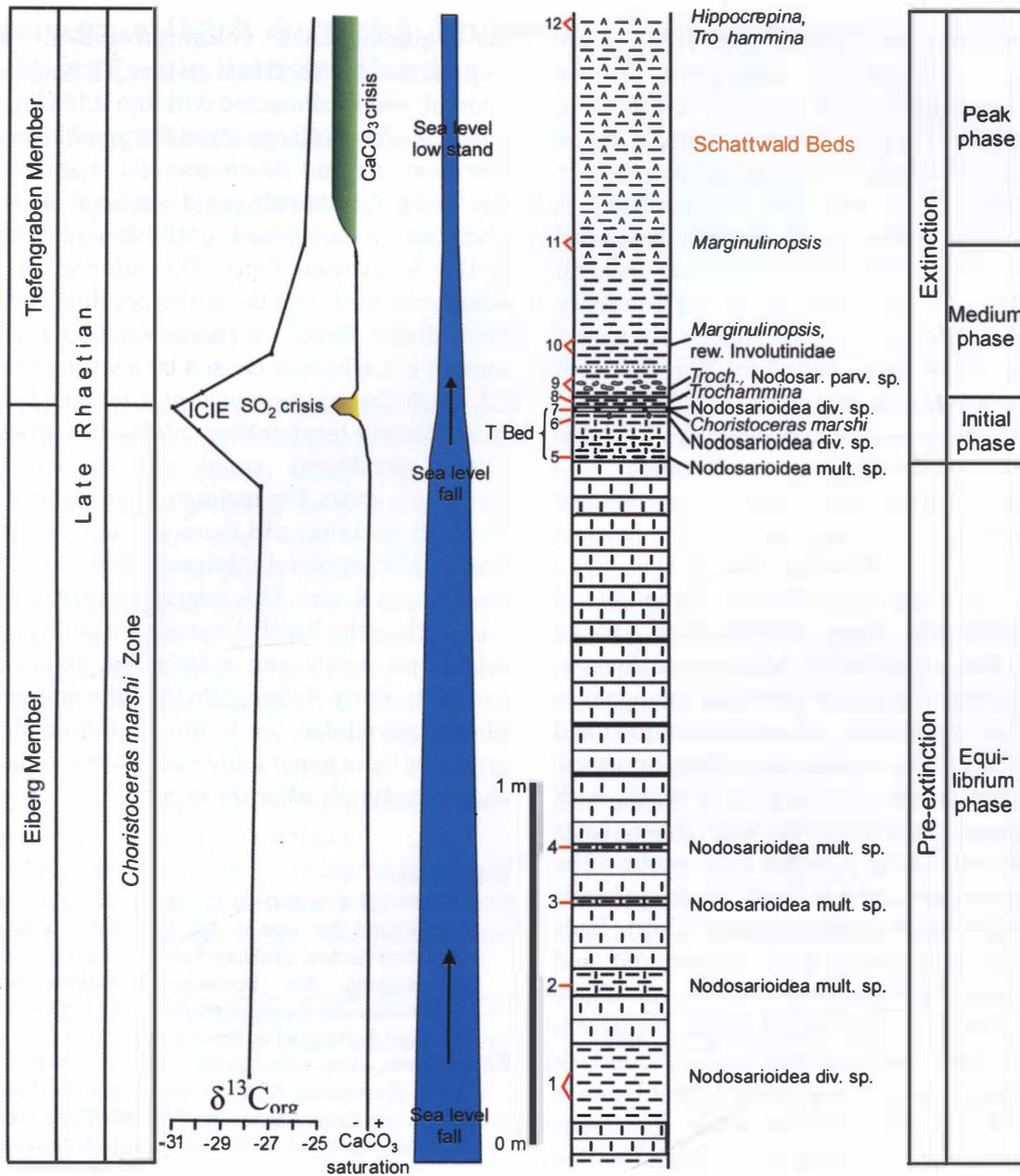


Fig. 1. Schlossgraben Section (HILLEBRANDT & KMENT 2009), ICIE = Initial Carbon Isotope Excursion (RUHL et al. 2009).

decreases and the top of the bed is formed by a laminated, approximately 1-cm-thick, bituminous layer with a strongly reduced Rhaetian foraminiferal fauna. The following 3-cm-thick argillaceous, nearly non-calcareous bed contains only compressed *Trochammina*. Above a bed with cylindrical traces and a poor fauna of Nodosarioidea follows. Large-sized *Marginulinopsis* characterize the bordering grey to yellowish marls (Fig. 1). These marls grade into red, mostly well-bedded, weakly calcareous, red clayey marls with *Hippocrepina* and compressed *Trochammina*. These Schattwald Beds are some meters thick

and are transitional to the grey Tiefengraben Member with the Rhaetian-Jurassic boundary in its lower part. A large-sized *Ammobaculites* species is common to very abundant in many samples of this member. In the lower part it co-occurs with common to abundant small-sized *Eoguttulina*, less common are *Dentalina* and smooth-shelled *Lingulina*. The *Lingulina tenera* group is very rare. Uncompressed, small-sized *Trochammina* are present in some samples of the lowest part. Nodosarioidea are low diverse, in the middle part of the member their diversity is a little higher. Attached Ammodiscidae can be abundant in the upper part of the lower

member and up to the lower part of the upper member. *Ammobaculites* disappears in the uppermost samples of the member. *Lenticulina*, *Astacolus*, and the *Lingulina tenera* group can be abundant in the uppermost part of the member. Oberhauserellidae are rare to abundant. A very similar evolutionary lineage compared with that of the Hallstatt Basin co-occurs with *Praegubkinella turgescens* at the T-J boundary interval. A new *Reinholdella* species appears 1 to 1.5 m above the T-J boundary. Together with *Ammobaculites* this new species dominates the foraminiferal faunas of many samples from the middle part of the Tiefengraben Member.

Only low-diverse and undersized foraminiferal assemblages were found in most samples from the Koessen Beds of the Allgäu Basins. A relatively diverse foraminiferal assemblage has been described by JAEGER (1997). The surface of the uppermost Koessen limestone bed is irregular and black (manganese crust). A stagnation of sedimentation and dissolution of the surface must have occurred. Above this surface 8 cm of grey marls with compressed *Trochammina* and inner casts of *Oberhauserella praerhaetica* occur. The Schattwald Beds are 4 m thick. No microfossils of animals have been recorded. These beds pass into grey marls with *Eoguttulina* and small-sized *Oberhauserella*. 40-60 cm above the Schattwald Beds *Praegubkinella turgescens* has been recorded, marking the T-J boundary. From there onwards the foraminiferal fauna is impoverished; tiny *Oberhauserella* specimens are rare, and simple-built agglutinating foraminifers predominate. Some meters higher a normal-sized fauna of diverse Nodosarioidea, with *Planularia inaequistriata* and *Ichthyolaria densicostata*, of probably Middle Hettangian age, appears.

As shown above, abundance, size, and diversity of foraminifers of the basins decrease from the South to the North, but also conformities exist. At the end of the Zlambach and Koessen beds the diversity of foraminifers rapidly decreases. This can be explained by

the beginning CAMP volcanism and the first step of the biotic crisis at the T-J boundary interval, and is connected with the ICIE (Fig. 1). *Trochammina* and large-sized *Marginulinopsis* or *Trochammina* and *Oberhauserella* characterize this event. A relatively rapid sea-level fall took place which continued until the deposition of the Schattwald Beds. The interval of the Schattwald Beds and the corresponding beds of the Hallstatt Basin are characterized by a low content of carbonate caused by a strong rise of CO₂, with the consequence of a further faunal crisis. Mainly foraminifers adapted to shallow marine conditions could not survive this continuous crisis. The majority of Nodosarioidea survived the crisis and many of them returned gradually from their withdrawal regions within the Tethyan Realm. This migration spread from the South to the North. New genera and species originated slowly and mostly not before the end of the Early Hettangian. Only the aragonitic Oberhauserellidae and the Reinholdellinae produced new genera and species even during and immediately after the crisis.

References

- HILLEBRANDT, A.V. & KMENT, K. (2009): Die Trias/Jura-Grenze und der Jura in der Karwendelmulde und dem Bayerischen Synklinorium. – Exkursionsführer, Jahrestagung der Deutschen Stratigraphischen Kommission für Jurastratigraphie in Fall 2009: 1–45; Erlangen (published by the authors).
- HILLEBRANDT, A.V., KÜRSCHNER, W.M. & KRYSZYN, L. 2007. A candidate GSSP for the base of the Jurassic in the Northern Calcareous Alps (Kuhjoch section, Karwendel mountains, Tyrol, Austria). – International Subcommission on Jurassic Stratigraphy ISJS Newsletter 34: 2–20.
- JAEGER, R.J. 1997. Foraminiferen und Ostracoden aus den Fleckenmergeln des kalkalpinen Lias – Biostratigraphie und Paläoökologie. – Münchner Geowissenschaftliche Abhandlungen A, 33: 1–111.
- KRISTAN-TOLLMAN, E. 1966. Die Foraminiferen aus den rhätischen Zlambachschichten der Fischerwiese bei Bad Aussee im Salzkammergut. – Jahrbuch der Geologischen Bundesanstalt, Sonderband 10: 1–189.
- RUHL, M., KÜRSCHNER, W.M. & KRYSZYN, L. 2009. Triassic-Jurassic organic isotope stratigraphy of key sections in the western Tethys realm (Austria). – Earth and Planetary Science Letters 281: 169–187.

Sinemurian (Early Jurassic) Ammonites from Five Card Draw, Nevada and Last Creek, British Columbia

PENGFEEI HOU*, PAUL L. SMITH, ANDREW H. CARUTHERS & SARAH J. PORTER

Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, V6T 1Z4, Canada; E-mail: phou@eos.ubc.ca, psmith@eos.ubc.ca, caruthers.andrew@gmail.com, sporter@eos.ubc.ca

*Corresponding author

The Sinemurian ammonite zonation for western North America (TAYLOR et al. 2001) is based on successions in northwest United States and Mexico, also incorporating the work of PÁLFY et al. (1994) which dealt with successions in Haida Gwaii (former Queen Charlotte Islands) in British Columbia, Canada. However, a large data set for the rest of Canada has not yet been included. This work aims at testing and refining the present zonation. Two fossiliferous successions were selected for study: the Sunrise Formation in Five Card Draw, west-central Nevada and the Last Creek Formation in Last Creek, southern British Columbia.

There are four zones recognized in the Five Card Draw section, namely in ascending order the Involutum, Leslei, Carinatum, and

Harbledownense zones. The Involutum Zone is characterized by the restricted occurrences of species of *Coroniceras* together with *Arnioceras nevadanum*. *Tmaegoceras nudaries*, and the endemic *Tipperoceras mullerense*. The Leslei Zone is characterized by various species of *Arnioceras* including *Arnioceras humboldti*, *A. arnouldi*, and *A. miserabile*. The upper part of the zone is characterized by the occurrences of *Arnioceras laevisimum* and the endemic *Bartolinoceras leslei*. The Carinatum Zone is characterized by the occurrences of *Epophioceras carinatum*, and *Asteroceras cf. varians*. Some poorly preserved specimens of *Asteroceras cf. jamesi* were found ex situ from this interval. Due to its difficulty in recognition, the Jamesi Zone in TAYLOR et al. (2001) is provisionally included within the

Stage \ Zone	Western North America	Northwest Europe	Age (Ma)
Pliensbachian	Imlayi	Jamesoni	← 190.8 ±1.0
Sinemurian	Harbledownense	Raricostatum	
	Jamesi	Oxynotum	
	Carinatum	Obtusum	← 195.3 ^{+2.9} _{-4.6}
	Leslei	Turneri	
	Involutum	Semicostatum	
	Trigonatum	Bucklandi	← 199.3 ±1.0
	Columbiae		
	Rursicostatum	Angulata	
	Hettangian		Mineralense

Fig. 1. Correlation of the Sinemurian Zonation in western North America with northwest Europe (after DEAN et al. 1961; SMITH et al. 1988; TAYLOR et al. 2001; LONGRIDGE et al. 2006). Ages of stage boundaries and uncertainties are from GRADSTEIN et al. (2012); the age of the equivalent of the basal Obtusum Zone is from PÁLFY et al. (2000).

upper part of the Carinatum Zone as an horizon. The Harbledownense Zone is characterized by the occurrences of abundant echioceratids and oxynoticeratids.

The two zones recognized in the Last Creek section, are the Involutum Zone and Leslei Zone of the Lower Sinemurian. Some *ex situ* ammonites from the top of the succession indicate that the Carinatum Zone may be present (MACCHIONI et al. 2005). The Involutum Zone is characterized here by the restricted occurrence of various species of *Coroniceras*. The top of the zone is marked by the first appearance of *Arnioceras*. *Tipperoceras* is known from this interval. The lower part of the Leslei Zone is characterized by the restricted occurrences of *Arnioceras* cf. *ceratitoides*, and *A. miserabile*. The upper part is characterized by the occurrences of *Arnioceras* cf. *humboldti*, *Caenisities brooki*, *C. turneri*, *C. pulchellus*, *Lytotropites fucinii*, *Procliviceras striatocostatum*, and *Togaticeras* sp. juv. *Arnioceras arnouldi* ranges throughout this zone. A detailed description of the fauna in this interval in Last Creek is given by MACCHIONI et al. (2005).

The primary standard zonal scheme for the Sinemurian Stage was established by DEAN et al. (1961) based on successions in northwest Europe, with numerous subsequent refinements summarized in PAGE (2003) and including the work of CARIOU & HANTZPERGUE (1997). The secondary Sinemurian zonal scheme for western North America, including reference assemblages in Canada, is correlative with the primary zonation as indicated in Fig. 1.

References

- CARIOU, E., & HANTZPERGUE, P. (eds.) 1997. Biostratigraphie du Jurassique Quest-Européen et méditerranéen: zonation parallèles et distribution des invertébrés et microfossiles. – Bulletin du Centre Recherches Elf Exploration Production, Mémoire 17: 1–440.
- DEAN, W.T., DONOVAN, D.T. & HOWARTH, M.K. 1961. The Liassic ammonite zones and subzones of the north-west European province. – Bulletin of the British Museum (Natural History) 4: 438–505.
- GRADSTEIN, F.M., OGG, J.G., SCHMITZ, M.D. & OGG, G.M. (eds.) 2012. – The Geologic Time Scale 2012: 793 p., Elsevier BV, Waltham, USA.
- LONGRIDGE, L.M., SMITH, P.L. & TIPPER, H.W. 2006. The Early Jurassic ammonite *Badouxia* from British Columbia, Canada. – Paleontology 49: 795–816.
- MACCHIONI, F., SMITH, P.L. & TIPPER, H.W. 2005. Late Early Sinemurian (Early Jurassic) ammonites from the Taseko Lakes map area, British Columbia. – Paleontology 49: 557–583.
- PÁLFY, J., SMITH, P.L. & TIPPER, H.W. 1994. Sinemurian (Lower Jurassic) ammonoid biostratigraphy of the Queen Charlotte Islands, Western Canada. – Geobios 27: 385–393.
- PÁLFY, J., SMITH, P.L. & MORTENSEN, J.K. 2000. A U-Pb and ⁴⁰Ar/³⁹Ar time scale for the Jurassic. – Canadian Journal of Earth Sciences 37: 923–944.
- PAGE, K.N. 2003. The Lower Jurassic of Europe: its subdivision and correlation. – Geological Survey of Denmark and Greenland Bulletin 1: 23–59.
- TAYLOR, D.G., GUEX, J. & RAKUS, M. 2001. Hettangian and Sinemurian ammonoid zonation for the Western Cordillera of North America. – Bulletin de la Société vaudoise des Sciences Naturelles, 87: 381–421.
- TAYLOR, D.G. 1998. Late Hettangian-Early Sinemurian (Jurassic) ammonite biochronology of the western Cordillera, United States. – Geobios 31: 467–497.
- SMITH, P.L., TIPPER, H.W., TAYLOR, D.G., & GUEX, J. 1988. An ammonite zonation for the Lower Jurassic of Canada and the United States: the Pliensbachian. – Canadian Journal of Earth Sciences 25: 1503–1523.

Evolutionary significance of latest Jurassic-earliest Cretaceous hydrocarbon seep assemblages from Central Spitsbergen, Svalbard

KRZYSZTOF HRYNIEWICZ¹ *, CRISPIN T. S. LITTLE², HANS ARNE NAKREM¹, ØYVIND HAMMER¹, MICHAEL R. SANDY³, ANDRZEJ KAIM⁴ & VINN OLEV⁵

¹Natural History Museum, University of Oslo, 1172 Blindern, 0318 Oslo; Email-krzysztof.hryniewicz@nhm.uio.no; E-mail: h.a.nakrem@nhm.uio.no, oyvind.hammer@nhm.uio.no

²School of Earth and Environment, Woodhouse Lane, University of Leeds, Leeds LS2 9JT, United Kingdom; E-mail: earctsl@leeds.ac.uk

³Department of Geology, University of Dayton, Dayton OH 45469-2364, USA; E-mail: msandy1@udayton.edu

⁴Institute of Palaeobiology, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland; E-mail:kaim@twarda.pan.pl

⁵Department of Geology, University of Tartu, Ravilla 14A, 50411Tartu, Estonia; E-mail: olev.vinn@ut.ee

*Corresponding author

Fifteen seep carbonate bodies from latest Jurassic to earliest Cretaceous black shales of the middle to outer shelf Slottsmøya Member contain a diverse (>30 species) assemblage of bivalves, gastropods, brachiopods, and polychaete tubes. Up to 14 bivalve species have been identified. They form a mixture of globally

distributed species and Boreal endemics. Bivalves are represented by *Nucinella*, two protobranch species, the pectinid *Camptonectes* and a number of *Buchia* species, with other taxa being only locally common. The seep fauna contains also at least eight gastropod taxa, known predominantly from contemporary normal



Fig. 1. Field view of one of the Jurassic-Cretaceous seep carbonates from Svalbard.

marine settings. Possible hokkaidoconchids are the only gastropods encountered, which are known to be restricted to vent and seep environments. A lingulid *Lingularia similis?* and at least five rynchonelliform brachiopods, which are also known from contemporary normal marine environments, comprise a brachiopod element of the Svalbard seep fauna. Serpulid tubes with organic tubes of possibly vestimentiferan affinity represent polychaetes that have so far been identified. The Jurassic-Cretaceous seeps of Svalbard contain a high diversity fauna composed of a mixture of various molluscs, with subordinate brachiopod and polychaete taxa, most of which are also known from normal marine settings in the Jurassic and Cretaceous of the Arctic. Predominance of normal marine molluscs in seep assemblages from Svalbard contrast with *Peregrinella* brachiopod-dominated seep assemblages, known from some Early Cretaceous localities. The palaeobiogeographic separation of the Boreal Realm is reflected by a predominantly Boreal shallow water fauna with a few world-wide distributed species. The high diversity, background fauna-dominated assemblage reflects a strong connection with the surrounding shallow marine environments. The most common chemosymbiotic bivalves are species of *Nucinella* and *Solemya*, whereas a thyasirid and a lucinid are known from a

single locality only. None of these genera is characteristic of seep environments since they occur in Mesozoic reduced marine sediments as well. The dominance of normal marine fauna from contemporary shelf settings in a seep environment is an expression of colonization of the seep environments by the shallow marine taxa.

References

- CAMPBELL, K.A. 2006: Hydrocarbon seep and hydrothermal vent paleoenvironments and paleontology: Past developments and future research directions. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 232: 362–407.
- HAMMER, Ø., NAKREM, H.A., LITTLE, C.T.S., HRYNIEWICZ, K., SANDY, M.R., HURUM, J.H., DRUCKENMILLER, P., KNUTSEN, E.M. & HØYBERGET, M. 2011: Hydrocarbon seeps from close to the Jurassic-Cretaceous boundary. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 306: 15–26.
- HJÁLMAUSDÓTTIR, H.R., NAKREM, H.A. & NAGY, J. 2012: Foraminifera from Late Jurassic – Early Cretaceous hydrocarbon seep carbonates, central Spitsbergen, Svalbard – preliminary results. – *Norwegian Journal of Geology* 92: 157–165.
- HOLMER, L.E. & NAKREM, H.A. 2012. The lingulid brachiopod *Lingularia* from lowermost Cretaceous hydrocarbon seep bodies, Sassenfjorden area, central Spitsbergen, Svalbard. – *Norwegian Journal of Geology* 92: 167–174.
- HRYNIEWICZ, K., HAMMER, Ø., NAKREM, H.A. & LITTLE, C.T.S. 2012. Microfacies of the Volgian-Ryazanian (Jurassic-Cretaceous) Sassenfjorden hydrocarbon seep carbonates from central Spitsbergen, Svalbard. – *Norwegian Journal of Geology* 92: 113–131.

Tetragonal serpulids from the Jurassic: testing the phylogenetic relationships by ultrastructural and mineralogical tube studies

ALEXEI IPPOLITOV¹ * & ELENA KUPRIYANOVA²

¹*Geological Institute of Russian Academy of Sciences, Moscow 119017 Russia; E-mail: ippolitov.ap@gmail.com*

²*The Australian Museum, 6 College Street Sydney NSW 2010 Australia; E-mail: elena.kupriyanova@austmus.gov.au*

*Corresponding author

Serpulid polychaetes typically inhabit cylindrical calcareous tubes that are attached to hard substrates and well-preserved in the fossil record from the Triassic onwards, being an important element of Jurassic (especially of Middle and Upper Jurassic) benthic communities. The fossil record of this group is, however, extremely poorly studied, mainly due to insufficiently developed taxonomy, which makes comparisons of fossil with Recent forms difficult. As a result, serpulids cannot provide clear paleoecological interpretations of fossils based on analogy with Recent forms.

During the last 10 years, outstanding ultrastructural variations among the Serpulidae were discovered (VINN et al. 2008), and, consequently, ultrastructures are now considered as a perspective tool for taxonomic investigations of fossils.

This case study deals with coiled and straight tetragonal tubes of serpulid polychaetes, well-known to paleontologists under the generic names *Nogrobs* and *Tetraserpula/Tetraditrupa*. These taxa originated and diverged during the Middle Jurassic and later spread worldwide. During the Mesozoic these serpulids were among the most common and abundant elements of serpulid faunas. Species in morphologically identical tubes, both coiled and straight, known as *Spirodiscus* and *Bathyditrupa*, respectively, inhabit bathyal and abyssal environments in Recent oceans up to over 6000 m depth. First palaeontologists (JÄGER 2005) and later zoologists (TEN HOVE & KUPRIYANOVA 2009) supported the opinion that Recent and Mesozoic forms are congeneric. The idea of their close relationship looks even more appealing considering a long-held view that ancient faunal elements (often known as “living

fossils”), widely distributed in shallow water communities during certain geological epochs, today often inhabit refugia of the deep sea.

To examine the relationship between fossil and Recent forms with similar morphology, we used SEM to analyse tube ultrastructure of numerous fossil serpulid tubes collected from more than 15 localities in Europe and compared them with the representative Recent material. Additionally, diffraction X-ray analysis was performed in order to determine mineralogical composition of the tubes.

Examination of the fossil material has shown that most of the specimens (excluding evidently diagenetically altered material from several localities) show a simple prismatic type of ultrastructure (SP, *sensu* VINN et al. 2008), and are purely calcitic. Preservation of fine original growth patterns of prismatic crystallites is a powerful argument for the primary nature of ultrastructures. Common structure confirms close phylogenetic relationship between coiled (*Nogrobs*) and uncoiled (*Tetraserpula/Tetraditrupa*) tube morphology.

On the contrary, Recent tetragonal tubes were found to be a taxonomic “conglomerate” comprising numerous unrelated species with very different types of tube ultrastructure, such as irregularly oriented prismatic (IOP), semi-ordered irregularly oriented prismatic (SOIOP), and spherulitic irregularly oriented prismatic (SIOP) *sensu* VINN et al. (2008). Ultrastructures are stable within each species, but none of them is comparable with the simple prismatic structure found in the fossil material. Additionally, mineralogical composition in most cases was found to be a mixture of calcite and aragonite, thus, differing from calcitic fossil species.

The results of our study mean that making direct comparisons, including ecological interpretations, between Recent and fossil tetragonal serpulid tubes is essentially incorrect. Similar tube morphology is most probably the result of adaptation to similar soft-bottom environments, atypical for most serpulids. However, the huge stratigraphic gap (65 ma.) between the youngest known fossil free tetragonal tubes and their recent counterparts still allows for the possibility of gradual evolution of the tube ultrastructures, a hypothesis that could be verified by further

discovery and examination of Cenozoic material.

References

- JÄGER, M. 2005. Serpulidae und Spirorbidae (Polychaeta sedentaria) aus Campan und Maastricht von Norddeutschland, den Niederlanden, Belgien und angrenzenden Gebieten. - *Geologisches Jahrbuch A157 (for 2004)*: 121-249.
- TEN HOVE, H.A. & KUPRIYANOVA, E.K. 2009. Taxonomy of Serpulidae (Annelida, Polychaeta): the state of affairs. - *Zootaxa* 2036: 1-126.
- VINN, O., TEN HOVE, H.A., MUTVEI, H. & KIRSIMÄE, K. 2008. Ultrastructure and mineral composition of serpulid tubes (Polychaeta, Annelida). - *Zoological Journal of the Linnean Society* 154: 633-650.

Belemnite zonal scale for the Late Sinemurian – Pliensbachian of Eastern Europe: an update based on data from the Ukrainian Carpathians

ALEXEI IPPOLITOV¹ * & JAN SCHLÖGL²

¹*Geological Institute of Russian Academy of Sciences, Pyzhevski Lane 7, 119017 Moscow, Russia; E-mail: ippolitov.ap@gmail.com*

²*Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynska dolina, 842 15 Bratislava, Slovakia; E-mail: schlogl@nic.fns.uniba.sk*

**Corresponding author*

Despite belemnites are widely considered by geologists to be a stratigraphically important group, in fact they are used as a basic tool for stratigraphic subdivision and correlation only for the Late Cretaceous of Europe. Numerous scales were elaborated for other Mesozoic intervals, but they mostly remain unused due to their low resolution. However, newest investigations (JANSSEN et al. 2012), based on careful morphological analysis of large sets of samples allowing to trace intraspecific variations, have shown that belemnites still can provide detailed zonal scales, comparable in resolution with ammonite zones and even biohorizons.

Formal belemnite scales for the Early Jurassic were elaborated only by STOYANOVA-VERGILOVA (1978) for Bulgaria, DOYLE & BENNETT (1995) for NW Europe, and COMBÉMORÉL (1997) for the NW and Mediterranean Europe. The most remarkable thing about all these scales is that the zones based on the same species may be of different age – for example, the Bisulcata Zone in Doyle's scale covers the whole Late Pliensbachian to Early Toarcian, but is restricted to the Early Toarcian in Combémoré's scale; the Apicicurvata Zone covers the whole Early Pliensbachian in the Doyle and in the Stoyanova-Vergilova scale, but only the late Early Pliensbachian in the scale of Combémoré. This artifact is based mainly on different interpretation of certain species by taxonomists.

Material for the present study comes from the Priborzhavskoe Quarry (WIERZBOWSKI et al. 2012), located in the Transcarpathian Region of West Ukraine. Sinemurian–Pliensbachian rocks here are represented by marls and marly limestone/siltstone alternations, and contain

abundant belemnite rostra, which are the predominant fossils here. Detailed bed-by-bed sampling of belemnite rostra, accompanied with ammonite record, allowed us to reconstruct the belemnite succession in great detail, including tracing the phylogenetic lineages between certain species. This analysis is used as a basis for the review of the existing belemnite biostratigraphic data, and it allows us to propose some emendations and improvements for the Early Jurassic belemnite scale.

All four zonal subdivisions of the Sinemurian–Pliensbachian interval of Bulgaria (STOYANOVA-VERGILOVA 1978) are well-recognizable in the Priborzhavskoe section. The *Nannobelus* sp. Zone, originally dated as Late Sinemurian, is characterized by the presence of small-sized representatives of the single genus *Nannobelus*. Our material shows that the uppermost part of this zone is characterized by a diversification event and, therefore, can be subdivided into two separate units. The belemnite fauna is accompanied by a rich ammonite association indicating the *Raricostatum* Zone of the Late Sinemurian.

The *Apicicurvata* Zone, characterized by even more diverse belemnite assemblages, has a complicated structure. The studied material from the Priborzhavskoe section shows that it can be clearly subdivided into 4 to 5 separate belemnite units, and 3 of them are based on the elements of the same lineage and, therefore, have high correlation potential. The index species of the zone, *Passaloteuthis apicicurvata* s.str., is restricted to the uppermost part of the zone, and the "classic" lower boundary of the unit at the base of the Pliensbachian is based on the appearance of large-sized rostra of the genus *Passaloteuthis*. The age estimated in the

Priborzhavskoe section is ?latest Raricostatum and Jamesonitobex zones (Early Pliensbachian). Questionably it includes also Davoei Zone of the late Early Pliensbachian, but ammonites of this age were still not found there.

The *Gastrobelus* Genozone was originally recognised and traced only in several sections in Bulgaria (STOYANOVA-VERGILOVA 1978). This zone was never used by subsequent authors, and even omitted in further discussions (see DOYLE & BENNETT 1995). However, in the Priborzhavskoe section this zone looks quite clear and well-defined. Further subdivision (into three subunits) is again possible here, based on fast-evolving early representatives of *Parapassaloteuthis*. The originally defined early Late Pliensbachian age of the zone is accepted here due to absence of ammonites in the corresponding interval. In Germany, however, well-recognizable *Gastrobelus ventroplanus* rostra appear in the Davoei Zone of the Early Pliensbachian (SCHUMANN 1974); thus the Early/Late Pliensbachian boundary can be located within the unit.

The base of Bruguieriana Zone is reflected in the reduction of belemnite biodiversity – now the single genus *Passaloteuthis* dominates the assemblage. This zone again can be subdivided by erecting two sub-units, based on two different phylogenetic lineages. However, it has to be mentioned that the index species *Passaloteuthis bruguieriana* should be revised and its variability is to be redefined. A Late Pliensbachian age of the zone, assumed by Stoyanova-Vergilova, is supported by isolated finds of ammonites belonging to the genus *Amaltheus* of the Margaritatus Zone, as well as by the belemnite *Pleurobelus compressus*, indicating the same zone. The uppermost part of this stratigraphic unit is condensed and contains ammonites of the Spinatum Zone (WIERZBOWSKI et al. 2012), indicating that the Bruguieriana Zone in Priborzhavskoe covers most part of the Late Pliensbachian.

Although the obtained belemnite succession looks quite clear, it is still far from being well-correlated with existing ammonite data. Ammonite finds provide several important “tie-points” for the belemnite scale, but still most boundaries of the belemnite scale are not well-dated in terms of ammonite zones, subzones, and biohorizons.

Phylogenetic considerations, supporting the proposed belemnite subdivision, together with the uniform sedimentation character and absence of recurrent communities in the Priborzhavskoe section, almost exclude the possibility that these belemnite complexes are ecological rather than evolutionary. Therefore, it can be stated that belemnites of the Early Jurassic in Priborzhavskoe allow to subdivide the Late Sinemurian – Early Pliensbachian interval into 12 units, approaching the resolution of ammonite subzones.

The study was supported by RFBR grant №12-05-00380-a.

References

- COMBÉMOREL, R. 1997. Belemnites. In: CARIOU, E. & HANTZPERGUE, P. (coord.), *Biostratigraphie du Jurassique ouest-européen et méditerranéen. Zonations parallèles et distribution des invertébrés et microfossiles*. – Bulletin de la Centre des Recherches Elf Exploration-Production, Mémoire 17: 157–167.
- DOYLE, P. & BENNETT, M.R. 1995. Belemnites in biostratigraphy. – *Palaeontology* 31: 815–829.
- JANSSEN, N.M.M., CLÉMENT, A. & BONT, W. 2012. Mediterranean Neocomian belemnites, part 4: belemnites of the Barremian stratotype section. – *Carnets de Géologie, Mémoires* 2012/02: 201–274.
- SCHUMANN, H.O. 1974. Die Belemniten des norddeutschen Lias Gamma. – *Geologisches Jahrbuch, Reihe A* 12: 1–85.
- STOYANOVA-VERGILOVA, M. 1978. Zonal subdivision of the Lower Jurassic in Bulgaria by means of belemnites. – *God. Sofisk. Univ. (Geol., Geogr.)* 70 (1977-1978): 161–192. [in Bulgarian]
- WIERZBOWSKI, A., KROBICKI, M. & MATYJA, B.A. 2012. The stratigraphy and palaeogeographic position of the Jurassic successions of the Priborzhavske-Perechin Zone in the Pieniny Klippen Belt of the Transcarpathian Ukraine. – *Volumina Jurassica* 10: 25–60.

Microfossil research using 3D imaging technology: an experimental study of Jurassic radiolarian fossils using X-ray micro-computed tomography

NAOTO ISHIDA^{1*}, NAOKO KISHIMOTO², ATSUSHI MATSUOKA³, KATSUNORI KIMOTO⁴, TOSHIYUKI KURIHARA⁵ & TAKASHI YOSHINO⁶

¹Center for Fostering Innovative Leadership, Niigata University, Niigata 950-2181, Japan; E-mail: nao.ishida21@mbn.nifty.com

²Department of Mechanical Engineering, Setsunan University, Neyagawa 572-8508, Japan; E-mail: kishimoto@mec.setsunan.ac.jp

³Department of Geology, Faculty of Science, Niigata University, Niigata 950-2181, Japan; E-mail: matsuoka@geo.sc.niigata-u.ac.jp

⁴Research Institute of Global Change, JAMSTEC, Yokosuka 237-0061, Japan; E-mail: kimopy@jamstec.go.jp

⁵Graduate School of Science and Technology, Niigata University, Niigata 950-2181, Japan; E-mail: kurihara@geo.sc.niigata-u.ac.jp

⁶Department of Mechanical Engineering, Toyo University, Kawagoe 350-8585, Japan; E-mail: tyoshino@toyo.jp

*Corresponding author

X-ray micro-computed tomography (Micro-CT) is a non-destructive method of obtaining a three-dimensional image of a millimetre- to micrometer-sized object from a set of X-ray cross-sectional images. To evaluate the potential of Micro-CT imaging technology for the investigation of microfossils, we have experimentally examined the skeletons of radiolarians, foraminifers, ostracods, and diatoms (e.g., MATSUOKA et al. 2012). This investigation of *Protunuma* (?) *ochiensis* MATSUOKA emphasizes the utility of Micro-CT for the paleontological description of radiolarian fossils.

Protunuma (?) *ochiensis* MATSUOKA is a four-segmented closed-end nassellaria that has

been recovered from Middle to Upper Jurassic sediments in Japan and the Tethys region. This species was first described by MATSUOKA (1983) based on conventional observation with a biological microscope and a scanning electron microscope (SEM). A Micro-CT device (SkyScan Micro-CT in SEM) attached to a SEM (JEOL JSM-6510) was used to take images of the internal structures and surface ornamentation of this species. This device has an image resolution of 300 nm/pixel.

A roentgenogram of *Protunuma* (?) *ochiensis* is shown in Fig. 1A. After adjusting X-ray properties such as wavelength and intensity, internal structures could be recorded through the thick (ca. 10 μm) exterior wall composed

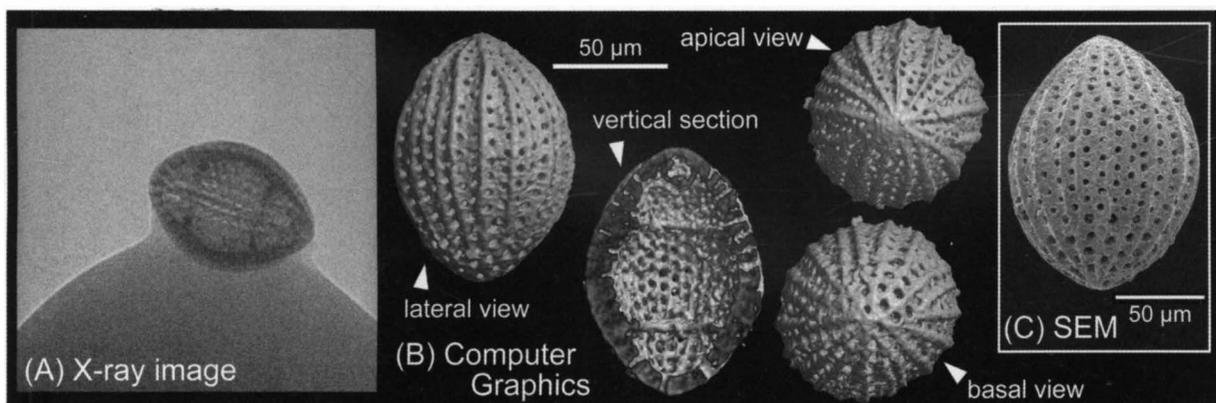


Fig. 1. A. X-ray photograph of *Protunuma* (?) *ochiensis* taken using the Micro-CT device. (B) Computer graphic images constructed from a set of X-ray photographs. (C) A SEM image of the same species.

of silica. Important taxonomic characters of this species, especially those documented in the original description such as outline, number of segments, and pore arrangement, were represented almost perfectly in the 3D computer graphics (Fig. 1B) synthesized from a set of cross-sectional images. In particular, characteristics of the plicae, an important surface ornamentation of this species, were clearly represented. The height and width of the specimen were easily calculated by software as 97 μm and 78 μm , respectively.

Based on the results of this experiment, the Micro-CT device is adequate for imaging the taxonomic characters of Jurassic radiolarians. Furthermore, we have succeeded in obtaining 3D images of more delicate radiolarian structures such as the initial spicules of Recent

nassellarians (ISHIDA et al. 2013). Micro-CT imaging may become an efficient method for radiolarian investigation in the near future.

References

- MATSUOKA, A. 1983. Middle and Late Jurassic radiolarian biostratigraphy in the Sakawa and adjacent areas, Shikoku, Southwest Japan. – *Journal of Geosciences, Osaka City University* 26: 1–48.
- MATSUOKA, A., YOSHINO, T., KISHIMOTO, N., ISHIDA, N., KURIHARA, T., KIMOTO, K. & MATSUURA, S. 2012. Exact number of pore frames and their configuration in the Mesozoic radiolarian *Pantanellium*: An application of X-ray micro-CT and layered manufacturing technology to micropaleontology. – *Marine Micropaleontology* 88–89: 36–40.
- ISHIDA, N., KISHIMOTO, N., MATSUOKA, A., KIMOTO, K., KURIHARA, T. & YOSHINO, T. 2013. Microstructures of plankton skeletons using 3D imaging technology. – *Bulletin of the Society for Science on Form* 27.

Paleoenvironment and sedimentation of deep marine spotted limestones and marls, Lower and Middle Jurassic (Western Carpathians, Tatra Mts.)

JOLANTA IWAŃCZUK & KATARZYNA SOBIEŃ

*Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland;
E-mail: jolanta.iwanczuk@pgi.gov.pl, katarzyna.sobien@pgi.gov.pl*

The study area is located in the eastern part of the Polish Tatra Mts. The Jurassic rocks there represent deep marine facies of the Križna Basin, (western branch of the Tethys), with a dominance of gray spotted limestones and marls, of the Fleckenkalk/Fleckenmergel type. The characteristic feature of the studied sections is an alternation of limestones, marly limestones, and shales in various proportions, depending on the stratigraphic interval. Based on the ammonite fauna, described by MYCZYŃSKI (2004) and IWAŃCZUK et al. (2012, 2013) the age of sediments has been identified as Late Sinemurian – Early Bathonian.

Microfacies analysis, together with magnetic susceptibility (MS) measurements on .cut samples were performed in order to reconstruct the palaeoenvironment during sedimentation of marl and spotted limestone. In addition, geochemical analyses were executed to evaluate redox conditions and to prove terrigenous origin of magnetic susceptibility.

Lithological and microfacies analysis allowed to subdivide the studied sediments into three main sequences. Magnetic susceptibility fluctuations are clearly visible along the studied profiles and reflect changes in the supply of detrital material into the basin, which is confirmed by the local tectonic events and eustatic sea level changes.

In the lower part of the section (Late Sinemurian – Early Pliensbachian) spiculitic limestone (spiculitic wackestone/packstone) dominates. The average value of the magnetic susceptibility is low and varies little, with a tendency to increase up-section. It coincides with the global eustatic curve of sea level changes and indicates a regressive cycle of Late Sinemurian – early Pliensbachian age (HALLAM 2000).

The middle part of the section (Late Pliensbachian – Early Bajocian) consists of limestones and calcareous marls interbedded

with marly shales (radiolarian wackestone/packstone with an admixture of mica and quartz grains). The terrigenous material differs in its composition. In this succession MS values are highly variable with a general tendency to decrease towards the top. However, in thin-sections we do not observe any changes in the amount of siliciclastic grains. Decrease in the MS value up-section is caused by changes in mineral composition, caused by changes in the source area which supplied clastic material to the basin. Petrographic observation leads to the conclusion that the detrital grains might be derived from destruction of the older sedimentary cover, perhaps the Triassic carbonate platform.

In addition we can observe first- and second-order fluctuations. The second-order rhythmic changes show a systematic delivery of detrital material into the basin and/or a cyclic decline of carbonate sedimentation. Consequently, a greater share of siliciclastic material could be controlled by paleoclimate changes (HALLAM 2000; OGG et al. 2012).

However, the general trend of the first-order changes in magnetic susceptibility can be correlated with the eustatic sea-level changes within the Tethys basin (HALLAM 2000). The MS curve indicates four transgressive-regressive cycles with a clear deepening trend up-section.. A significant increase in supply of detrital material in the central part of the profile can be explained by local tectonic events (Devin rift phase), described by PLAŠIENKA (2003).

In the uppermost part of the section (Late Bajocian – Early Bathonian) radiolarian limestones and radiolarites (radiolarian wackestone with subordinate filament wackestone) appear. MS values are less variable and clearly decrease, which might point to a reduction of detrital material supply to the basin. This is probably due to deepening of the basin (HALLAM 2000).

References

- HALLAM, A. 2000. A review of the broad pattern of Jurassic sea level changes and their possible causes in the light of current knowledge. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 167: 23–37.
- MYCZYŃSKI, R. 2004. Toarcian, Aalenian and Early Bajocian (Jurassic) ammonite faunas and biostratigraphy in the Pieniny Klippen Belt and the Tatra Mts, West Carpathians. – *Studia Geologica Polonica* 123: 7–131.
- IWAŃCZUK, J., IWANOW, A. & WIERZBOWSKI, A. 2012. Lower Jurassic to lowermost Middle Jurassic at Kopy Sołtysie in the High Tatra Mts., Poland: stratigraphy, facies and ammonites. In: JÓZSA, S., REHÁKOVÁ, D. & VOJTKO, R. (eds.), *Environmental, structural and stratigraphical evolution of the Western Carpathians*. – 8th Esseweca Conference 6-7.12.2012, Abstract book: 19, Bratislava.
- IWAŃCZUK, J., IWANOW, A. & WIERZBOWSKI, A. 2013. Lower Jurassic to lower Middle Jurassic succession at Kopy Sołtysie and Płaczliwa Skala in eastern Tatra Mts (Western Carpathians) of Poland and Slovakia: stratigraphy, facies and ammonites. – *Volumina Jurassica*, in press
- OGG, J.G., HINNOV, L.A. & HUANG, C. 2012. Jurassic. In: GRADSTEIN, F.M., OGG, J.G., SCHMITZ, M. & OGG, G. (eds.), *The geologic time scale: 731–791*. Elsevier, Amsterdam.
- PLAŠIENKA, D. 2003. Dynamics of Mesozoic pre-orogenic rifting in the Western Central Carpathians. – *Mitteilungen der Österreichischen Geologischen Gesellschaft* 94: 79–98.

Middle Jurassic Bivalves from Charu area, Jaisalmer district, Rajasthan, India

R. L. JAIN¹, R. P. KACHHARA² & R. L. JODHAWAT³

¹Palaeontology Division 1, Geological Survey of India, 15 A & B Kyd Street, Kolkata-700016, India; E-mail: rljaingsi@gmail.com

²31, Mayurvan Colony, Panariyo ki Madadi, Udaipur-313002, Rajasthan, India; E-mail: kachharar@yahoo.com

³25/A, Saheli Nagar, Near Sahelion ki Bari, Udaipur-313001, Rajasthan, India

Jaisalmer is known for its marine Jurassic faunal assemblages. Thirteen specimens of Bivalvia have been collected from the yellow limestone horizon of the Bada Bag Member of the Jaisalmer Formation from the Charu area, Jaisalmer district, Rajasthan. The taxa are figured and described in the present paper to update the stratigraphy of the Bada Bag Member in the Charu area. Eight taxa: *Parallelodon* sp., *Modiolus* (*M.*) *patchamensis* COX, *Modiolus* sp., *Pinna* (*Pinna*) sp., *Pteroperna* sp., *Eopecten* sp., *Homomya* sp., and *Pleuromya uniformis* (J. SOWERBY) have been identified. These bivalve genera have a much longer range than ammonites and brachiopods. The faunal

assemblage bears a similarity with Middle Jurassic (Bathonian) faunas of England and Germany. The Bathonian ammonite genus *Clydoniceras* BLAKE was reported from the same locality by PRASAD et al. (2007). Based on the above data and on the faunal assemblage the Bada Bag Member of the Charu area is broadly assigned a Middle Jurassic (Bathonian) age.

References

- PRASAD, S., JAIN, R.L. & SRIVASTAVA, M.S. 2007. Record of Middle Jurassic (Bathonian) Ammonite genus *Clydoniceras* BLAKE from Jaisalmer Basin, western Rajasthan. – Journal of the Geological Society of India 69: 53–56.

Palaeobiogeographic significance of the Middle Jurassic pholadomyoid bivalves from Kachchh, western India

ANAND K. JAITLEY

Center of Advanced Studies in Geology, Banaras Hindu University, Varanasi 221 005, India; E-mail: akjaitly@gmail.com

Situated on the western margin of the Indian plate at a palaeolatitude of 33°S, the Kachchh Basin is known world over for its rich occurrence of Middle to Late Jurassic mollusks. During that time, the basin received a thick pile of marine sediments, about 750 m in thickness, representing sediments of a siliclastic ramp and a carbonate ramp, as well as mixed carbonate-siliciclastic sediments. These Middle Jurassic sediments range in age from Bajocian (possibly Aalenian) to Callovian.

Amongst the Middle Jurassic benthic communities of Kachchh, pholadomyoid bivalves are one of the dominant groups in both diversity and quantity. These are represented by 13 genera, viz. *Pholadomya* G.B. SOWERBY, 1823, *Agrawalimya* SINGH, JAITLEY & PANDEY, 1982, *Girardotia* DE LORIO, 1903, *Goniomya* AGASSIZ, 1841, *Homomya* AGASSIZ, 1843, *Osteomya* MOESCH, 1874, *Pachymya* J. DE C. SOWERBY, 1826, *Machomya* DE LORIO, 1868, *Ceratomya* SANDBERGER, 1864; *Ceratomyopsis* COSSMANN, 1915, *Pleuromya* AGASSIZ, 1843,

Platymoidea COX, 1964, and *Thracia* J. DE C. SOWERBY, 1823. The genus *Agrawalimya* SINGH, JAITLEY & PANDEY is endemic whereas the rest is cosmopolitan in distribution. These genera are represented by 30 constituent species, of which only six species are endemic and the remaining ones are cosmopolitan. Distribution of these bivalves was much affected by the evolutionary history of the basin which is a rift basin that has been inundated by the sea sometime during the Middle Jurassic owing to the opening of the Arabian Sea. By and large these faunas are characteristic of the southern hemisphere and belonged to the East African biochore of the Tethyan Realm or to the so-called Ethiopian faunal province. An attempt has been made to ascertain the usefulness of these pholadomyoids by analysing their (palaeo-) autecology and distribution pattern in different parts of the globe in evaluating the Middle Jurassic palaeobiogeography and to establish the migrating routes within the Tethyan Realm vis-à-vis the Boreal Realm.

Jurassic-Cretaceous plant mega- and microfossils from subsurface Gondwana sediments of the Jangareddygudem area, Chintalapudi subbasin, India

NEERJA JHA*, NEERU PRAKASH & HARINAM JOSHI

Birbal Sahni Institute of Palaeobotany, 53 University Road Lucknow - 226007, India; E-mail: neerjajha@yahoo.co.uk

**Corresponding author*

The Godavari Graben – one of the biggest Gondwana basins of India, contains a more or less complete succession from Permian to Cretaceous age. Regional exploration for coal and other minerals in the Jangareddygudem area of the Chintalapudi sub-basin was undertaken by SCCL and MECL in order to establish the structure, stratigraphy, and coal potentiality of the area. Core samples from different depth levels were collected for palynological studies. Impressions/compressions of plant fossils at various depth levels were observed in the core samples of borehole MJR- 11. In spite of the fragmentary nature of fossils, the external morphological features, i.e. shape and venation pattern of the leaves are quite distinct and permit identification up to specific level. Occurrence of the well preserved Mesozoic Upper Gondwana “*Ptilophyllum*” flora comprising *Ptilophyllum cutchense*, *P. acutifolium*, *Pachypteris indica*, *Elatocladus jabalpurensis*, *Pagiophyllum gollapalensis*, and equisetaceous axes have been recovered from the depth range of 293-398 meters in the borehole MJR-11. The assemblage is dominated by bennettitalean fronds and conifers. Pteridosperms are represented only by the genus *Pachypteris*. Ferns are absent. Gingkoales and Pentoxylales are not recorded. The assemblage is quite similar to the Gollapalle Formation described by PANDYA & SUKH-DEV (1990) and the Sehora flora of the Jabalpur Formation in the common occurrence

of *Pachypteris*, Equisetalian axes, *Ptilophyllum*, *Elatocladus*, and *Pagiophyllum*.

Palynological studies carried out on these megafossil-bearing sediments of borehole MJR-11 have revealed the presence of Jurassic–Cretaceous palynomorphs in the Jangareddygudem area. A variety of palynomorphs has been recorded between 293-398 m depth in borehole MJR-11. The palynoassemblage consists of *Callialasporites trilobatus*, *Ischyosporites*, *Matonisporites*, *Foveosporites*, *Aequitriradites*, *Appendicisporites*, *Lametriletes*, *Coronatispora*, *Impardecispora*, *Concavissimisporites*, *Podocarpidites*, *Astropollis*, *Triporoletes*, *Deltoidospora*, *Klukisporites*, *Contignisporites*, *Gleicheniidites senonicus*, *Chasmatosporites*, *Minutosaccus*, *Cyathidites*, *Brachysaccus*, *Osmudacidites*, *Hamiapollenites*, *Alisporites*, *Playfordiaspora*, *Schizosporis*, *?Goubinisporea*, and *Laevigatosporites*. Tricolpate and monocolpate pollen are very rare.

The present paper deals with the integrated palaeobotanical and palynological studies of terrestrial deposits of the Jangareddygudem area. Both plant mega- and microfossils indicate a Late Jurassic – Early Cretaceous age of these sediments.

References

- PANDYA & SUKH-DEV 1990. Fossil Flora of Gollapalle Formation. In: JAIN K.P. & TIWARI R.S. (eds.). - Proceedings of Symposium Vistas in Indian palaeobotany. - Palaeobotanist 38: 147–154.

Environmental significance of the trace fossils of Middle Jurassic rocks, Patcham Island, Kachchh, western India

JAQUILIN K. JOSEPH¹, SATISH J. PATEL¹ * & NISHITH Y. BHATT²

¹Department of Geology, The M. S. University of Baroda, Sayajiganj, Vadodara – 390 002, India; E-mail: sjpatel@gmail.com

²Department of Geology, M.G. Science Institute, Navrangpura, Ahmedabad – 380 009, India

*Corresponding author

The Patcham Island is the westernmost island of the island belt of northern Kachchh and is 70 km north of Bhuj, the district headquarter. It lies between N23°43'43" to 24°00'22" and E69°40'00" to 69°58'40" and covers an area of ~550 km². The present investigation was also extended to Kuar bet, a small islet that lies 2 km northwest of Patcham Island, between N23°58'30" to 24°03'30" and E69°42'00" to 69°45'30". The Patcham Island consists of two hill ranges, Kaladongar and Goradongar. The study area comprises the well developed oldest Mesozoic succession of Kachchh which ranges in age from Bajocian to Callovian.

BISWAS (1977) classified the Mesozoic rocks of Patcham Island into two formations, the lower Kaladongar and the upper Goradongar Formation (Fig.1); both formations have been further subdivided into seven members. The

Kaladongar Formation comprises a ~465-m-thick sequence and is subdivided into three informal members; (i) Dingy Hill/Kuar Bet member (Bajocian), (ii) Kaladongar Sandstone member (Bathonian), and (iii) Babia Cliff Sandstone member (Bathonian). These rocks are highly fossiliferous containing abundant bivalves, gastropods, brachiopods, corals, and echinoderms. A succession of limestones, shale, and sandstones, above the Kaladongar Formation is grouped under the Goradongar Formation. This formation is ~152 m thick and has been subdivided into four informal members: the (i) Goradongar Flagstone, (ii) Gadaputa Sandstone, (iii) Raimalro Limestone and (iv) Modar Hill members (BISWAS 1977). It is Bathonian-Callovian in age (FÜRSICH et al. 1994) and mainly consists of mixed siliciclastic-carbonate sediments with shales and limestones

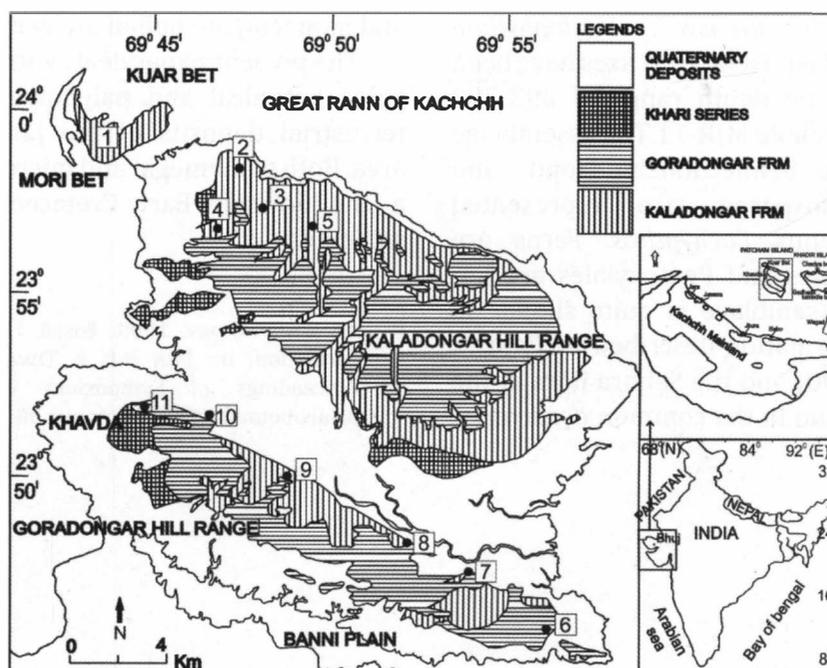


Fig. 1. Location and geological map of study area.

Table 1. Distribution of trace fossils in different ichnoassemblage and their probable depositional environments.

Ichnoassemblage	Associated trace fossils	Characteristics	Depositional environments
<i>Arenicolites</i> assemblage	<i>Arenicolites carbonarius</i> , <i>A. statheri</i> , <i>A. isp.</i> , <i>Thalassinoides nodosus</i> , <i>Palaeophycus tubularis</i> , <i>Rhizocorallium irregulare</i> , <i>Monocraterion tentaculatum</i> , <i>Skolithos linearis</i> , <i>Planolites beverleyensis</i> , <i>Diplocraterion parallelum</i> , <i>Taenidium serpentinum</i> , <i>Ophiomorpha nodosa</i> , <i>Helicolithus sampelayoi</i> , <i>Chondrites targionii</i>	Dominance of suspension- over deposit-feeders	Foreshore to middle shoreface
<i>Asterosoma</i> assemblage	<i>Asterosoma radiforme</i> , <i>A. cf. radiforme</i> , <i>A. ludwigae</i> , <i>Phycodes palmatus</i> , <i>Rhizocorallium irregulare</i> , <i>Thalassinoides horizontalis</i>	Deposit-feeders dominant over suspension-feeders; probable makers are crustacean decapods	Transitional zone to offshore
<i>Gyrochorte</i> assemblage	<i>Gyrochorte comosa</i> , <i>Didymaulichnus lyelli</i> , <i>Thalassinoides isp.</i> , <i>Arenicolites carbonarius</i> , <i>Palaeophycus tubularis</i> , <i>Laevicyclus isp.</i> , <i>Lockeia siliquaria</i> , <i>Gordia arcuata</i> , <i>Pilichnus isp.</i>	Deposit-feeders dominant over suspension-feeders; producers of these traces are crustaceans and polychaetes	Transitional zone to offshore
<i>Rhizocorallium</i> assemblage	<i>Rhizocorallium jenense</i> , <i>R. irregulare</i> , <i>R. uraliense</i> , <i>Diplocraterion parallelum</i> , <i>Gyrochorte comosa</i> , <i>Arenicolites carbonarius</i> , <i>Palaeophycus tubularis</i> , <i>Skolithos linearis</i> , <i>Phycodes palmatum</i> , <i>Asterosoma radiforme</i> , <i>Ophiomorpha nodosa</i> , <i>Lockeia siliquaria</i> , <i>L. amygdaloids</i> , <i>Walcottia devilsdingli</i> , <i>Protovirgularia dichotoma</i> , <i>B. coronus</i>	Suspension-feeders and deposit-feeders both dominant; structures formed by deposit feeders and mobile detritus-feeders	Middle shoreface to offshore
<i>Thalassinoides</i> assemblage	<i>Thalassinoides horizontalis</i> , <i>T. suevicus</i> , <i>T. isp.</i> , <i>Gordia arcuata</i> , <i>Rhizocorallium irregulare</i> , <i>R. jenense</i> , <i>Ophiomorpha nodosa</i> , <i>Arenicolites isp.</i> , <i>Phycodes cf. palmatum</i> , <i>Palaeophycus tubularis</i> , <i>Pilichnus isp.</i>	Opportunistic animals that exploited similar kind of niches; probable trace makers are crustaceans	Upper shoreface to Lower shoreface
<i>Planolites-Palaeophycus</i> assemblage	<i>Palaeophycus alternatus</i> , <i>P. striatus</i> , <i>P. tubularis</i> , <i>P. annulatus</i> , <i>Planolites beverleyensis</i> , <i>Lockeia siliquaria</i> , <i>Thalassinoides horizontalis</i> , <i>Arenicolites isp.</i> , <i>Rhizocorallium irregulare</i> , <i>R. jenense</i> , <i>Chondrites targionii</i>	Characterized by feeding and grazing traces; producers most probably like polychaetes	Transitional zone to offshore
<i>Phycodes</i> assemblage	<i>Phycodes circinatum</i> , <i>P. palmatus</i> , <i>P. cf. palmatus</i> , <i>P. cf. curvipalmatus</i> , <i>Asterosoma radiforme</i> , <i>Rhizocorallium irregulare</i> , <i>Hartsellea sursumramosa</i> , <i>Thalassinoides suevicus</i> , <i>Planolites beverleyensis</i>	Predominance of deposit-feeders over suspension-feeders; probable trace makers are vermiform annelids and crustaceans	Transitional zone to offshore
<i>Ophiomorpha</i> assemblage	<i>Ophiomorpha nodosa</i> , <i>Rhizocorallium irregulare</i> , <i>R. jenense</i> , <i>Skolithos linearis</i> , <i>Planolites beverleyensis</i> , <i>Arenicolites carbonarius</i> , <i>Thalassinoides nodosa</i> , <i>Palaeophycus tubularis</i> , <i>Chondrites targionii</i> , <i>Taenidium serpentinum</i> , <i>Rhabdoglyphus isp.</i>	Opportunistic behavior of organisms	Offshore to middle shoreface
<i>Skolithos</i> assemblage	<i>Skolithos linearis</i> , <i>Planolites beverleyensis</i> , <i>Arenicolites carbonarius</i> , <i>A. isp.</i> , <i>Monocraterion tentaculatum</i> , <i>Ophiomorpha nodosa</i> , <i>Palaeophycus tubularis</i> , <i>Chondrites targionii</i> , <i>Taenidium baretii</i>	Suspension- as well as the deposit-feeders; probable makers are vermiform annelids	Foreshore to middle shoreface

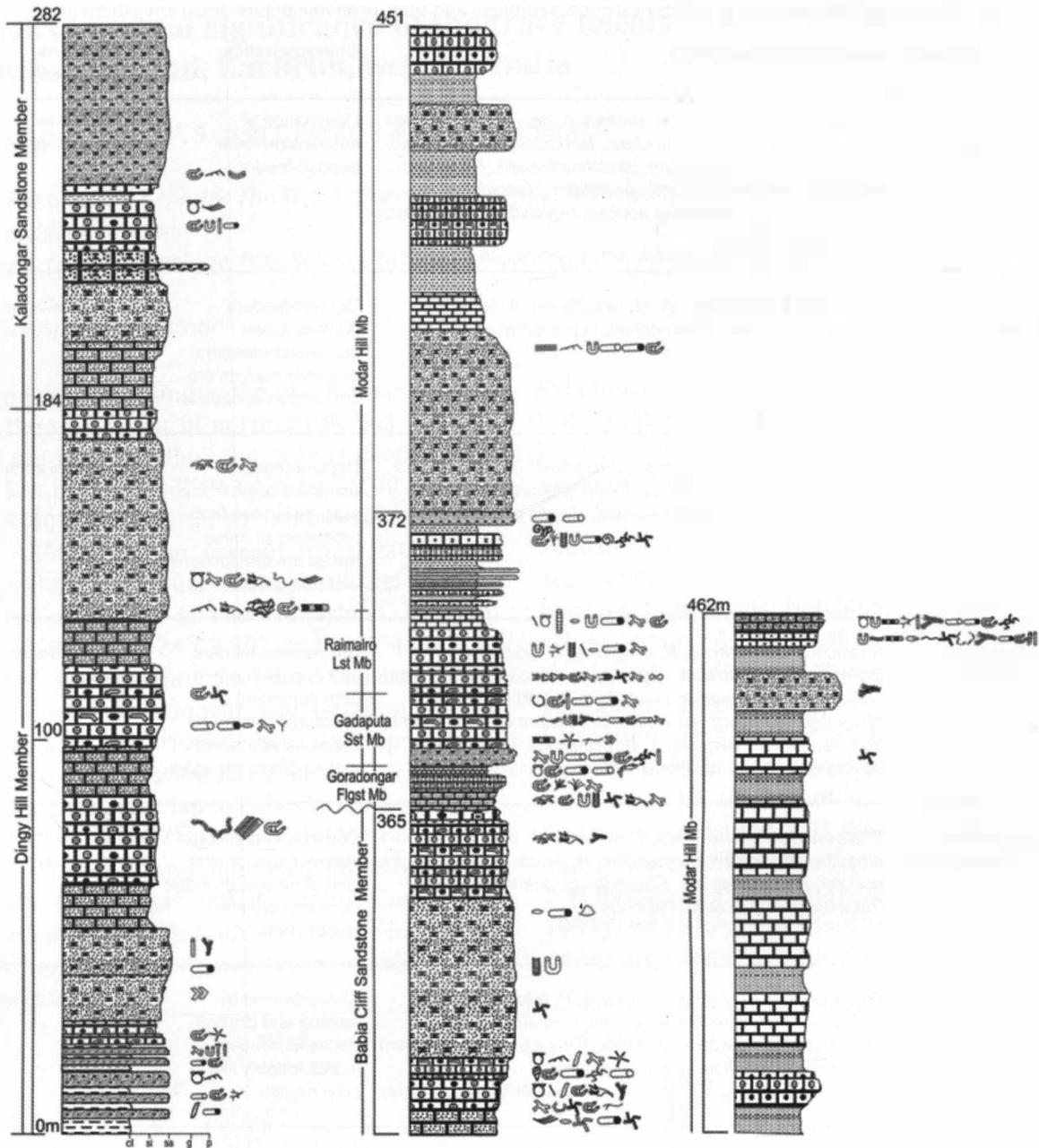


Fig. 2. Composite litholog showing the distribution of trace fossils in Middle Jurassic rocks of Patcham Island.

(PATEL et al. in press a, b).

The whole succession chiefly consists of mixed siliciclastic-carbonate dominated units whereby pure limestones and sandstones commonly are interbedded with shales (Fig. 2). Sedimentologically, the succession shows clear demarcation in composition; the Kaladongar Formation is characterized by siliciclastic-dominated mixed sediments, while the Goradongar Formation is composed of carbonate-dominated mixed sediments. The mixed sediments shows a wide range in their composition and are classified based on

the MOUNT (1985) classification scheme. A composite litholog of the Mesozoic succession of the Patcham Island based on bed forms, lateral and vertical continuity, and structural characteristics is prepared. The shale also shows variation in composition: the lower part of the succession is more argillaceous, while the upper part is more calcareous in nature. The base of the Kaladongar Formation consists of a granite-cobble-conglomerate but occasional intraformational conglomerates are also seen at different stratigraphic levels.

The whole succession is highly bioturbated

and consists of diverse groups of trace fossils; indistinct forms are also abundant. A total of 67 ichnospecies of 43 ichnogenera were identified and further were grouped into five ethological categories based on behavioural patterns. Many trace fossil species reappear throughout the succession and are observed with different combinations leading to an increase in trace fossils diversity but each layer is characterized by a single ecologically-related group of trace fossils forming nine recurring ichnoassemblages namely, *Arenicolites*, *Asterosoma*, *Gyrochorte*, *Rhizocorallium*, *Thalassinoides*, *Planolites-Palaeophycus*, *Phycodes*, *Ophiomorpha*, and *Skolithos* assemblage.

Each ichnoassemblage is distinguishable by a number of ecological parameters and hence reflects the most dominant physical parameter that is responsible for the deposition of the sedimentary succession of the Patcham Island. The ichnoassemblages indicate the development of the Skolithos, Mixed Skolithos-Cruziana and Cruziana ichnofacies. The trace fossils data reveal six distinct depositional facies which include offshore, offshore transitional zone, lower shoreface, middle shoreface, upper

shoreface, and foreshore facies (Table 1). The ichnoassemblages of the Mesozoic succession of the Patcham Island indicate cyclicity in environmental facies and reflect fluctuating energy conditions and sea levels during Bajocian to Callovian times.

References

- BISWAS, S.K. 1980. Mesozoic rock stratigraphy of Kutch, Gujarat. – Quarterly Journal of the Geological, Mining and Metallurgical Society of India 49: 1–52. [for 1977]
- FÜRSICH, F.T., PANDEY, D.K., CALLOMON, J.H., OSCHMANN, W. & JAITLEY, A.K. 1994. Contributions to the Jurassic of Kachchh, western India. II. Bathonian stratigraphy and depositional environment of the Sadhara Dome, Pachchham Island. – *Beringeria* 12: 95–125.
- MOUNT, J. 1985. Mixed siliciclastic and carbonate sediments: a proposed first order textural and compositional classification. – *Sedimentology* 32: 435–442.
- PATEL, S.J., JAQUILIN, K.J. & BHATT, N.Y. in press, a. Sequence Stratigraphic Analysis of the Mixed Siliciclastic-Carbonate Sediments (Middle Jurassic) of the Patcham Island, Kachchh, Western India: An Ichnological Approach. – *Journal of Geological Society of India*.
- PATEL, S.J., JAQUILIN, K.J., AND BHATT, N.Y. in press, b. Ichnology of the Goradongar Formation, Goradongar Hill Range, Patcham Island, Kachchh, Western India. – *Journal of Geological Society of India*.

Towards an integrated Jurassic biostratigraphy for eastern Greenland

SIMON R. A. KELLY¹ *, F. JOHN GREGORY², BILL BRAHAM³, DOMINIC P. STROGEN⁴ & ANDREW G. WHITHAM¹

¹CASP, University of Cambridge, West Building, 181a Huntingdon Road, Cambridge CB3 0DH, United Kingdom; E-mail: simon.kelly@casp.cam.ac.uk

²11 Corner Hall, Hemel Hempstead, Herts HP3 9HL, United Kingdom; E-mail: billbraham1957@yahoo.co.uk

³Petrostrat Ltd, Tan-y-Craig, Parc Caer Seion, Conwy, Wales LL32 8FA, United Kingdom; E-mail: john.gregory@petrostrat.com

⁴GNS Science, 1 Fairway Drive, Avalon, PO Box 30-368, Lower Hutt, New Zealand; E-mail: dominic.strogen@gmail.com

*Corresponding author

The thick and relatively complete Jurassic succession of eastern Greenland provides a unique biostratigraphic record for the North Atlantic region. The main biostratigraphic control for the succession has been provided by molluscs, especially ammonites and to a lesser extent by bivalves and belemnites. For example the late John Callomon and colleagues recognised 86 boreal ammonite-bearing horizons in the Mid to Late Jurassic, allowing an average duration of less than 300,000 years for each interval. Palynological and micropalaeontological schemes for Greenland remain less comprehensive, but continue to improve. Offshore in the North Sea a precision of about 700,000 and 1,000,000 years can be achieved by palynomorphs and micropalaeontology respectively. The Greenland succession provides an important opportunity to integrate the micropalaeontology and palynology into the well-documented and more detailed ammonite macrofaunal succession. Collecting directly from outcrop often achieves better and more accurate results than from recovered chippings from cored samples. Seldom are continuous cores available for analysis from mudstone successions and only rarely are macrofossils

such as ammonites recovered.

Reliance upon any single organism group can only provide an incomplete biostratigraphic picture, especially when one moves from marine to non-marine environments. This is particularly so for the Early Jurassic rocks of eastern Greenland. Integrated data is very important here as no single biostratigraphic group can be used successfully throughout, and there are only three significant ammonite faunas during this period.

CASP field-work from 1990 to 2012 has resulted in the collection of much biostratigraphic material which has been documented using *Stratabugs*. In this article published data are summarised together with previously unpublished data in table form. The integrated charts have detailed columns for ammonite biozones and horizons, palynological and microfossil biozones. More limited information is available on belemnites, bivalves and macroflora. This integrated biostratigraphy for eastern Greenland is of importance for the offshore oil-industry in the northern North Atlantic and Barents Shelf as well as to students of the Jurassic outcrops of Scotland, onshore Norway and Svalbard.

Palaeoenvironmental changes through a Panthalassic margin record of the early Toarcian Oceanic Anoxic Event

DAVID KEMP¹ * & KENTARO IZUMI²

¹*Environment, Earth and Ecosystems, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK; E-mail: david.kemp@open.ac.uk*

²*Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan; E-mail: izumi@eps.s.u-tokyo.ac.jp*

**Corresponding author*

The early Toarcian Oceanic Anoxic Event (OAE, 182 Ma) represents one of the most severe environmental perturbations of the Phanerozoic. A key diagnostic feature of the event is a -4 to -8‰ excursion in the C-isotope composition of marine organic matter, marine carbonate and terrestrial plant material. In addition, there is evidence during the event for elevated rates of faunal turnover, seawater warming, an increase in global weathering rates, and widespread seawater deoxygenation. To date, the majority of the evidence for palaeoenvironmental change during the early Toarcian OAE has come from European (i.e. Tethyan and Boreal) localities, and the record of the event from the Panthalassic Ocean margin is poorly known. Previous studies have identified the event from Panthalassic successions based on the negative C-isotope excursion (e.g., AL-SUWAIDI et al. 2010; IZUMI et al. 2012). Presently however, geochemical data that can be used to inform our understanding of weathering and redox conditions through these successions have not been reported. This is important, however, because although it has been demonstrated that the carbon cycle perturbation during the event was a global phenomenon, outstanding questions remain over the precise extent and timing of weathering and redox changes in different parts of the world. To address this issue, we have sampled and studied at high resolution a record of the early Toarcian OAE deposited on the shelf of the western margin of the Panthalassic Ocean. The succession, part of the Nishinakayama Formation of the Tabe Basin

exposed in the Sakuraguchi-dani valley, Toyora area of SW Japan, consists of organic-rich siltstones and mudstones, with intercalated sandstone horizons. We have defined more precisely the structure of the C-isotope event in this succession by augmenting previously published C-isotope data with higher resolution C-isotope analyses of organic matter. Moreover, we have allied these isotopic data with high-resolution elemental (XRF) and organic geochemical data. We have used these data to assess in detail the precise nature of palaeoredox changes occurring before, during and after the event, and how these changes relate to coeval changes in C-isotopes. Our data highlight differences in the timing of seawater deoxygenation relative to C-isotope changes in the Tabe Basin compared to European sections. In addition, our elemental data across the event suggest the presence of changes in the nature and flux of sediment into the basin, possibly in relation to changes in relative sea level, but also perhaps as a consequence of hydrological changes driven by the event itself.

References

- AL-SUWAIDI, A.H. et al. 2011. First record of the Early Toarcian Oceanic Anoxic Event from the Southern Hemisphere, Neuquen Basin, Argentina. – *Journal of the Geological Society of London* 167: 633–636
- IZUMI, K. et al. 2012. Early Toarcian (Early Jurassic) oceanic anoxic event recorded in the shelf deposits in the northwestern Panthalassa: Evidence from the Nishinakayama Formation in the Toyora area, west Japan. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 315–316: 100–108.

High-resolution microfossil results from the Toarcian Oceanic Anoxic Event, Yorkshire, UK

ALICE E. KENNEDY¹ *, ANGELA L. COE¹, WILLIAM D. GOSLING¹ & JAMES B. RIDING²

¹*Department of Environment, Earth and Ecosystems, Centre for Earth, Planetary, Space and Astronomical Research, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK; E-mail: alice.kennedy@open.ac.uk, a.l.coe@open.ac.uk, william.Gosling@open.ac.uk*

²*British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK; E-mail: jbri@bgs.ac.uk*

*Corresponding author

The ecological specialism of microfossils, together with their ability to produce in high numbers, good preservation in the fossil record, and small size makes them highly sensitive and very suitable as a proxy for examining environmental change on short time-scales. In this study, we present new high-resolution data on the range and abundance of foraminifera, terrestrial palynomorphs and dinoflagellates from strata recording the extreme environmental changes driven by the Toarcian Oceanic Anoxic Event.

The Toarcian (Early Jurassic) Oceanic Anoxic Event (OAE) is marked by the widespread deposition of organic-rich mudrocks and a pronounced carbon-isotope excursion that contains four abrupt shifts (e.g. KEMP et al. 2011). A wide range of other geochemical proxies indicate that extreme environmental change occurred at this time including: a shift in oxygen-isotope composition interpreted to represent a 7 to 13°C rise in global temperatures (BAILEY et al. 2003; DERA et al. 2009); changes in the osmium- and strontium-isotope compositions indicating enhanced rates of chemical weathering (COHEN et al. 2004) and a change in the molybdenum-isotope composition interpreted as reflecting a global increase in the areal extent of marine anoxia (PEARCE et al. 2008). The interval between the Pliensbachian-Toarcian boundary and the Toarcian OAE is associated with a mass extinction. This extinction affected the marine invertebrate realm most severely. CASWELL et al. (2009) present a summary of the evidence for the extinction from previous studies and, with the additional of new data, identify one true extinction horizon which corresponds with the first abrupt negative carbon-isotope shift during the Toarcian OAE.

Previous microfossil studies on the Toarcian OAE show a number of profound changes including a decrease in size of foraminifera followed by a barren interval (HYLTON 2000), changes in abundance of terrestrial palynomorphs and dinoflagellates and an increase in the abundance of extremophiles, *Tasmanites*, and sphaeromorphs which coincides with a disappearance event of dinoflagellates (BUCEFALO PALLIANI et al. 2002). However, all of these studies were completed prior to the high-resolution geochemical and macrofossil data set for the Toarcian OAE which demonstrates changes on the 1000 to 10,000s year scale.

To achieve a higher resolution and regular data set directly comparable with the geochemistry, we have collected samples through the Toarcian OAE every 2.5 cm. We have used the same stratigraphic positions and North Yorkshire, UK coast sections as the published high-resolution geochemical proxies (e.g., KEMP et al. 2011; PEARCE et al. 2008) and macrofossils (CASWELL et al. 2009). Our results show: (i) extensions to the range of some foraminifera species; (ii) changes in the diversity of foraminifera; (iii) changes in the relative abundance of foraminifera and microgastropods/microbivalves and (iv) that the abundance of palynomorphs and dinoflagellates varies on short time-scales that are closely linked to environmental changes indicated by the geochemical proxies.

Our preliminary results demonstrate that the previously used, and fairly standard, extraction technique for Toarcian foraminifera from indurated organic-rich mudrocks using hydrogen peroxide (e.g., HYLTON 2000; REOLID et al. 2012) resulted in corrosion and may have extended or potentially caused the

apparent foraminiferal barren interval. We have developed a new method involving repetitive freeze-thawing followed by soaking in white spirit and sodium hexametaphosphate. This has resulted in increased disaggregation of the sample from 5 to 50% and the extraction of a more diverse and abundant assemblage of foraminifera than previously reported from the same stratigraphic interval. The microfossils also demonstrated no evidence of damage.

References

- BAILEY, T.R., ROSENTHAL, Y., MCARTHUR, J.M., VAN DE SCHOOTBRUGGE, B. & THIRLWALL, M.F. 2003. Paleooceanographic changes of the Late Pliensbachian-Early Toarcian interval: a possible link to the genesis of an Oceanic Anoxic Event. – *Earth and Planetary Sciences* 212: 307–320.
- BUCEFALO PALLIANI, R.B., MATTIOLI, E. & RIDING, J.B. 2002. The response of marine phytoplankton and sedimentary organic matter to the early Toarcian (lower Jurassic) oceanic anoxic event in northern England. – *Marine Micropaleontology* 46: 223–245.
- CASWELL, B.A., COE, A.L. & COHEN, A.S. 2009. New range data for marine invertebrate species across the early Toarcian (Early Jurassic) mass extinction. – *Journal of the Geological Society* 166: 859–872.
- COHEN, A.S., COE, A.L., HARDING, S.M. & SCHWARK, L. 2004. Osmium isotope evidence for the regulation of atmospheric CO₂ by continental weathering. – *Geology* 32: 157–160.
- DERA, G., PUCÉAT, E., PELLENARD, P., NEIGE, P., DELSATE, D., JOACHIMSKI, M.M., REISBERG, L. & MARTINEZ, M. 2009. Water mass exchange and variations in seawater temperature in the NW Tethys during the Early Jurassic: Evidence from neodymium and oxygen isotopes of fish teeth and belemnites. – *Earth and Planetary Science Letters* 286: 198–207.
- HYLTON, M. 2000. Microfaunal investigation of the Early Toarcian (Lower Jurassic) extinction event in N.W. Europe. – Unpubl. PhD Thesis, University of Plymouth.
- KEMP, D. B., COE, A.L., COHEN, A.S. & WEEDON, G.P. 2011. Astronomical forcing and chronology of the early Toarcian (Early Jurassic) oceanic anoxic event in Yorkshire, UK. – *Paleoceanography* 26: 1–17.
- PEARCE, C.R., COHEN, A.S., COE, A.L. & BURTON, K.W. 2008. Molybdenum isotope evidence for global ocean anoxia coupled with perturbations to the carbon cycle during the Early Jurassic. – *Geology* 36: 231–234.
- REOLID, M., SEBANE, A., RODRIGUEZ-TOVAR, F.J. & MAROK, A. 2012. Foraminiferal morphogroups as a tool to approach the Toarcian Anoxic Event in the Western Saharan Atlas (Algeria). – *Palaeogeography, Palaeoclimatology, Palaeoecology* 323–325: 97–99.

Palaeobiogeographical study of the Middle-Upper Jurassic corals in East-Central Iran

KAVEH KHAKSAR¹ *, MANOOCHEHR FARBOODI² & ALIREZA KHAKSAR³

¹Department of Civil Engineering, Rudehen Branch, Islamic Azad University - Rudehen, Iran; E-mail: k.khaksar@riau.ac.ir

²Department of Soil Science, Islamic Azad University, Mianeh branch, Mianeh City, Iran; E-mail: farboodi@miau.ac.ir

³Islamic Azad University, Karaj branch, Karaj-Iran

*Corresponding author

During the Jurassic the Iranian platform was situated north of the equator and near the Euroasian platform. Corals are one kind of the most abundant Jurassic fossils in Iran, because of the best environmental conditions for growth and survival.

On the Iran Plate (Sanandaj-Sirjan, Central Iran, Alborz and Azerbaijan), Jurassic rocks are representative of two large and independent sedimentary cycles whose boundaries have been attributed to tectonic events. The first cycle is pertaining to the Lower to Middle Jurassic and contains coal-bearing shale and sandstone, which have been deposited in lagoonal and nearshore environments. Its thickness varies from several meters to over 3,000 meters. The lower boundary of this group is identified by the Early Cimmerian disconformity and the upper boundary by the Mid-Cimmerian event. The second sedimentary cycle is composed of ammonite-bearing limestones and marls and

ends with red siliciclastic strata or evaporates. Rocks in this sedimentary cycle have been deposited between two tectonic events; the Mid-Cimmerian (Middle Jurassic) and the Late Cimmerian (early Cretaceous) event. This sedimentary cycle is named Magu Group.

Located as a triangle in the middle of Iran, Central Iran is one of the most important and complicated structural zones in Iran. According to STÖCKLIN (1968), Central Iran is bordered by the Alborz Mountains in the north, Lut Block in the east, and Sanandaj-Sirjan in the south-southwest, whereas NABAVI (1976) considers the northern part of the Lut Block as part of the Central Iran (Fig. 1).

Fossiliferous marine beds of Early Jurassic age occur in the form of thin, ammonite-bearing sandstone and limestone intercalations in the plant bearing succession, the oldest ones, of Early Liassic (Sinemurian) age, have been found in the Kerman area. Paleontological

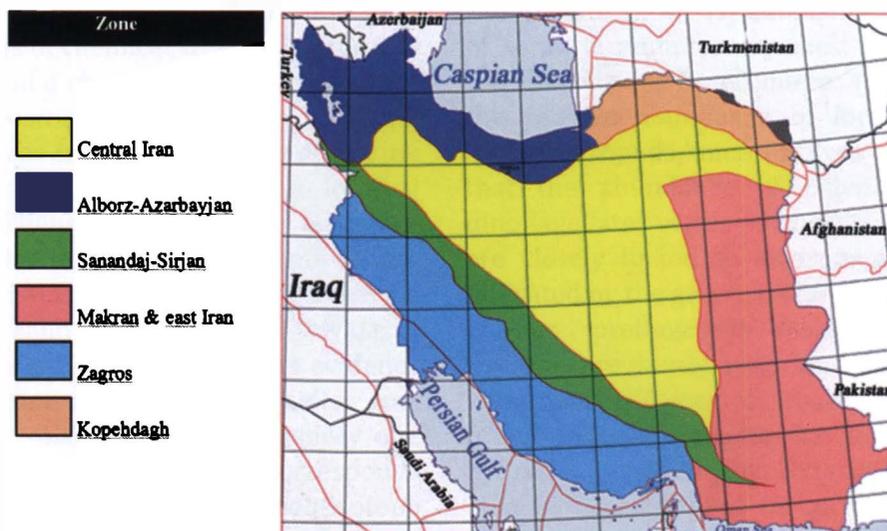


Fig. 1. Structural units of Iran.

evidence for marine Pliensbachian is uncertain. A widespread marine transgression is indicated in the Toarcian-Bajocian (Bathonian) of the Kerman-Yazd-Tabas area (Badamu Limestone). Calcareous deposits prevail in the Middle-Upper Jurassic and in the Upper Jurassic (Qaleh Dokhtar Fm., Esfandiar Limestone Fm. of East Iran).

The coral fauna from the Jurassic of Central Iran comprise 38 genera and have been studied for the first time by FLÜGEL (1966) from the Shotori Mountains, PANDEY & FÜRSICH (2003)

Table 1. Coral genera of Central-East Iran and their distribution in the different biogeographic provinces of Jurassic time.

Provinces Species	Iran	South America	North America	Europe	Eurasia	north Antarctic (India)	South-east Asia	South-west Asia	Africa	Madagascar
<i>Actinastrea</i>	★	★	★	★	★	★	★		★	
<i>Cyathophora</i>	★			★	★		★		★	
<i>Cyathophylliopsis</i>	★	★	★	★						
<i>Confusastraea</i>	★	★	★	★	★				★	
<i>Montlivaltia</i>	★	★	★	★	★	★	★	★	★	★
<i>Cyathophylliopsis</i>	★						★			
<i>Latiphyllia</i>	★			★	★					
<i>Confusastraea</i>	★	★		★	★	★			★	
<i>Favites</i>	★						★	★		
<i>Trigerastraea</i>	★	★		★			★	★	★	★
<i>Ampakabastraea</i>	★			★	★	★		★	★	★
<i>Stibastrea</i>	★					★				★
<i>Calamophylliopsis</i>	★			★	★		★	★	★	
<i>Dermosmilia</i>	★			★	★		★			
<i>Dimorphomeandra</i>	★			★						
<i>Craterastraea</i>	★					★		★	★	
<i>Latomeandra</i>	★						★			
<i>Dimorpharaea</i>	★			★	★	★	★	★	★	
<i>Periseris</i>	★			★				★		
<i>Acrosmilia</i>	★			★				★		
<i>Microsolena</i>	★			★	★		★	★	★	★
<i>Trochoplegma</i>	★			★		★		★		
<i>Rhipidogyra</i>	★			★	★				★	
<i>Codonosmilia</i>	★								★	
<i>Acanthogyra</i>	★			★			★			
<i>Thecosmilia</i>	★	★	★	★	★		★		★	
<i>Epistreptophyllum</i>	★			★	★	★	★	★	★	
<i>Trocharea</i>	★			★		★	★	★		
<i>Columnaphyllia</i>	★			★						

from east-central Iran and by KHAKSAR (2010) from the the Middle Shale Member of Qal-eh-Dokhtar Formation (Tabas area, East Iran).

If we exclude corals with endemic character, there are 30 genera in the Jurassic of Central Iran. Nine coral provinces have been established in the Jurassic: Europe, North America, South America, Australia, Madagascar, south-west Asia, south-east Asia, Euroasia, and Africa. Each province includes several zoogeographic areas. The Jurassic corals of Iran have been compared with corals of the different provinces (Table 1). As Table 1 shows the corals assemblages of Central-East Iran have the greatest similarity (23 common genera) with the European Province. For this reason the Central-East Iran basin is part of the European province in Jurassic paleozoogeography. East Asia and North Africa also exhibit important similarity with Central-East Iran (15 genera in common). West Asia and Euroasia show a stronger relationship towards the Late Jurassic with 13 genera in common. India has important similarity with the corals from the Central-East Iranian basin because of ten genera in common. Seven genera are shared with South America, and the common elements with provinces of northern America and Madagascar decrease to five genera. The greater the distance to other provinces, such as northern America and Madagascar, the smaller is the degree of similarity.

The similarity of the Central-East Iranian coral assemblage with European corals is accountable because both areas were comparatively close to each other, being situated on the northern margin of the Tethys during the Jurassic.

References

- FLÜGEL, E. 1966. Mitteljurassische Korallen vom Ostrand der Großen Salzwüste (Shotori-Kette, Iran). – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 126: 46–91.
- KHAKSAR, K. 2010. Stratigraphical position of Jurassic corals from Middle Shale Member of Gala-Dokhtar Formation (Tabas Area-East Iran). – The 8th International Congress on the Jurassic system, August 9-13, 2010, Shehong of Suining, Sichuan, China.
- NABAVI, M.H. 1976. An introduction to geology of Iran. – Geological Survey of Iran, Tehran. [in Persian]
- PANDEY, D.K. & FÜRSICH, F.T. 2003. Jurassic corals of east-central Iran. – Beringeria 32: 1–140.
- STÖCKLIN, J. 1968. Structural history and tectonics of Iran. A review. – American Association of Petroleum Geologists Bulletin 52: 1229–1258.

An overview of the Jurassic dinosaur fossil record from India: Implications for depositional facies and palaeoenvironments

ASHU KHOSLA

Centre of Advanced Study in Geology, Panjab University, Sector-14, Chandigarh-160014, India; E-mail: khosla100@yahoo.co.in

The record of Indian sauropod dinosaurs is now well known from the Lower Jurassic of Pranhita Godavari Valley, Adilabad District, Andhra Pradesh, southern India, and the Early Middle Jurassic of Kachchh, Gujarat. The Indian dinosaurian record starts with the Upper Dharmaram Formation (Andhra Pradesh), which is of Early Jurassic age (Sinemurian) and has yielded three sauropodomorph dinosaurs namely *Lamplughsaura dharmaramensis*, *Pradhania gracilis*, and an indeterminate one (KUTTY et al. 2007). *Lamplughsaura dharmaramensis* was a heavily built adult individual measuring about 10 m in length and represented by a partial postcranial skeleton containing teeth with hardly any or missing coarse denticles on the mesial edge. Other characteristic features include the caudal cervical neural spines exhibiting a vertically oriented ligamentous furrow on the cranial and caudal surfaces and the distal end of tibia covering about 66 % of transverse width of the astragalus (KUTTY et al. 2007). *Pradhania gracilis* is a small (4 m) adult dinosaur and is known by fragmentary material such as maxilla with a very prominent longitudinal ridge medially (KUTTY et al. 2007). The overlying early Jurassic Kota Formation of the Pranhita Godavari Valley has yielded three types of dinosaur skeletal material. The first type contains numerous cranial and postcranial bones of a large sauropod, *Barapasaurus tagorei*, which has slender limbs, and spoon-shaped teeth with coarse denticles. The ilium possesses a well-developed anterior process, the ischium is relatively slender and rod-like distally, and the pubis has a well-developed terminal expansion (JAIN et al. 1975). The second sauropod *Kotasaurus yamanpalliensis* is represented by more than twelve individuals and characterized by dorsal vertebrae and a low iliac blade (YADAGIRI 1988, 2001). The third dinosaur type belongs to ornithischia (ankylosauria) and the

material includes parts of skull, teeth, large number of body armour plates, vertebrae, and parts of girdle bones (NATH et al. 2002). The sediments of the Dharmaram Formation are represented by alternating pebbly, coarse cross-bedded sandstones, red clays, and mudstones and show an upward-fining sequence, which seems to have been deposited under a laterally shifting meandering stream (RUDRA 1982). The Kota Formation conformably overlies the Dharmaram Formation. The Kota Formation represents a typical continental deposit and, based on lithologies, shows two different kinds of facies. The lower part of Kota Formation is composed of fine-grained cross-bedded, poorly sorted arkosic sandstones (250 m) with pebbles of banded chert, red mudstones and yellow green clays (50 m) at the base, and was deposited in a fluvial environment (river deltas). The sequence is overlain by creamy, bedded limestone and calcareous shale, which are further overlain by a 100-m-thick sequence of mudstones, sandstones, siltstones, and ferruginous clays with desiccation cracks suggesting deposition in inland lakes (YADAGIRI & RAO 1987; FEIST et al. 1991). The invertebrate fauna is represented by ostracodes, charophytes, and floral elements such as pollens but the vertebrate fauna especially of the Kota Formation is represented by semionotid fishes (*Lepidotes*, *Parapedium* and *Tetragonolepis*), sauropod dinosaurs, a pterosaur (*Campylognathoides*), a coelacanth (*Indocoelacanthus robustus*), teleosaurid crocodiles, turtles, lizards, and mammals that are indicative of aquatic, terrestrial, playa-type lakes with increased salinity possibly resulting from an arid climate and arboreal habitat (JAIN et al. 1975; RUDRA 1982; LOYAL et al. 1996; NATH et al. 2002).

In Western India, Kachchh (Gujarat) represents the classical area for the study of Jurassic dinosaurs. Fragmentary dinosaur skeletal material comprising vertebrae and

limb elements along with large petrified wood pieces has been recorded from a coarse-grained sandstone and conglomerate horizon of Kuar Bet, Patcham Island which is of ?Aalenian-Early Bajocian age (earliest Middle Jurassic; SATYANARAYANA et al. 1999). Dinosaur bone-rich horizons are well exposed in the Dingy Hill member of the Kaladongar Hill range (Patcham Island) and Kuar Bet of northern Kachchh. The Kaladongar Formation (a 450-m-thick sequence), consists of mixed siliciclastic-carbonate sediments intercalated with shales, and this formation represent six different facies (micritic mudrock, micritic sandstone, muddy micrite, sandy micrite, allochemic sandstone and sandy allochemic limestone (JOSEPH et al. 2012). Based on sedimentological and trace fossil studies the depositional environments of the dinosaur-bearing Kaladongar Formation represent nearshore (SATYANARAYANA et al. 1990) and foreshore to offshore environments under fluctuating wave and current energy (JOSEPH et al. 2012). The overlying marine Chari Formation, which is Callovian in age, is 200 m thick and is primarily composed of shale, sandstone and limestone and has yielded the proximal part of a hind limb bone (tibia) of a sauropod dinosaur from Jumara, Kachchh Mainland (JANA & DAS 2002). The dinosaur bone was associated with ammonites and was deposited in warm, shallow marine shelf facies (JANA & DAS 2002). More recently, fragmentary scattered remains of massive sauropods of Middle Jurassic (Bajocian) age have also been recovered from non-marine parts of the Khadir Formation of Khadir Island (Kachchh). The material includes a metacarpal, a first pedal claw and a fibula, which belongs to the Camarasauromorpha and represents the oldest evidence of that derived dinosaur group (MOSER et al. 2006).

References

- FEIST, M., BHATIA, S.B. & YADAGIRI, P. 1991. On the oldest representative of the family Characeae and its relationship with the Porocharaceae. – *Bulletin de la Societe botanique de France* 138: 25–32.
- JANA, S.K. & DAS, S.S. 2002. A report of a 157.8 m.y.-old dinosaur bone from the Jurassic marine Chari Formation, Kutch, Gujarat and its taphonomic significance. – *Current Science* 82 (1): 85–88.
- JAIN, S.L., KUTTY, T.S., ROY CHOWDHURY, T. & CHATTERJEE, S. 1975. The sauropod dinosaur from the Lower Jurassic Kota Formation of India. – *Proceedings of the Royal Society, London Series A* 188: 221–228.
- KUTTY, T.S., CHATTERJEE, S., GALTON, P.M. & UPCHURCH, P. 2007. Basal sauropodomorphs (Dinosauria: Saurischia) from the Lower Jurassic of India: Their anatomy and relationships. – *Journal of Paleontology* 81: 1218–1240.
- JOSEPH, J.K., PATEL, S.J. & BHATT, Y. 2012. Trace fossil assemblages in mixed siliciclastic-carbonate sediments of the Kaladongar Formation (Middle Jurassic), Patcham Island, Kachchh, Western India. – *Journal of the Geological Society of India* 80: 189–214.
- LOYAL, R.S., KHOSLA, A. & SAHNI, A. 1996. Gondwanan dinosaurs of India: affinities and palaeobiogeography. – *Memoirs of the Queensland Museum* 39: 627–638.
- MOSER, M., MATHUR, U.B., FÜRSICH, F.T., PANDEY, D.K. & MATHUR, N. 2006. Oldest camarasauromorph sauropod (Dinosauria) discovered in the Middle Jurassic (Bajocian) of the Khadir Island, Kachchh, western India. – *Paläontologische Zeitschrift* 80: 34–51.
- NATH, T.T., YADAGIRI, P. & MOITRA, A.K. 2002. First record of armoured dinosaur from the Lower Jurassic Kota Formation, Pranhita-Godavari valley, Andhra Pradesh. – *Journal of the Geological Society of India* 59: 575–577.
- RUDRA, D.K. 1982. Upper Gondwana stratigraphy and sedimentation in the Pranhita-Godavari Valley, India. – *Quarterly Journal of the Geological, Mining and Metallurgical Society of India* 54 (3 and 4): 56–79.
- SATYANARAYANA, K., DASGUPTA, D.K., DAVE, A. & DAS, K.K. 1999. Record of skeletal remains of dinosaur from early Middle Jurassic of Kuar Bet, Kutch, Gujarat. – *Current Science* 77: 639–641.
- YADAGIRI, P. 1988. A new sauropod *Kotasaurus yamanpalliensis* from Lower Jurassic Kota Formation of India. – *Records of the Geological Survey of India* 11: 102–127.
- YADAGIRI, P. 2001. The osteology of *Kotasaurus yamanpalliensis*, a sauropod dinosaur from the Early Jurassic Kota Formation of India. – *Journal of Vertebrate Palaeontology* 21: 242–252.
- YADAGIRI, P. & RAO, B.R.J. 1987. Contribution to the stratigraphy and vertebrate fauna of Lower Jurassic Kota Formation, Pranhita-Godavari valley, India. – *The Palaeobotanist* 36: 230–244.

Ostracod biostratigraphical zonation of the Middle Jurassic beds of western India - a review

S. C. KHOSLA

GA-11, Sector 5, Hiran Magri, Udaipur – 313 002, India; E-mail: sckhosla1@yahoo.com

The Middle Jurassic beds in western India are widely exposed in the Kachchh and Jaisalmer basins of Gujarat and Rajasthan states, respectively. These beds represent marine facies and are rich in both macro- and microfaunas. In the Kachchh Basin the beds crop out in three east-west trending anticlinal hill ranges and the isolated landmass of Wagad. The three hill ranges are broken up by transverse undulations into number of domes, the erosion of which has exposed successive beds in a concentric series of small scarps, which afford an ideal opportunity to the fossil collector. In the Jaisalmer Basin, the beds are exposed in a stretch extending between Thaiyat Village in the east and Ludharwa Village in the west of Jaisalmer city.

We (S.C. KHOSLA and his Ph.D. students S.R. JAKHAR, M.H. MOHAMMED, MANISHA KUMARI, A. DARWIN FELIX, and SANJAY DUBEY) of the Department of Geology, Mohanlal Sukhadia University, Udaipur have carried out extensive research work on the Middle Jurassic ostracods of Kachchh and Jaisalmer basins during the last two decades. We have described a total of 130 species from the Habo, Jhura, and Jumara domes of the Kachchh Mainland, Pachchham, Khadir, and Bela islands of the Northern Island Belt in the Rann of Kachchh and from the Jaisalmer Basin.

On the basis of the distribution of ostracods three range zones are recognized in the Middle Jurassic of the Kachchh Mainland. These are the Progonocythere laeviscula Range Zone (Late Bathonian – Early Callovian), Majungaella perforata kachchhensis Partial Range Zone

(middle Late Callovian) and Majungaella perforata kachchhensis – Galliaecytheridea remota Concurrent Range Zone (middle Late Callovian).

Five range zones are recognized in the Northern Island Belt. They are the Trichordis hadibhadangensis Range Zone (Bajocian–Bathonian), Cytheropteron micropunctata Range Zone (Bathonian), Progonocythere laeviscula Range Zone (Late Bathonian–Early Callovian), Fastigatocythere (Habocythere) mouwanaensis Range Zone (Callovian), and Majungaella perforata kachchhensis – Galliaecytheridea remota Concurrent Range Zone (middle Late Callovian).

Four range zones are recognized in the Jaisalmer District. They are the Trichordis hadibhadangensis Range Zone (Bajocian–Bathonian), Majungaella perforata kachchhensis – Fastigatocythere (Batella) falcata Concurrent Range Zone (Late Bathonian–Early Callovian), Majungaella perforata kachchhensis – Galliaecytheridea remota Concurrent Range Zone (middle Late Callovian), and the Majungaella perforata kachchhensis – Galliaecytheridea remota Interval Zone (middle Late Callovian).

The common zones in the Kachchh Mainland and the Jaisalmer Basin compare well with each other and are extremely useful in interbasinal correlation. They have been standardized with foraminiferal and ammonite zones, wherever possible.

The Jurassic-Cretaceous short-lived atoll coral reefs around active volcanoes in the Western Tethys (Ukrainian Carpathians)

MICHAŁ KROBICKI^{1,2}, ANNA FELDMAN-OLSZEWSKA³, JOLANTA IWAŃCZUK³ & OLEH HNYLKO⁴

¹Polish Geological Institute – National Research Institute, Królowej Jadwigi 1, 41-200 Sosnowiec, Poland; E-mail: michal.krobicki@pgi.gov.pl

²AGH University of Science and Technology, Mickiewicza 30, 30-059 Kraków, Poland; E-mail: krobicki@geol.agh.edu.pl

³Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland; E-mail: anna.feldman-olszewska@pgi.gov.pl, jolanta.iwanczuk@pgi.gov.pl

⁴Institute of Geology and Geochemistry of Combustible Minerals of NAS of Ukraine, Naukova 3a, 79060 Lviv, Ukraine; E-mail: ohnilko@yahoo.com

The Outer Flysch Carpathians is one of the biggest belt of stack of flysch nappes in Europe. It occupied a large part of central-European countries and is almost exclusively constructed by siliciclastic flysch-type rocks. In the frontal part of the Marmarosh Massif in the Ukrainian Carpathians the Outer Dacides-Severinides are represented by the Kamynnyi Potik and Rachiv units (nappes). The Rachiv nappe is represented by folded Lower Cretaceous flysch dipping generally toward the southwest under the Kamynnyi Potik unit and is overthrust on the Porkulets Nappe (SLACZKA et al. 2006 with references).

The other types of the flysch-type rocks are represented by rare occurrences of calcareous flysch (e.g., the Jurassic–Cretaceous so-called Cieszyn Formation in Czech Republic and Poland or its facial and stratigraphic equivalent – the Sinaia Beds in Romania), full of allodapic carbonate intercalations with shallow-water resedimented elements such as ooids, fragments of thick-shelled benthic fossils, green-algae, etc.

Extremely sporadic are pyroclastic turbidites which are concentrated within the Transcarpathian Ukrainian part of the Flysch Carpathians and occur in the Ukrainian–Romanian transborder zone (Kamynnyi Potik Unit).

The Kamynnyi Potik Unit (Nappe) occurs in the vicinity of Rachiv city and in the SE prolongation of this unit to the Chyvchynian Mountains. Such unique flysch-type rocks are usually developed as more or less thin intercalations both of coarse- and fine-grained calcareous pyroclastic beds within thin-bedded light- and dark-grey micritic limestones occasionally with lenses

of dark cherts. Sedimentologically we can interpret them as distal deep-marine lobes of turbidite fans. In contrast, more coarse-grained pyroclastic sandstones and fine-grained pyroclastic conglomerates could represent more proximal turbidites. All these rocks type exhibit typical flysch features including sharp base of beds with clasts of allochthonous material, fractionation of grains, ripple lamination, and increase of pelagic character of the topmost part of beds (up to micritic limestones). The most proximal facies displays a chaotic calcareous-pyroclastic breccia with blocks of the micritic and organodetritic limestones and basalts (even as pillow lava fragments) which occur within a volcanic/tuffitic matrix, and represent, most probably, submarine debris flows. In our reconstruction, this facies has a continuous transition to proximal flysch-type facies in the same basin on the one side, and to massive basaltic pillow lava flows on the other side, which often co-occur with these debris flows.

The volcanic-sedimentary complex of the Chyvchyn Mt. does not form a single stratigraphic sequence, as was assumed in previous studies. Recently, our geological mapping work showed that this complex forms the tectonic klippe which consists four small tectonic scales (HNYLKO et al. 2012). Structurally, the lowermost is developed as thin-bedded light- and dark-grey micritic limestones with lenses of dark cherts. It is interbedded with coarse-/fine-grained calcareous pyroclastic turbidites (flysch) (Kamynnyi Potik Fm.) and is similar to the stratotype of this formation in the Kamynnyi Potik stream near Rakhiv (KROBICKI 2012). The second scale mostly consists of

calcareous-pyroclastic breccia with blocks of the micritic and organo-detritic limestones and basalts which occur within a volcanic/tuffitic matrix, which represents, most probably, submarine debris flows (KROBICKI et al. 2013a, b). The third scale is composed of breccia with volcanic matrix and clasts of the effusive rocks (occasionally as pillow lava fragments) and rare limestones. The fourth scale crops out on the Chyvchyn peak and is represented by massive basalts with typical pillow lava structures. These successions have probably been formed during latest Jurassic/earliest Cretaceous time in the Outer Dacide-Severinide part of the Carpathian basins.

In both cases, in the Kamynnyi Potik section and the Chyvchyn Mt., we found biotrititic limestones full of corals and remains of other benthic fauna (brachiopods, bivalves, crinoids, etc). In the former section this type of limestones is overlain by biotrititic crinoidal limestones with several pyroclastic layer intercalations, which occur also within coral-bearing limestones. In the latter section a large thickness of debris flow is full of large blocks of coral limestones. In our opinion, most probably they represent short-lived atoll coral reefs, which surrounded volcanoes. The coral reefs did not survive for a long time due to extensive volcanic activity with huge amounts of pyroclastic ash and due to synsedimentary gravity debris flows that originated after rapid, big explosions of volcanoes.

In our opinion, the latest Jurassic – earliest Cretaceous volcanic activity in this part of the Carpathian basins could be one of the best keys to understanding the geodynamic history of the northernmost part of the Neotethys. These successions have probably been formed during the Jurassic–Cretaceous time in the Outer Dacide-Severinide part of the Carpathian basins. The Chyvchyn nappe could be a remnant of the

Transilvanides (MEDVEDEV & VARITCHEV 2000). Final clarification of this problem is impossible without the correlation of the Chyvchyn Mt. structures with the volcanic formations of the Romanian Carpathians (especially Farcaul and Mihailecul mounts).

References

- HNYLKO, O., KROBICKI, M., FELDMAN-OLSZEWSKA, A. & IWAŃCZUK, J. 2012. Volcanic-sedimentary complex of the Kamynnyi Potik Unit on the Chyvchyn Mount (Ukrainian Carpathians). In: JOZSA, Š., REHÁKOVÁ, D. & VOJTKO, R. (eds.), Environmental, Structural and Stratigraphical Evolution of the Western Carpathians. 8th Conference 2012, Abstract Book: 14, Bratislava.
- KROBICKI, M. 2012. Field trip. In: KROBICKI, M. (ed.), JURASSICA X: Jurassic-Lower Cretaceous deposits of the Pieniny Klippen Belt and surrounding areas (Ukraine – Transcarpathians, Eastern Slovakia). – Abstracts and field trip guide-book, Rakhiv-Beňatina 25-30.06.2012: 31–56. Państw. Inst. Geol. – PIB, Warszawa. [in Polish only]
- KROBICKI, M., HNYLKO, O., FELDMAN-OLSZEWSKA, A. & IWAŃCZUK, J. 2013a. Kamynnyi Potik Unit in the Ukrainian Carpathians and its volcanogenic rocks. In: FODOR, L. & KOVER, S. (eds.) 11th Meeting of the Central European Tectonic Studies Group (CETeG), Vargesztes (Western Hungary, Vertes and Gerecse Hills, Mor wine region), 24-27th April 2013, - Abstract Book: 38-40.
- KROBICKI, M., IWAŃCZUK, J., FELDMAN-OLSZEWSKA, A. & HNYLKO, O. 2013b. Jurajsko-kredowe utwory wulkanogeniczne jednostki kamiennopotockiej (gora Czywczyn, Karpaty Ukrainskie) – wstępne badania sedimentologiczne. In: KROBICKI, M. & FELDMAN-OLSZEWSKA, A. (eds.), V Polska Konferencja Sedymologiczna POKOS 5'2013. – Głębokomorska sedymencja fliszowa – sedymologiczne aspekty historii basenów karpaccich, 16-19.05.2013, Zywiec: 189–191.
- MEDVEDEV, A.P. & VARITCHEV, A. 2000. Pra-Carpathians (Construction and de-construction). 115 p., Lviv [in Ukrainian only]
- ŚLĄCZKA, A., KRUGLOV, S.S., GOŁONKA, J., OSZCZYPKO, N. & POPADYUK, I., 2006. Geology and hydrocarbon resources of the Outer Carpathians, Poland, Slovakia, and Ukraine: general geology. In: GOŁONKA, J. & PICHA, F. (eds.), The Carpathians and their foreland: geology and hydrocarbon resources. – AAPG Memoir 84: 221–258.

Palaeoenvironmental context and palaeoecological significance of microbialites – metazoan assemblages from condensed deposits at the Middle–Upper Jurassic transition (Getic Unit, Southern Carpathians, Romania)

IULIANA LAZĂR* & MIHAELA GRĂDINARU

Department of Geology, Faculty of Geology and Geophysics, University of Bucharest, 1 N. Bălcescu Bd, 010041 Bucharest, Romania; E-Mail: iuliana.lazar@g.unibuc.ro; mihaela.gradinaru@yahoo.com

**Corresponding author*

Condensed deposits and different types of related discontinuities represent distinguished patterns of the peri-Tethyan Jurassic successions, which were extensively studied for the evaluation of the palaeoenvironmental features of different parts of the sedimentary basins during the time intervals characterized by reduced sedimentation (FÜRSICH et al. 1992 and references therein) and also for the fascinating palaeoecology and evolution of their characteristic hard substrate communities (TAYLOR & WILSON 2003 and extensive references therein), as well as for the interesting taphonomy of their fossil assemblages. Sections with condensed deposits at the Middle-Upper Jurassic transition are well known from the peri-Tethyan Europe (Portugal, Spain, France, Switzerland, Germany, Poland, Hungary, and Romania). Numerous hypotheses have been proposed for the origin of these deposits, most of them being related to the tectonic events generated during the Jurassic by the recognized general extension in the Tethyan domain. In the southern Carpathians the effects of these tectonic events are recognized within the sedimentary successions belonging to the Getic Nappe, one of the major geotectonic units of the Median Dacides (SĂNDULESCU 1984). In the southern Carpathians, the sedimentary cover of the Getic Domain is represented by Triassic–Lower Cretaceous rocks preserved in different zones (e.g., Rucăr-Bran zone, Bucegi Mountains, Piatra Craiului Mountains), which evolved as segments of a ridge area (e.g., Leaota Ridge; cf. PATRULIUS 1969).

The aim of this contribution is to describe the interactions between different types of microbialites (such as ferruginous stromatolites/microstromatolites and agglutinated

stromatolites) and different metazoans (such as serpulid tube worms, agglutinated polychaete tube worms, bryozoans, and even arthropods) documented within the fossil assemblages of Middle Jurassic condensed sequences from the southern Carpathians in Romania.

Eight Jurassic sections represented by mixed carbonate-siliciclastic condensed sequences (Bajocian–Oxfordian) were studied, which are located in two main zones: the Rucăr-Bran zone and the Bucegi Mountains. The methodology for this study included complementary palaeontological, sedimentological, mineralogical, geochemical, and taphonomic approaches. One-hundred-fifty petrographic thin-sections have been prepared and analysed to determine the grain composition and the types of carbonate cements, microstructures, and microfacies types; thirty polished slabs were examined under the cathodoluminescence (CL) microscopy. Samples were also analysed for carbon and oxygen stable isotopes.

The sector of the Leaota ridge (corresponding to the studied zones) evolved during the Bajocian–Oxfordian interval from a mid- to distal shelf setting to a deep-water setting near the topmost part of the slope. Due to the faulting and differential subsidence of this ridge, the resulting fault blocks acted like short-lived swells where condensed deposits and Fe-mineralized hardgrounds formed. Contemporaneous tectonic activity related to the extensional processes within the strongly deformed European continental margin are, for the first time, documented in the studied zone by differences in thickness and stratigraphic extension of the condensed members within the studied sections, as well as by the presence of neptunian dykes, clastic dykes and tectonic

breccias developed at submarine fault scarps.

Specific environments/micro-environments appropriate for development of different types of deep-water microbialites associated with certain types of metazoans developed in connection with the previously mentioned events. Three types of microbialite–metazoan assemblages have been observed in the studied successions:

- The first one is referring to the ferruginous microstromatolites that cover the hardground surfaces and erosional cavities or form the cortex of oncoids and macro-oncoids, associated with dense colonies of serpulids, agglutinated polychaete tube worms, bryozoans, and encrusting foraminifera. This is the first record of agglutinated polychaete tube worms – ferruginous microstromatolite assemblages. These assemblages are developed in the topmost part of the Bathonian – Early Callovian condensed level; the morphology of the ferruginous microstromatolites, their microbial origin, and the palaeoenvironmental context of their genesis have been discussed in detail in a previous paper (LAZĂR et al. 2013).
- The second one is referring to sub-horizontal, irregular cavities of variable thickness (0.1–0.3 m), filled by red bioclastic packstone-wackestone; intensive microbial activity within these submarine cavities is documented by the presence of Fe-endostromatolites, Frutexitis-like structures, and by the local development of agglutinated stromatolites containing numerous crustacean microcoprolites of *Favreina carpatica* (SENOWBARI-DARYAN et al. 2013). These cavities occur in the topmost part of a pink bioclastic, micritic, and pelmicritic limestone (1.5 m) containing Middle to Late Callovian ammonites.
- The third type is represented by stromatactis cavities and other types of submarine fissures and cavities containing troglobite metazoans such as the ostracod *Pokorniopsis* and rare serpulids associated

with peloidal agglutinated stromatolites; these assemblages were observed in the topmost part of the Callovian limestone beds.

The described microbialite–metazoan assemblages are palaeoecologically significant as they represent records of short-term events producing fluctuations of palaeoenvironmental parameters (such as water energy, degree of oxygenation, availability of food resources, availability of grains of specific sizes and shapes, and of protected hard substrates suitable for settlement) during prolonged intervals of condensed sedimentation. The multi-disciplinary approach of the present study allows the evaluation of small-scale changes within past environments where such interactions are recorded. Such studies are of importance as they could be correlated with synsedimentary tectonic events that likely were associated with locally hydrothermal vents, but they also reflect the effects of regional and global changes documented for this time interval in different peri-Tethyan areas.

The present study represents the results of an extensive project supported by CNCS PN-II-ID-PCE-2011-3-0025.

References

- FÜRSICH, F.T., OSCHMANN, W., SINGH, I.B. & JAITLY, A.K. 1992. Hardgrounds, reworked concretion levels and condensed horizons in the Jurassic of western India: their significance for basin analysis. – *Journal of Geological Society London* 149: 313–331.
- LAZĂR, I., GRĂDINARU, M. & PETRESCU, L. 2013. Ferruginous microstromatolites related to Middle Jurassic condensed sequences and hardgrounds (Bucegi Mountains, Southern Carpathians, Romania). – *Facies* 59: 359–390. doi:10.1007/s10347-012-0313-5
- PATRULIUS, D. 1969. *Geologia Masivului Bucegi și a Culoarului Dâmbovicioara*. 329 pp., Editura Academiei RSR, București.
- SĂNDULESCU, M. 1984. *Geotectonica României*. 336 pp., Ed Tehnică, București.
- SENOWBARI-DARYAN, B., LAZĂR, I. & BUCUR, I.I. 2013. *Favreina carpatica* nov. ichnosp. (crustacean-microcoprolite) from the Middle Jurassic of Rucăr-Bran zone (Southern Carpathians, Romania). – *Rivista italiana di Paleontologia e Stratigrafia* 119: 175–182.
- TAYLOR, P.D. & WILSON, M.A. 2003. Palaeoecology and evolution of marine hard substrate communities. – *Earth Science Reviews* 62:1–103.

Jurassic – Early Cretaceous evolution of the passive margin of the Moesian Plate (Danubian Unit, Romanian Carpathians)

IULIANA LAZĂR¹ *, MICHAŁ KROBICKI^{2,3}, MIHAELA GRĂDINARU¹ & MIHAI E. POPA¹

¹*Department of Geology, Faculty of Geology and Geophysics, University of Bucharest, 1 N. Bălcescu Bd, 010041 Bucharest, Romania; E-mail: iuliana.lazar@g.unibuc.ro, mihaela.gradinaru@yahoo.com, mihai@mepopa.com*

²*Polish Geological Institute – National Research Institute, Królowej Jadwigi 1, 41-200 Sosnowiec, Poland; E-mail: michal.krobicki@pgi.gov.pl*

³*AGH University of Science and Technology, Mickiewicza 30, 30-059 Kraków, Poland; E-mail: krobicki@geol.agh.edu.pl*

**Corresponding author*

The Southern Carpathians are built up of a succession of nappes and thrust sheets with a complicated geotectonic structure within the Carpathian Fold Belt. The studied successions belong to the sedimentary cover of the Danubian Units, one of the most complex geotectonic units of the Marginal Dacides that are interpreted as part of the strongly deformed European continental margin (SĂNDULESCU 1994). The Danubian nappes represent the most external Carpathian units, as they continue south of the Danube in Miroć (Serbia) and in the Stara Planina and Prebalkan (Bulgaria) tectonic units (SĂNDULESCU 1994; KRÄUTNER & KRSTIĆ 2002). The Danubian Units include several thrust complexes while the studied succession (Munteana–Dumbrăvița section) belongs to the Upper Danubian nappe complex (according to IANCU et al. 2005), largely exposed in the western part of the Danubian window in the Svinița area (western part of the Southern Carpathians). Here, a unique, continuous succession, over 300 m in thickness, represented by the Jurassic – Early Cretaceous strata of Munteana–Dumbrăvița section along the Danube River in Romania has been studied in detail. This succession belongs to the Sirinia Basin (also known as the Svinița–Svinecea Mare sedimentary zone), which was studied by RĂILEANU (1960), among other researchers. This large outcrop documents a deepening-upwards sequence with a full record of an opening marine/oceanic realm since the earliest Jurassic up to the earliest Cretaceous, along the southern passive margin of the Moesian Plate. This sequence is generally represented by siliciclastic, and mixed

carbonate-siliciclastic deposits in the lower part, and by more and more pelagic carbonates in its middle part with carbonate-siliceous rocks, and by nodular limestones with cherts and allodapic intercalations in the upper part, being finally covered by pelagic, micritic limestones with cherts. The whole sequence could be subdivided into at least 10 lithofacies units. The oldest strata (1) are yellow and whitish arcose-type, terrestrial sandstones with paleosols, macro- and microflora (Glavcina Formation, Hettangian – Early Sinemurian in age). The younger beds are strictly marine (2; about 60 m in thickness) developed as brownish massive, medium- and thick-bedded calcareous sandstones, full both of benthic fauna (e.g., bivalves – mostly grypheids, brachiopods – occasionally forming mass occurrences and producing brachiopod coquinas) and nektonic fauna (levels with ammonites and rich in belemnites), but large pieces of driftwood are rare. Some beds with abundant ferruginous ooids occur as well, especially in the lower and middle part of this area. Sedimentary structures such as cross-bedding and storm-induced features occur occasionally and document shallow-marine regimes below the fair-weather wave-base. But the shallowest episode is represented by fine- and coarse-grained sandstones with big (up to 4 cm in diameter) quartz pebbles and mudstones, with coal layers in the uppermost part of these beds. Still younger (3; 62 m) are grey, pseudo-nodular, coral-bearing, bioclastic limestones in the lower part, rich in branching corals which also form small patch reefs. Numerous bivalve borings occur in these coral colonies.

Another fauna is represented by brachiopods, bivalves, and isolated crinoids. In the upper part occur well-bedded biodetritic limestones, occasionally with *Lithotis*-type bivalves and *Aptyxiella*-type gastropods, with thin intercalations of mudstones (up to 1.5 m thick). Sedimentologically, this part of the outcrop is represented by short-lived shallow-marine carbonate platforms, primary with a coral-dominated ramp, later influenced by terrestrial material of little deeper environments. These units (1-3) represent most probably the Lower Jurassic (Middle-Late Sinemurian up to Toarcian – ?Early Aalenian; the Munteana Formation, a lateral facies of the Sirinia Basin).

The next episode of sedimentation (4; 5.5 m) is represented by a rapid change of carbonate production and recorded by cherry-red crinoidal limestones of deeper regimes, showing condensation features which include Fe-Mn laminated crusts (bacterial microbialites) to the topmost part of this unit. It is also the last occurrence of isolated, fine grains of quartz, and this is why these facts could be interpreted as final drawing of macrobenthic fauna-bearing carbonate environments of the shallow (1-3) and moderate deep (4) seabottom, documenting one of the most important re-organization of the wide opening ocean. This unit (4) represents the Middle Jurassic (Bajocian-Bathonian; Saraorschi Formation), which is overlain by strictly pelagic, fully marine carbonate-siliceous sediments. The first sequence is represented by red marls and red nodular limestones of Ammonitico Rosso-type (5; 8.5 m) (?Bathonian – Lower Callovian; Toplita Formation), more similar to typical Mediterranean Ammonitico Rosso marneux. The deepest episode of sedimentation took place during the original complex (6) of green, variegated and red siliceous limestones with cherts, or thin-bedded radiolarites, almost 55-m-thick (Middle Callovian; Seretina Formation). The first massive limestone bed without cherts marks the base of a new part of the succession (7; almost 45 m) still strictly pelagic, but its middle and upper parts yielding cherts yet again. The colors of these beds are variable, from variegated to reddish, while in the middle part, the first allodapic (calcareous turbidites) limestones occur. These beds exhibit typical turbidite features with sharp, erosional base, fractionation of grains/clasts, and cross-

bedding (Upper Callovian/Oxfordian-Lower Kimmeridgian; Zeliște Formation).

The transition to the younger part of sequence (8; at least 60 m) is gentle and is represented by the occurrence in the topmost part of this unit of some beds of pseudo-nodular limestones. However, this younger unit starts with red nodular Ammonitico Rosso-type limestones (more similar to Rosso ad Aptichi in Italian nomenclature), and in the lower part contains cherts, but in the middle and upper parts the thickness of allodapic limestone interbeds (up to an 6.4-m-thick bed) increases. Several clasts in such type of beds represent shallow-water carbonates (occasionally with corals and/or ooids and algae) and document rapid and huge re-deposition from a carbonate source area, probably a carbonate platform with coral reefs and oolitic shoals. This unit corresponds to the Kimmeridgian – Tithonian interval, belonging to the Greben Formation. Still younger beds (9 and 10; at least 50 m or more) are thin- and medium-bedded light-grey micritic limestones similar to *Maiolica* facies (the Murguceva Formation; uppermost Tithonian – Lower Hauterivian). This part of the outcrop is tectonically incomplete but it documents still a pelagic type of sedimentation in quiet, deep-water environments.

The Munteana-Dumbrăvița section is one of the best profiles of the Southern Carpathians in Romania, comprising the whole Jurassic and the earliest Cretaceous strata of the Danubian Units. From a paleogeographic point of view, this succession documents very well the opening of a new oceanic domain and, according to the geotectonic sketch, it represents the passive margin of a continent, in this case the Moesian Plate.

References

- IANCU, V., BERZA T., SEGHEDI A., GHEUCA I. & HANN H.-P. 2005. Alpine polyphase tectono-metamorphic evolution of the South Carpathians: A new overview. – *Tectonophysics* 410: 337–365.
- KRÄUTNER, H.G. & KRSTIĆ, B. 2002. Alpine and pre-Alpine structural units within the Southern Carpathians and Western Balkanides. – *Geologica Carpathica* 53, Special Issue, Proceedings of XVII Congress of Carpathian-Balkan Geological Association, Bratislava.
- RĂILEANU, G. 1960. Recherches géologiques dans la région Sviña-Fața Mare. – *Ann. Com. Geol.* 26–28: 347–383.
- SĂNDULESCU, M. 1994. Overview on Romanian geology. – *Romanian Journal of Tectonics and Regional Geology* 75: 3–15.

Jurassic ammonite faunas of northern Iran and their palaeobiogeographic significance

MAHMOUD REZA MAJIDIFARD

Research Institute for Earth Sciences, Geological Survey of Iran, Tehran, Iran; E-mail: m_majidifard@yahoo.com

The Upper Bajocian–Tithonian ammonite faunas of NNE Iran are mostly of Submediterranean affinity, but elements of Subboreal, Mediterranean, and Ethiopian (Madagascar, eastern Africa, Ethiopia, Somaliland, and Kachchh) provinces are occasionally intermingled. Among the 30 genera only a few can be regarded as belonging to one of the Subboreal, Mediterranean or Ethiopian provinces. In order to unravel the origin of the faunal elements and their migration routes, the relationship of the ammonite fauna of Iran to that of other regions was analysed. On the whole, at the species level the Aalenian to early Bajocian ammonite faunas of northern and central Iran show a very close relationship to that of northwestern Europe. A characteristic feature of this fauna is the scarcity of Phylloceratidae (accounting for less than 1% to up to 3%) and the lack of Lithoceratidae. In contrast, from the Late Bajocian to Oxfordian Phylloceratidae account for more than 50% of the ammonites in the studied sections. This feature can be explained by differing depth

preferences of the groups, because in central and northern Iran very shallow water conditions prevailed during the Aalenian to Early Bajocian (Shemshak Sea). As a result of the Late Bajocian sea level rise following the Mid-Cimmerian tectonic event fairly deep marine environments were established especially in the Alborz and Koppeh Dagh basins (Dalichai and Chaman-Bid formations, respectively). The dominating ammonites inhabiting these basins show a clear relationship to the Submediterranean province. This is supported by the occurrence of Submediterranean ammonites such as *Garantiana*, *Macrocephalites*, *Morphoceras*, *Pachyceras*, *Larcheria*, *Orthosphinctes*, *Dichotomoceras*, and *Richterella* and some cosmopolitan taxa such as *Cadomites*, *Oxycerites*, *Taramelliceras*, *Hecticoceras*, and *Reineckeia*. Moreover, palaeogeographic reconstructions place the Iranian platform at a latitude of 30° N during the Jurassic, which is equivalent to European areas situated at the southern margin of Eurasia.

Middle Jurassic ostracod fauna from Jaisalmer, Rajasthan, India

KUMARI MANISHA*, MANISH M. LAL & S. VIDHYA

Department of Earth Sciences, SPCAS, Pondicherry University, Puducherry 605014, India; E-mail: drmkumari@gmail.com

*Corresponding author

The Mesozoic beds of the Jaisalmer Basin, Rajasthan, have long been known to geoscientists. These beds cover a large area of about 4200 km², attain a maximum thickness of 1085 m on the surface and range in age from the Lias to Aptian (DAS GUPTA 1975). The beds are predominantly marine and are rich in both macro- and microfaunas. In the present work, the author has followed DAS GUPTA (1975) for the stratigraphic classification of the Jurassic succession of the basin. The Hamira Member comprises a succession of yellow, buff-coloured arenaceous limestones, yellowish shales, and marly limestone and contains gastropods, brachiopods, and bivalves. The Joyan Member consists of light-yellow shale, yellow fossiliferous sandstone and hard, buff-coloured limestone with corals, well exposed around Joyan, along the Jaisalmer-Polji-ki-Deri Road to Kanodh, and along the Mohangarh road. Bivalves and corals occur in this member. The Fort Member is divisible into a lower unit of white to off-white sandstone with minor intercalations of calcareous shales, and an upper unit of yellow and greyish yellow limestone with or without fossils, along with marl and shale; the member contains foraminifers, ostracods, bivalves, gastropods, echinoids, and brachiopods. The Badabag Member comprises soft, yellow, cross-bedded sandstone, fossiliferous marl, a flat pebble conglomerate, buff and golden yellow limestone, both with and without fossils, and yellow and greenish shales. Brachiopods, bivalves, ostracods, and foraminifers are well preserved in this member. The Kuldhara Member comprises golden yellow-brown limestone with or without fossils, marl, greenish shales, oolitic limestone beds, and cross-bedded sandstone. The rich fossil assemblage consists of brachiopods, bivalves, cephalopods, ostracods and foraminifers.

In all twenty-two sections at different

localities, covering all five members of the Jaisalmer Formation, have been systematically sampled. All members yielded a rich and well preserved ostracod fauna which is represented by 151 species. These belong to 38 genera (excluding 8 indeterminate taxa). Seventy species are new records from the basin: *Acanthocythere* sp. cf. *A. sphaerulata*, *Acrocythere khoslai*, *Anchistrocheles* sp. A, A. sp. B, *Bairdopillata* sp. A, B. sp. B, *Bhatina* sp., *Bythoceratina* sp., *Bythocypris jaisalmerensis*, B. sp. A, B. sp. B, *Bythoceratina reticulata*, *Cytherella jurassica*, C. sp., *Cytherelloidea reticulata*, C. sp. A, C. sp. B, *Cytheropteron badabagensis*, C. sp. A, C. sp. B, C. sp. C, C. sp. D, C. sp. E, *Darwinula* sp., *Eocytheridea elongata*, *Eucytherura badabagensis*, *E. nagorii*, E. sp. B, *Fabanella paradimorpha*, *F. minae*, *F. badabagensis*, *F. parasarda*, *F. cylindrica*, *F. rectangulata*, *F. sp.*, *Fastigatocythere* sp. cf. *F.? spinisulcata*, *F. (Amicytheridea) triangulata jaisalmerensis*, *F. (A.) sp. A*, *F. (A.) sp. B*, *F. (Habocythere) sp.*, *F.? (Batella) sp.*, *Galliaecytheridea* sp., *Glabbellacythere parahussaini*, *Leiria* sp., *Lophocythere* sp., *Macrodentina jaisalmerensis*, *Mandelstamia jakhari*, *M.? jaisalmerensis*, *Micropneumatocythere joyanensis*, *M. paramasurdiensis*, *M. sp.*, *Monoceratina jajiyaensis*, *M. sp.*, *Morkhovenicythereis jaisalmerensis*, *Paracypris jaisalmerensis*, *P. trapizea*, *Paradoxorhyncha punctata*, *P. jaisalmerensis*, *Paranotacythere* sp., *P. sp. A*, *Procytheridea jaisalmerensis*, *P. sp.*, *Progonocythere ovata*, *P. sp.*, *Protobuntonia* sp., *Theriosynoecum* sp. A, *T. sp. B*, *Trichordis minuta* and *T. sp.* Seventy-five species are assigned to already known taxa. Six species – Genus A–F are indeterminate.

Based on the stratigraphic distribution of the ostracods, five zones are proposed. They are, in ascending order, the *Micropneumatocythere joyanensis* Range Zone (Bajocian), *Trichordis*

hadibhadangensis Range Zone (late Bajocian – early Bathonian), *Cytheropteron micropunctata* Range Zone (Bathonian), *Macrodentina jaisalmerensis* Range Zone (late Bathonian – early Callovian), *Majungaella perforata kachchhensis* Range Zone (middle – late Callovian). The *M. perforata kachchhensis* Range Zone has been further subdivided into the following three subzones: the *Majungaella perforata kachchhensis* – *Fastigatocythere (Batella) falcula* Concurrent Range Subzone, *Majungaella perforata kachchhensis* – *Galliaecytheridea remota* Concurrent Range Subzone, and the *Majungaella perforata kachchhensis* – *Galliaecytheridea remota* Interval Subzone.

Of these, two zones, the *Trichordis hadibhadangensis* and *Cytheropteron micropunctata* Range zones, were originally described from Kachchh by KHOSLA et al. (1997, 2005).

The paper is based on the fieldwork carried out under the DST sponsored Research project no. SR/FTP/ES-04/2003. The first author is highly thankful to the Department of Science and Technology, Government of India, New Delhi, for the grant of financial assistance to take up the study. Grateful thanks are due to Prof. S.P. MOHAN, Dr. S.M. HUSSAIN, and Dr. S. GANDHI (all are from Department of Geology, University of Madras, Chennai) for their kind help rendered during the first author's visit to Chennai for taking SEM photography.

References

- DAS GUPTA, S.K. 1975. A revision of the Mesozoic – Tertiary stratigraphy of the Jaisalmer basin, Rajasthan. – Indian Journal of Earth Sciences 2: 77–94.
- JONES, T.R. & SHERBORN, C.D. 1888. On some Ostracoda from the Fuller's Earth, Oolite and Bradford Clay. – Proceedings of the Bath Natural History Field Club 6: 249–278.
- KHOSLA, S.C., JAKHAR, S.R. & MOHAMMED, M.H. 1997. Ostracodes from the Jurassic of Habo Hill, Kachchh, Gujarat. – Micropaleontology 43: 1–39.
- KHOSLA, S.C., MANISHA, K., DARWIN F.A., JAKHAR, S.R. & NAGORI, M.L. 2005. Middle Jurassic Ostracoda from the Northern Island Belt, Rann of Kachchh, Gujarat, India. – Journal of Palaeontological Society of India 50: 17–64.

Recent progress in ecological studies on living radiolarians and its application to the Jurassic ecosystem – End-Triassic mass extinction and early Jurassic recovery in the pelagic realm

ATSUSHI MATSUOKA

Department of Geology, Niigata University, Niigata 950 2181, Japan; E-mail: matsuoka@geo.sc.niigata-u.ac.jp

Research on living radiolarians has been carried out at the Sesoko Marine Station of the University of Ryukyus and the Sado Marine Biological Station of Niigata University for more than 20 years. This research has provided us with fundamental data on radiolarian ecology including feeding behavior (MATSUOKA 2007; SUGIYAMA et al. 2008), symbiosis (TAKAHASHI et al. 2003; YUASA et al. 2012), possible parasitism (SUZUKI et al. 2009), and other aspects of radiolarian biology.

Detailed observations on the feeding behavior of laboratory-cultured radiolarian specimens make it possible to understand the relationship between skeletal morphology and feeding behavior. Four types of feeding strategies well correspond to skeletal morphology in extant radiolarian taxa (MATSUOKA 2007). High diversity of radiolarian skeletal morphology is partly related to variations in feeding strategies. The wide variation in feeding behavior means that radiolarians occupy several kinds of ecological niches in marine environments.

We can infer feeding behavior of extinct radiolarian groups based on their skeletal morphology. Once we recognise the role of radiolarians in the food web of modern ocean environments, we can apply it to reconstruct marine ecosystems in the past. Fluctuation in morphological diversity of radiolarian skeletons is well documented in the fossil record. This fluctuation can be interpreted as changes in the number of ecological niches in the marine ecosystem through time.

We try to reconstruct the ecosystem evolution during the end-Triassic mass

extinction event and early Jurassic recovery by applying our knowledge of living radiolarian studies. The end-Triassic mass extinction is characterized by an abrupt collapse of the marine ecosystem, represented by a drastic decline of Triassic radiolarians. Only a limited number of radiolarian taxa could survive this event. These taxa include *Canoptum*, *Pantanellium*, and *Bipedis*. The early Jurassic recovery was gradual and stepwise. Full recovery of the marine ecosystem, represented by re-entry of multi-segmented nassellarians such as *Parahsuum*, *Droltus*, and *Bagotum*, took place in the Sinemurian.

References

- MATSUOKA, A. 2007. Living radiolarian feeding mechanisms: new light on past marine ecosystems. – *Swiss Journal of Geoscience* 100: 273–279.
- SUGIYAMA, K., HORI, R.S., KUSUNOKI, Y. & MATSUOKA, A. 2008. Pseudopodial features and feeding behavior of living nassellarians *Eucyrtidium hexagonatum* HAECKEL, *Pterocorys zancleus* (MÜLLER) and *Dictyocodon prometheus* HAECKEL. – *Paleontological Research* 12: 209–222.
- SUZUKI, N., KURIHARA, T. & MATSUOKA, A. 2009. Sporogenesis of an extracellular cell chain from the spheroidal radiolarian host *Haliomilla capillaceum* (HAECKEL), Polycystina, Protista. – *Marine Micropaleontology* 72: 157–164.
- TAKAHASHI, O., MAYAMA, S. & MATSUOKA, A. 2003. Host-symbiont associations of polycystine Radiolaria: epifluorescence microscopic observation of living Radiolaria. – *Marine Micropaleontology* 49: 187–194.
- YUASA, T., Horiguchi, T., MAYAMA, S., MATSUOKA, A. & TAKAHASHI, O. 2012. Ultrastructural and molecular characterization of cyanobacterial symbionts in *Dictyocoryne profunda* (polycystine Radiolaria). – *Symbiosis* 57: 51–55.

On the Oxfordian-Kimmeridgian (Upper Jurassic) boundary – current state of knowledge

BRONISŁAW A. MATYJA¹ & ANDRZEJ WIERZBOWSKI² *

¹*Institute of Geology, University of Warsaw, Żwirki i Wigury 93, 02-089 Warszawa, Poland; E-mail: matyja@uw.edu.pl*

²*Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland; E-mail: andrzej.wierzbowski@pgi.gov.pl*

*Corresponding author

The Kimmeridgian Stage was named by D'ORBIGNY in the first half of the 19th century after the village of Kimmeridge at the Dorset Coast, but it was SALFELD (1913) at the beginning of 20th century, who first defined the base of the Stage at the base of the Kimmeridge Clay corresponding to a marked change in the Aulacostephanidae ammonite family lineage – from the genus *Ringsteadia* to the genus *Pictonia*. According to that definition the older genus *Ringsteadia* was indicative of the Pseudocordata Zone of the uppermost Oxfordian, whereas the appearance of the genus *Pictonia* defined the base of the Baylei Zone of the lowermost Kimmeridgian. Although the definition seems perfect, it has born some inconveniences: (1) Ammonites of the family Aulacostephanidae show limited palaeogeographic distribution being known mostly from the fairly small Subboreal Province of NW Europe; (2) the transition between the genera *Ringsteadia* and *Pictonia* at the Dorset Coast is not continuous because of a stratigraphical gap at the base of the Kimmeridge Clay – hence a part of the succession at the Oxfordian-Kimmeridgian boundary is not represented in these sections. Marked differences between the coeval ammonite faunas between the Subboreal ammonite succession in northwestern Europe and the Submediterranean and Mediterranean ammonite successions in middle and southern Europe resulted also in erroneous correlation of the Oxfordian-Kimmeridgian boundary standard in the past, which additionally complicated the problem. It should be remembered that the currently accepted Oxfordian-Kimmeridgian boundary in the Submediterranean-Mediterranean successions (base of the Platynota Zone or Silenum Zone)

runs about two ammonite zones higher (about 1.3 myr) than the Subboreal standard (OGG et al. 2012).

The Flodigarry section at Staffin Bay in Skye, northern Scotland, has been recently proposed as the primary standard for the base of the Kimmeridgian Stage by the Kimmeridgian Working Group, and the International Subcommission on Jurassic Stratigraphy. The continuous succession of Subboreal ammonites of the family Aulacostephanidae (from *Ringsteadia* to *Pictonia*) recognized here makes it possible to distinguish both the Pseudocordata Zone and the Baylei Zone, with the lowest recognized ammonite horizon – the *Pictonia flodigarriensis* horizon (absent in the Dorset sections) which marks the real base of the Kimmeridgian Stage. The Boreal ammonites of the family Cardioceratidae show also a continuous succession, from *Amoeboceras* to *Plasmatites*, corresponding to the transition from the Rosenkrantzi Zone to the Bauhini Zone, the boundary of which is also coeval with the base of the Kimmeridgian Stage (MATYJA et al. 2006; WIERZBOWSKI 2010).

The Submediterranean/Mediterranean subdivisions of the stratigraphical interval in question corresponding to the so-called “Submediterranean Upper Oxfordian” includes the Bimammatum Zone *sensu lato* and the Planula Zone; for correlation reasons (see also below) it is better, however, to split the former into two independent zones: the Hypselum Zone below and the Bimammatum Zone *sensu stricte* above. The stratigraphical interval corresponding to the Hypselum Zone (= Semiarmatum Zone) includes the Semimammatum Subzone, the Semiarmatum Subzone, and the Berrense Subzone (cf. BONNOT et al. 2009), whereas that

of the Bimammatum Zone. the Bimammatum Subzone and the Hauffianum Subzone. The bulk of these chronostratigraphic units is defined on the basis of Submediterranean-Mediterranean ammonites having wide correlation potential in the World, especially of the families Aspidoceratidae and Oppeliidae.

The Subboreal and Boreal ammonites occurring in the Submediterranean succession in Europe (Poland and Germany) indicate that the whole Planula Zone, and at least the bulk of the Bimammatum Zone correlates with a lower part of the Subboreal Baylei Zone and a lower part of the Boreal Bauhini Zone. It results from the occurrence, in this stratigraphical interval, of such ammonites as the Boreal *Amoeboceras* (*Plasmatites*), as well as of the Subboreal *Prorasenia* and *Pictonia* (MATYJA et al. 1997; WIERZBOWSKI et al. 2010). In contrast, the newly undertaken studies in the Hypselum Zone reveal the presence of the Boreal *Amoeboceras rosenkrantzi* Spath and the Subboreal *Ringsteadia* and *Microbiplices* indicative of the Pseudocordata Zone. Although a precise position of the boundary between the Subboreal Pseudocordata Zone and the Baylei Zone, as well as that of the coeval boundary between the Boreal Rosenkrantzi and the Bauhini Zone, both corresponding to the base of the Kimmeridgian Stage, cannot be so far precisely recognized in the Submediterranean succession, this should be drawn not far from the boundary between the Hypselum (Semiarmatum) Zone and the Bimammatum Zone. It should be remembered that the stratigraphical level at the transition between the Hypselum and the Bimammatum zones in the Submediterranean succession is very prospecting for wider stratigraphic correlations because of marked changes in ammonite faunas – in the Oppeliidae – in the *Taramelliceras* lineage (transition from *T. externnodosum* to *T. costatum*), as well as in the *Ochetoceras* lineage (appearance of

O. marantianum). Marked changes occurred also in the Aspidoceratidae as shown by the decline of *Euaspidoceras*, and appearance of *Aspidoceras* and *Physodoceras*, as well as the occurrence of the “transitional” forms of the *Neaspidoceras* – *Clambites* type. As the studies of the section crucial for the correlations are ongoing we hope that soon the detailed position of the Oxfordian/Kimmeridgian boundary in the Submediterranean succession will be established.

The study was financed by the National Science Centre (grant 2012/05/B/ST 10/02121).

References

- BONNOT, A., MARCHAND, D., COURVILLE, P., FERCHAUD, P., QUEREILHAC, P. & BOURSICO, T. P.-Y. 2009. Le genre *Epipeltoceras* (Ammonitina, Perisphinctaceae, Aspidoceratidae) sur le versant parisien du seuil du Poitou (France): faunes ammonitiques, biostratigraphie et biozonation de la zone a Bimammatum *pars* (Oxfordien supérieur). – *Revue de Paléobiologie* 28: 371–411.
- OGG, J.G., HINNOV, L.A. & HUANG, C. 2012. Jurassic. In: GRADSTEIN, F.M., OGG, J.G., SCHMITZ, M. & OGG, G. The Geologic Time Scale: 731–791, Elsevier, Amsterdam.
- MATYJA, B.A., WIERZBOWSKI, A. & WRIGHT, J.K. 2006. The Sub-Boreal/Boreal ammonite succession at the Oxfordian/Kimmeridgian boundary at Flodigarry, Staffin Bay (Isle of Skye), Scotland. – *Transactions of the Royal Society of Edinburgh, Earth Sciences* 96: 387–405.
- SALFELD, H. 1913. Certain Upper Jurassic strata of England. – *Quarterly Journal of the Geological Society, London* 69: 423–432.
- WIERZBOWSKI, A. 2010. On the Oxfordian/Kimmeridgian boundary and its GSSP – current state of knowledge. – *Volumina Jurassica* 8: 177–182.
- MATYJA, B.A. & WIERZBOWSKI, A. 1997. The quest for unified Oxfordian/Kimmeridgian Boundary: implications of the ammonite succession at the turn of the Bimammatum and Planula zones in the Wieluń Upland, central Poland. – *Acta Geologica Polonica* 46: 77–105.
- WIERZBOWSKI, A., GŁOWNIAK, E. & PIETRAS, K. 2010. Ammonites and ammonite stratigraphy of the Bimammatum Zone and lowermost Planula Zone (Submediterranean Upper Oxfordian) at Bobrowniki and Raciszyn in the Wieluń Upland, central Poland. – *Volumina Jurassica* 8: 49–102.

Ammonite distribution in late Middle-Upper Jurassic deposits of epicratonic Poland: the key to ecology, biogeography, palaeogeography and geotectonic events

BRONISŁAW A. MATYJA¹ * & ANDRZEJ WIERZBOWSKI²

¹*Institute of Geology, University of Warsaw, Żwirki i Wigury 93, 02-089 Warszawa, Poland; E-mail: matyja@uw.edu.pl*

²*Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland; E-mail: andrzej.wierzbowski@pgi.gov.pl*

**Corresponding author*

Late Middle and Late Jurassic deposits rich in ammonites are widely distributed in the epicratonic areas of Poland. The epicratonic marine basin of Poland was that time bordered by land areas from the north and the east, and widely open towards the south, the Tethys Ocean.

Northern and central Poland was dominated by siliciclastic deposits from the Callovian to the Tithonian. The northern area was characterized also by several phases of development of shallow-water carbonate platforms, whereas in central Poland patchy spongy bioherms and coral reefs developed on domal structures formed by halokinetic movements of Permian salts. In contrast, the siliciclastic sediments which prevailed in the Callovian in southern Poland were replaced by the sponge megafacies during Oxfordian times, and these were followed by widely distributed shallow-water carbonate platform deposits during the Early Kimmeridgian. Flooding of the carbonate platform took place at the end of the Early Kimmeridgian and this resulted in appearance of siliciclastic facies which were uniformly developed over wide areas of the epicratonic Poland during the Late Kimmeridgian and Early Tithonian. The shallow-water carbonate deposits formed in environments of variable salinity appeared at the beginning of the Late Tithonian. These resulted in the total disappearance of the ammonite faunas, and in consequence were followed by the deposition of evaporates during the Berriasian.

Changes in ammonite spectra were traced in relation to sedimentation history. These are based on published and unpublished data giving the detailed distribution of ammonites

in several sections of epicratonic Poland for a distance of over 500 km from the land areas in the north and the Tethys Ocean in the south. The ammonites studied represent the stratigraphical interval from the Callovian to the Tithonian. The percentage shares of the different ammonite groups (families and subfamilies) are presented. The detailed biostratigraphy and facies patterns related to the evolution of the epicratonic basin of Poland make it possible to recognize the changes in ammonite spectra in space and time.

The Boreal Province was firmly established in the area of northern Poland at least from the Lamberti Chron of the latest Callovian up to the Tenuicostatum Subchron of the Middle Oxfordian. The ammonite spectra show the dominance of the family *Cardioceratidae*, the representatives of which account for about 90% of the whole number of specimens. The Submediterranean ammonites dominated in central and northern Poland from the Plicatilis Chron (well after its earliest time) of the Middle Oxfordian up to the end of the *Bifurcatus* Chron of the Late Oxfordian. The Boreal ammonites (*Cardioceratidae*) reappeared in the Hypselum Chron (Late Oxfordian) along with the first appearance of the Subboreal ammonites (*Aulacostephanidae*). Both these groups continued successively their occurrence with minor fluctuations and declined close to the end of Kimmeridgian, but another group of Subboreal ammonites (*Virgatitidae*) appeared in the Early Tithonian (Early Volgian) and existed until the total ecologically controlled disappearance of ammonites at the beginning of the Late Tithonian.

The area of southern Poland, corresponding

to the south-western Mesozoic border of the Holy Cross Mts and the whole Polish Jura Chain from the beginning of the Callovian (MATYJA & GIŻEJWSKA 1979; DEMBICZ & PRASZKIER 2003) up to the Planula Chron of the latest Oxfordian in Submediterranean subdivision or of the Early Kimmeridgian in the Boreal/Subboreal subdivisions (MATYJA 1977; WIERZBOWSKI 1978; MATYJA & GŁOWNIAK 2003), belonged to the Submediterranean Province. Such interpretation is a consequence of the common occurrence of representatives of the families Perisphinctidae, Aspidoceratidae, Ataxioceratidae, Reineckeidae, Macrocephalitidae, Oppeliidae, and Lissoceratoidae which constitute together over 50% of the whole number of specimens, occasionally along with the admixture of several percentages of Phylloceratidae. The representatives of Boreal and Subboreal families (Cardioceratidae and Aulacostephanidae) constituted, however, up to 30% of the specimens, both in the Callovian and in the Early and the earliest Middle Oxfordian (Boreal Spread of ARKELL 1956). Later on, the Boreal ammonites appeared at least twice: in the Semimammatum Subchron of the Hypselum Chron (MATYJA & WIERZBOWSKI 1988), and in the *litocerum* horizon of the Hauffianum Subchron of the Bimammatum Chron (MATYJA & WIERZBOWSKI 1997) – both appearances representing short-time invasions in which the number of Boreal Cardioceratidae exceeded 60% of the whole ammonite spectra.

Due to the small number of data it is still not clear when the Subboreal Province reached the southern epicratonic Poland. The area of central Poland along with the adjoining part of southern Poland belonged to the Subboreal Province already from the latest Hypselocyclum Chron at the junction of the Early and Late Kimmeridgian (MATYJA & WIERZBOWSKI 1998) onwards.

The ammonites of the Subboreal family Virgatitidae appeared in northern and central Poland in the Fallax Subchron of the latest

Kimmeridgian and markedly dominated over the Submediterranean Oppeliidae and Aspidoceratidae. Beginning from the Pseudoscythica Chron (Early Tithonian – Early Volgian) the representatives of the family Virgatitidae accounted for 100% in the ammonite spectra both in northern and southern Poland thus closely linking the Polish basin with the seas of the Russian Platform.

The study was financed by the National Science Centre (grant 2012/05/B/ST 10/02121).

References

- ARKELL, W.J. 1956. Jurassic Geology of the World. 806 p., Oliver and Boyd, Edinburgh.
- DEMBICZ, K. & PRASZKIER, T. 2003. Stratygrafia, mikrofacje i środowisko sedimentacji osadów keloweju z profilu Włodowic koło Zawiercia. – Tomy Jurajskie I: 35–52.
- MATYJA, B.A. 1977. The Oxfordian of the south-western margin of the Holy Cross Mts. – Acta Geologica Polonica 27: 41–64.
- MATYJA, B.A. & GIŻEJWSKA, M. 1979. Distribution of Callovian and Lower Oxfordian ammonite faunas in Poland. – Acta Geologica Polonica 29: 177–185.
- MATYJA, B.A. & GŁOWNIAK, E. 2003. Następstwo amonitów dolnego i środkowego oksfordu w profilu kamieniołomu w Ogródzieńcu i ich znaczenie biogeograficzne. – Tomy Jurajskie I: 53–58.
- MATYJA, B.A. & WIERZBOWSKI, A. 1998. The stratigraphical and palaeogeographical importance of the Oxfordian and Lower Kimmeridgian succession in the Kcynia IG IV Borehole. – Biul. Państw. Inst. Geol. 382: 35–70.
- MATYJA, B.A. & WIERZBOWSKI, A. 1988. The two *Amoeboceras* invasions in Submediterranean Late Oxfordian of Central Poland. In: Rocha, R.B. & Soares, A.F. (eds.), 2nd International Symposium on Jurassic Stratigraphy I: 421–432, Lisboa.
- MATYJA, B.A. & WIERZBOWSKI, A. 1996. Biogeographic differentiation of the Oxfordian and Early Kimmeridgian ammonite faunas of Europe and its stratigraphic consequences. – Acta Geologica Polonica 45: 1–8.
- MATYJA, B.A. & WIERZBOWSKI, A. 1997. The quest for a unified Oxfordian/Kimmeridgian boundary: implications of the ammonite succession at the turn of the Bimammatum and Planula zones in the Wieluń Upland, Central Poland. – Acta Geologica Polonica 47: 77–105.
- WIERZBOWSKI, A. 1978. Ammonites and stratigraphy of the Upper Oxfordian of the Wieluń Upland, central Poland. – Acta Geologica Polonica 28: 299–333.

Phricodoceratinae SPATH, 1938 (Mollusca, Cephalopoda): ontogeny, evolution & paleobiogeography

CHRISTIAN MEISTER¹ * & JEAN-LOUIS DOMMERGUES²

¹Natural History Museum of Geneva, Department of Geology and Paleontology, CH-1211 Geneva, Switzerland; E-mail: christian.meister@ville-ge.ch

²UFR Sciences Vie, Université de Bourgogne, CNRS/uB, UMR 5561, Biogéosciences Dijon, F-21000 Dijon, France; E-mail: jean-Louis.Dommergues@u-bourgogne.fr

*Corresponding author

Phricodoceratidae is an original and rare Lower Jurassic family represented by the genus *Phricodoceras* HYATT, 1900 which contains ten species: *P. taylori* (J. DE C. SOWERBY, 1826), *P. lamellosum* (D'ORBIGNY, 1844), *P. urkuticum* (GECZY, 1959), *P. paronai* (BETTONI, 1900), *P. bettonii* GECZY, 1976, *P. venzoi* FANTINI SESTINI, 1978, *P. cornutum* (SIMPSON, 1843), *P. oistoides* GECZY, 1976, *P. imbricatum* (BETTONI, 1900), and

P. cantaluppii FANTINI SESTINI, 1978. It ranges from the Upper Sinemurian (Raricostatum Zone) to the Upper Pliensbachian (Spinatum Zone) corresponding to a range of about 6 to 7 millions years. Exhaustive results, based on the revision of the different species with their complete synonymy and on morphological, stratigraphic and paleogeographic approaches, allow proposing an evolutive history of *Phricodoceras* (MEISTER 2007). A hypothesis of sexual dimorphism where *P. taylori* => *P. bettonii* => *P. venzoi* may represent the microconchs and *P. lamellosum* => *P. urkuticum* => *P. paronai* the macroconchs are also given. The discovery, by MEISTER et al. (2010), of a key taxon (i.e., *Angulaticeras spinosus* MEISTER, SCHLÖGL & RAKÚS, 2010) allows with certainty to understand the origin of *Phricodoceras* and to place it among the Schlotheimiidae (Fig. 1). It shows that the discovery of intermediate forms is often the key to phyletic reconstructions in ammonites.

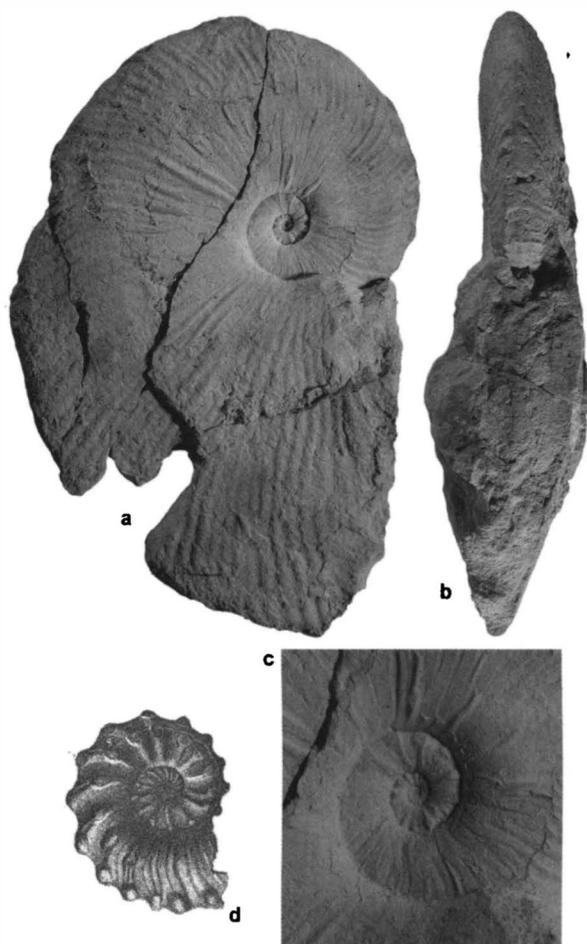


Fig. 1. a, b, c: *Angulaticeras spinosus* MEISTER, SCHLÖGL & RAKÚS. d: *Phricodoceras taylori* (SOWERBY).

References

- DOMMERGUES, J.-L. & MEISTER, C. in press. Significance of intermediate forms in phyletic reconstruction of ammonites: Early Jurassic *Phricodoceras* case study. - Acta Palaeontologica Polonica. <http://dx.doi.org/10.4202/app.2011.0148>.
- MEISTER, C. 2007. Les Phricodoceratidae SPATH, 1938 (Mollusca, Cephalopoda): ontogenèse, évolution et paléobiogéographie. - Geodiversitas 29: 87-117.
- MEISTER, C., DOMMERGUES, J.-L., DOMMERGUES, C., LACHKAR, N. & EL HARIRI, K. 2011. Les ammonites du Pliensbachien du jebel Bou Rharraf (Haut Atlas oriental, Maroc). - Geobios 44: 117.e1-117.e60.
- MEISTER, C., SCHLÖGL, J. & RAKUS, M. 2011. Sinemurian ammonites from Male Karpaty Mts., Western Carpathians, Slovakia. Part 1: Phylloceratoidea, Lytoceratoidea, Schlotheimiidae. - Neues Jahrbuch für Geologie und Paläontologie Abhandlungen 259: 25-88.

Microfacies of the Bathonian sediments of the Jumara Domē, Kachchh, western India: Inference of depositional environments

ARPAN MISRA

AMD, Department of Atomic Energy, W.R., Jaipur 302 033, India; E-mail: arpanmisra@yahoo.com

The Kachchh Basin is a pericratonic rift basin situated at the western margin of the Indian plate and forms a classic area for Jurassic rocks in India. The Jumara Dome forms a prominent exposure of the Bathonian sediments in the basin. A rigorous facies analysis based on microfacies towards reconstruction of the depositional environment and setting of carbonate sedimentation with correlation of basin components had been lacking. Thus an important Kachchh Mainland outcrop of the Bathonian sediments viz. the Jumara Dome was taken up for the present study. Detailed stratigraphic sections of the Bathonian rocks have been measured for the purpose. Macrofacies have been recorded for corroborating the microfacies data. Microfacies analysis has been carried out by studying thin-sections of rock samples under the microscope with the aim to interpret the depositional environment and setting during Bathonian times.

The Bathonian sediments at the Jumara Dome are characterized by well-bedded limestone-marl/marlstone alternations with tempestite beds and massive limestones (packstones and grainstones), and have been classified as Patcham and Jhurio formations in descending order. The section has several units where the limestones show a nodular fabric. The microfacies types can be grouped into three associations. Association (1) contains bioclastic mud- to wackestones, peloidal grainstones, and bioclastic floatstones. Fine-grained peloidal grainstones and packstones have appreciable percentages of peloids and contain small-sized bioclasts. The association forms well-bedded limestone-marl/marlstone alternations. This indicates a marine, open sea, mid to outer (deep) carbonate ramp environment. Bioclastic wackestones, especially in the lower part of the section represent a low-energy, setting below the storm wave-base which gave way to a higher energy setting as indicated by peloidal packstones and bioclastic floatstones (containing

quartz-bearing angular to subangular intraclasts and ferruginous ooids) higher up in the section. Bioclastic limestones containing a diverse and abundant fauna indicate a productivity and is in accordance with such depositional settings. The Sponge Limestone member of the Patcham Formation is represented by this association. The microfacies association (2) contains bioclastic mudstones, bioclastic wackestones, bivalve packstones, and bivalve float- to rudstones. The association forms well-bedded limestone-marl/marlstone alternations and represents a largely low-energy depositional environment which had seen phases of slight influence of storm events. Tempestitic shell beds which show ferruginization and an increased content of terrigenes (sand-sized quartz grains) and ooids (including broken ones) represent episodes of higher energy conditions. The Jumara Coral Limestone member of the Jhurio Formation is represented by this association. The microfacies association (3) contains ferruginous echinoderm/bioclastic packstones, ferruginous intraclastic packstones, and echinoderm grainstones. In this association the well-bedded limestone-marl/marlstone intercalations are absent. The association represents reworked sediments of the transgressive phase in a higher-energy setting. Sorting of grains is variable. High degree of ferruginization, appreciable terrigenous (sand-sized quartz grains) influx, presence of ooids (including a few broken ones) and oncoids, and a relatively high percentage of intraclasts almost throughout the unit are characteristic features. The Echinoderm Packstone belonging to the Jhurio Formation is represented by this association. The presence of granular sparite cement along with fibrous cement and syntaxial rim cement, the sorting, and the bioclastic content of the sediment support the prevalence of such environments.

A carbonate ramp setting seems to have been prevalent at the time of sedimentation

of the carbonates during Bathonian times. In general, the depositional environment seems to have been an open marine, mid to outer (deep) ramp. It was largely low energy, just below the storm wave-base with phases of slight influence

of storm events, shifting occasionally adjacent to the storm wave-base. Reworked sediments of the transgressive phase witnessed a relatively high-energy depositional environment.

Ammonite zonation of the Boreal Bathonian Stage of Greenland

VASILY MITTA¹ * & PETER ALSEN²

¹*Borissiak Paleontological Institute RAS, Profsoyuznaya 123, Moscow 117997, Russia; E-mail: mitta@paleo.ru*

²*Geological Survey of Denmark and Greenland (GEUS), Oster Voldgade 10, DK-1350 Copenhagen K, Denmark; Email: pal@geus.dk*

*Corresponding author

The report presents the first results of the revision of the Middle Jurassic ammonite collections from East Greenland, stored at the Museum of Natural History of Copenhagen, and collected by J. Callomon, T. Birkelund, and many other researchers.

The Boreal Bathonian is characterized, first of all, by ammonites of the Family Cardioceratidae, belonging to the genera *Cranocephalites*, *Arctocephalites*, *Arcticoceras* (Subfamily Arctocephalitinae), and *Cadoceras* (Subfam. Cadoceratinae) forming a phyletic evolutionary lineage (CALLOMON 1985). According to CALLOMON (1993, etc.) the first appearance of *Arctocephalites* is in the Arcticus Zone, replacing ancestral *Cranocephalites*. All ammonites found in the Arcticus and Greenlandicus zones, were referred to various species of *Arctocephalites*. The succeeding Ishmae Zone is dominated by the genus *Arcticoceras*, the descendants of *Arctocephalites*; in that zone a single *Oxycerites* (Fam. Oppeliidae) appears also. The genus *Keplerites* (Fam. Kosmoceratidae) has its first appearance in the Cranocephaloide Zone and the cardioceratids are still referred to the *Arcticoceras*. The Variabile Zone sees the first appearance of *Cadoceras* which occurs together with *Arcticoceras* and *Keplerites*. Higher, in the Calyx, Apertum, and Nordenskoeldi zones, various *Cadoceras* and *Keplerites* are indicated. According to CALLOMON (1993), the Bathonian–Callovian boundary presumably lies at the base of Apertum Zone; the Bajocian–Bathonian boundary is not defined.

A re-study of the collections shows that the entire range of the Arcticus–Cranocephaloide zones of East Greenland contains two morphotypes of cardioceratid shells, and can almost be proven for all zones. One general morphology includes flattened shells with a

relatively high sub-oval section and narrow umbilicus (*Arctocephalites* ex gr. *arcticus/greenlandicus*, *Arcticoceras* ex gr. *ishmae/cranocephaloide*). The second morphotype includes shells more or less inflated, with thick whorls, a wider umbilicus, and generally with a more coarsely ribbed sculpture (*Arctocephalites* ex gr. *sphaericus/freboldi*, *Arcticoceras* ex gr. *harlandi/ishmae* var.).

Transitional forms between these morphotypes are observed only in the lower part of the Arcticus zone. Apparently, at this time, there was a phylogenetic divergence within the Arctocephalitinae. The most suitable valid generic name from the literature for the inflated species is *Greencephalites* REPIN, 2007, with the type species *Cadoceras freboldi* SPATH.

During the revision of the collections we have tried to take into account definitions of the late J.H. CALLOMON, whom we honor as a fellow elder and a teacher. Accordingly, the Arcticus zone as a whole is characterized by *Greencephalites sphaericus* (SPATH); the lower part of the Greenlandicus zone by *G. crassus* (MADSEN), its upper part by *G. freboldi* (SPATH).

In the Ishmae Zone the genus *Greencephalites* is represented by a new species that is yet to be described. In the Cranocephaloide zone of East Greenland ammonite shells have usually been subject to varying degrees of compaction, and it is commonly impossible, to determine the original width of whorls; however, the zone appears to be dominated by the last representatives of *Arcticoceras*. Recent collections (Alsen Coll.) from this zone in North-East Greenland include a specimen with wide umbilicus of early whorls. This finding represents a lowermost occurrence of the genus *Cadoceras* in the Middle Bathonian. In the Variabile Zone and above the cardioceratids are presented

Proposed Zonation		Ammonite genera		Zonation after Callomon, 1993	
Lower Callovian	Norden-sjøskoldi			<i>nordensjøskoldi</i> β	Norden-sjøskoldi
				<i>nordensjøskoldi</i> α	
Upper Bathonian	Apertum	<i>Keplerites</i>		<i>cf. aff. breve</i>	Apertum
		<i>Cadoceras</i>		<i>tenuifasciculatus</i>	
				<i>apertum</i> γ	
				<i>apertum</i> β	
				<i>apertum</i> α	
	Calyx			<i>verdeksjøfjansis</i>	Calyx
				<i>peramplus</i>	
	Variable			<i>rosenkrantzii</i>	Variable
				<i>inflatus</i>	
Middle Bathonian	Cranoc-phaloide			<i>tychonis</i>	Cranoc-phaloide
				<i>cranocephaloide</i>	
Lower Bathonian	Ishmae	<i>Oxyerites</i>		<i>crassiplicatum</i>	Ishmae
		<i>Greencoephalites</i>		<i>ishmae</i> β	
				<i>ishmae</i> α	
				<i>harlandi</i>	
Greenlandicus		<i>Arctocephalites</i>		<i>freboldi</i>	Greenlandicus
				<i>greenlandicus</i>	
				<i>micrumbilicatus</i>	
Upper Bajocian	Arcticus			<i>delicatus</i>	Arcticus
				<i>arcticus</i>	

Fig. 1. Subdivision of the Bathonian Stage of East Greenland.

mainly by species of this genus, which is most likely a direct descendant of *Greencoephalites*.

The Ishmae zone has been shown to belong to the upper half of the Lower Bathonian (e.g., MITTA & SELTZER 2002) and this was confirmed by MITTA et al (2004, 2012). The Greenlandicus Zone is correlated with the lower half of the Lower Bathonian of the West-European standard, and the Arcticus Zone presumably belongs to the Upper Bajocian. We propose to limit the Ishmae Zone to the range of *Arcticoceras harlandi* RAWSON and *A. ishmae* (KEYSERLING), as is customary in other boreal regions such as Arctic Canada, Northern Siberia and the Petshora Basin (MELEDINA 1987; POULTON 1987). Three faunal horizons: *crassiplicatum*, *cranocephaloide*, and *tychonis* represent the Middle Bathonian Cranocephaloide zone, thus

extended to its original definition. The Variable and Calyx zones are referred to the Upper Bathonian.

Representatives of *Keplerites* from the *Cadoceras apertum*- range interval CALLOMON & BIRKELUND have marked nodes at the rib bifurcations resembling Early Callovian *Keplerites kepleri* (OPPEL) and Late Bathonian *K. dietli* SCHAIRER. However, occurring above are shells of *K. tenuifasciculatus* CALLOMON with thick ribs which undoubtedly belong to the Upper Bathonian. Accordingly, the entire Apertum Zone is here assigned to the Upper Bathonian. The proposed changes in the scale of the Bathonian Stage are shown in Fig. 1.

Supported by the Program of the Presidium RAS no. 28 and by grant RFBR no. 11-05-01122.

References

- CALLOMON, J.H. 1985. The evolution of the Jurassic ammonite family Cardioceratidae. – Palaeontology, Special Paper 33: 49–90.
- CALLOMON, J.H. 1993. The ammonite succession in the Middle Jurassic of East Greenland. – Bulletin of the Geological Society of Denmark 40: 83–113.
- MELEDINA, S.V. 1987. Ammonites and zonal stratigraphy of the Callovian of subboreal regions of USSR. 182 p., Moscow (Nauka). [In Russian]
- MITTA, V.V., BARSKOV, I.S., GRÜNDEL, J., ZAKHAROV, V.A., SELTZER, V.B., IVANOV, A.V., ROSTOVTCOVA, J.A. & TARASOVA, L.O. 2004. - The Upper Bajocian and Lower Bathonian in the section near Saratov. – Vernadsky Museum Novitates 12: 1–39. [In Russian]
- MITTA, V.V. & SELTZER, V.B. 2002. First finds of Arctocephalitinae (Ammonoidea) in the Jurassic of the south-eastern Russian Platform, and the correlation of the Boreal Bathonian Stage with the standard scale. – Transactions Sci. Research Geological Institute, Saratov State University N.S. 10: 12–39. [In Russian]
- MITTA, V.V., SHURYGIN, B.N., DZYUBA, O.S., KOSTYLEVA, V.V., GLINSKIKH, L.A., SELTZER, V.B., IVANOV, A.V. & URMAN, O.S. 2012. Preliminary results of study the Bathonian (Middle Jurassic) rocks in the vicinity of Saratov in year 2012. – Problems of paleoecology and historical geology: 151–163. Saratov, State Technical University. [In Russian]
- POULTON, T.P. 1987. Zonation and correlation of Middle Boreal Bathonian to Lower Callovian (Jurassic) ammonites, Salmon Cache Canyon, Porcupine River, northern Yukon. – Bulletin of the Geological Survey of Canada 358: VII + 155 p.

Boreal-Tethyan correlation of the Bajocian-Bathonian boundary beds in the Sokur section (Central Russia): new insights into an old story

VASILY MITTA¹ *, VIKTORIA KOSTYLEVA², OXANA S. DZYUBA³, LARIS GLINSKIKH³, BORIS N. SHURYGIN³, VLADIMIR SELTZER⁴ & ALEXEY IVANOV⁵

¹*Borissiak Paleontological Institute RAS, Profsoyuznaya 123, Moscow 117997, Russia; E-mail: mitta@paleo.ru*

²*Geological Institute RAS, Pyzhevsky lane 7, Moscow 119017; E-mail: kovicto@yandex.ru*

³*Trofimuk Institute of Petroleum Geology and Geophysics SB RAS; Novosibirsk, Russia; E-mail: shuryginbn@ipgg.sbras.ru, glor@mail.ru*

⁴*Saratov State University, Astrahanskaya 83, Saratov 410012, Russia; E-mail: seltsevb@mail.ru*

⁵*Saratov State Technical University, Politehnicheskaya 77, Saratov 410054, Russia; E-mail: Yashkovia@mail.ru*

*Corresponding author

The Boreal-Tethyan correlation of the Bajocian-Bathonian boundary beds is one of the most complex problems of Mesozoic biostratigraphy. The standard zonal scales of the Upper Bajocian and lower Bathonian are based on the West European (Submediterranean) successions of parkinsoniids. The zonal scales of the "Boreal Bathonian" (CALLOMON 1993), which crops out over a vast area (East Greenland, northern Pechora, North Siberia, Arctic Canada, North Alaska) are based on the succession of arctocephalitines and until recently their correlation with the primary standard scale was only tentative.

Direct Boreal-Tethyan correlation of the Bajocian-Bathonian boundary beds has only become possible recently. Deposits in the same geological section (Sokur Quarry near Saratov) contain both ammonites of the Peri-Tethyan family Parkinsoniidae (*Parkinsonia*, *Oranicerias*), typical of the Bajocian-Bathonian boundary beds, and members of the boreal Cardioceratidae (subfamily Arctocephalitinae: *Arcticoceras* and *Arctocephalites*), characteristic of the "Boreal Bathonian" (MITTA & SELTZER 2002). A subsequent integrated study has revealed here not only the Boreal ammonite zone, but also associated "Boreal" Bathonian zones based on bivalves, foraminifers, and belemnites. These data allow adequate correlation of the Boreal zonation with Tethyan scales in the boundary interval of the Upper Bajocian and Lower Bathonian (MITTA et al. 2012).

Two zones based on Parkinsoniidae are

recognized in the lower part of this section, *Pseudocosmoceras michalskii* and *Oranicerias besnosovi*. These beds are conformably overlain by beds with *Arcticoceras harlandi* and *A. ishmae* and hence assigned to the namesake zones of the Boreal Jurassic zonation. At the same time, the section contains beds with *Retroceramus bulunensis* and *R. vagt*, reliably correlated in the Boreal succession with ammonite zones (Fig. 1). Furthermore, the highest occurrences of *Oranicerias* in the section are associated with the earliest record of *Arcticoceras harlandi*.

The age of beds with *Arcticoceras ishmae* and closely related species has been a subject of discussion for some time. In the Boreal succession, the Harlandi and Ishmae zones until now were provisionally dated as Middle Bathonian (ZAKHAROV et al. 1997; SHURYGIN et al. 2011). Considering that the interval of distribution of the genus *Oranicerias* in the Peri-Tethyan regions is restricted to the two lowest subzones of the Zigzag Zone, in the Sokur section the association of *Oranicerias* and first *Arcticoceras* suggests an Early Bathonian age of the lower beds containing species of *Arcticoceras* and *Retroceramus*, which define zones of the Boreal (secondary) standard succession. Thus, the study of the Sokur section, which is a unique succession of Bajocian-Bathonian boundary beds in the Boreal-Tethyan ecotone, provides a solution to the hotly debated problem of the Boreal-Tethyan correlation.

Supported by RAS Programs 23 and 28 and RFBR grants 11-05-01122, 12-05-00453, 13-05-00423.

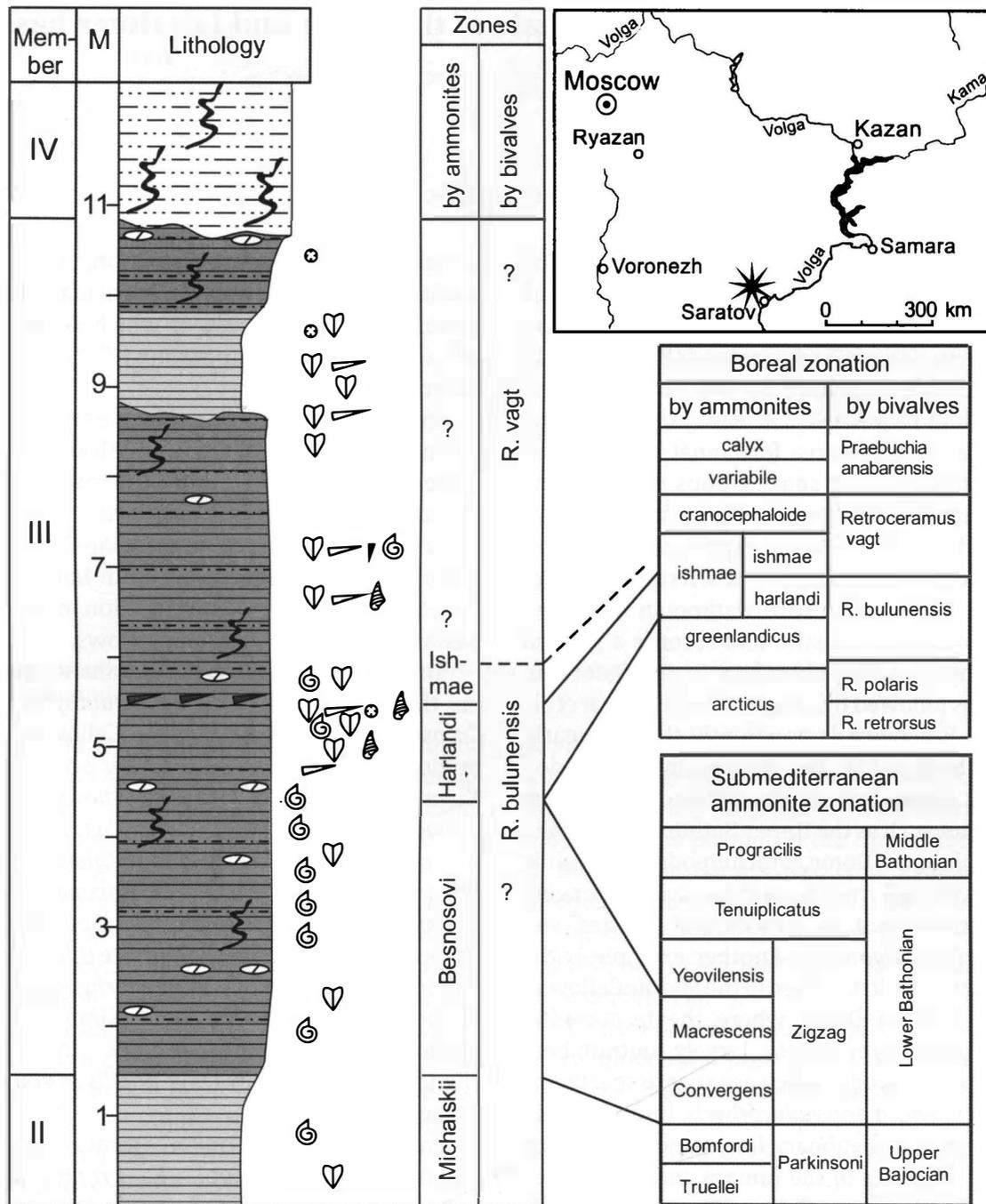


Fig. 1. The Bajocian-Bathonian boundary beds of the Sokur section (Central Russia) and Boreal-Tethyan correlation.

References

CALLOMON, J.H. 1993. The ammonite succession in the Middle Jurassic of East Greenland. – Bulletin of the geological Society of Denmark 40: 83–113.
 MITTA, V.V. & SELTZER, V.B. 2002. First finds of Arctocephalitinae (Ammonoidea) in the Jurassic of the south-eastern Russian Platform, and the correlation of the Boreal Bathonian Stage with the standard scale. – Transactions Sci. Research Geological Institute, Saratov State University N.S. 10: 12–39. [In Russian]
 MITTA, V.V., SHURYGIN, B.N., DZYUBA, O.S., KOSTYLEVA, V.V., GLINSKIKH, L.A., SELTZER, V.B., IVANOV, A.V. & URMAN, O.S. 2012. Preliminary results of study the Bathonian (Middle Jurassic) rocks in the vicinity of Saratov in

year 2012. – Problems of paleoecology and historical geocology: 151–163, Saratov. [In Russian]
 SHURYGIN, B.N., NIKITENKO, B.L., MELEDINA, S.V., DZYUBA, O.S. & KNYAZEV, V.G. 2011. Comprehensive zonal subdivisions of Siberian Jurassic and their significance for Circum-Arctic correlations. – Russian Geology and Geophysics 52: 825–844.
 ZAKHAROV, V.A., BOGOMOLOV, YU.I., IL'INA, V.I., KONSTANTINOV, A.G., KURUSHIN, N.I., LEBEDEVA, N.K., MELEDINA, S.V., NIKITENKO, B.L., SOBOLEV, E.S. & SHURYGIN, B.N. 1997. Boreal zonal standard and biostratigraphy of the Siberian Mesozoic. – Russian Geology and Geophysics 38: 965–993.

Brachiopod diversity in the Jurassic of the Kutch and Jaisalmer basins, western India

DEBAHUTI MUKHERJEE

Palaeontology Division 1, CHQ, Geological Survey of India, Kolkata

The Jaisalmer and Kutch basins in the western part of India started to form as a result of intense tectonic activity associated with the fragmentation of Gondwanaland (BISWAS 1991) and became inundated by the sea during the Early/Middle Jurassic. The newly formed basins provided a virgin area for faunal invasion and rapid speciation of some groups of organisms and thus have a spectacular fossil record, of which brachiopods are a major component. In Kutch, the sedimentary fill consists of carbonates in the Middle and Late Bathonian and then dominantly siliciclastics and records a general deepening which culminates in the Oxfordian and was followed by a regression (FÜRSICH et al., 2003). Brachiopods apparently thrived nearly throughout, but the number and diversity varied widely depending on the lithofacies. In some horizons, such as the Upper Bathonian coral bed of the Jumara Dome, brachiopods are prolific and diverse (5 rhynchonellid species belonging to three genera, 4 terebratulid species and two zeilleriid genera). Another example is the argillaceous siltstone bed in the Middle Callovian of the Jumara Dome where the terebratulid *Kutchithyris breviplicata* largely outnumbers other brachiopods, which are sparse specimens of *K. ingluviosa* and *Aulacothyris*. In contrast, in the shale–concretionary limestone units of the Upper Callovian of the Jumara and Jara domes brachiopods are much fewer in number.

In the Bathonian and Callovian, brachiopods are much diverse and abundant in the Jumara and Keera domes, whereas in the Jhura Dome they become prolific and diverse only during Late Callovian and Oxfordian. The Jara and Jumara domes occupied a more offshore position whereas the Jhura Dome was much closer to the coast in the Middle Jurassic. Therefore, during the Late Callovian sea-level highstand, the Jara, Jumara and Keera domes probably represent deeper parts of the basin, in which a fine-grained and probably soupy substrate inhibited colonisation by brachiopods. The Jhura Dome,

occupying a shallower position, shows a proliferation of brachiopods, particularly of the terebratulid *Kutchithyris*, of which six species are abundant in the uppermost Callovian and Oxfordian.

In Kutch, *Kutchithyris* is the lone terebratulid but in the Jaisalmer Basin along with *Kutchithyris* two other terebratulid genera, the cosmopolitan *Plectoidothyris* and *Bihenithyris*, are also dominating. In the Kimmeridgian–Tithonian, *Somalithyris* has been recorded in both basins (Fig. 1). The brachiopod distribution in both the basins can be summarized as follows.

In Jaisalmer, the two dominant genera in the Bathonian are *Plectoidothyris* and *Cryptorhynchia*, and in the Callovian the predominant taxa are *Kutchithyris breviplicata*, *K. mitra*, *K. ingluviosa*, *K. dhosaensis*, *K. jooraensis*, *Bihenithyris*, *Aulacothyris* sp. and *A. pala*, *Bihendulirhynchia*, *Gibbirhynchia*, *Rhynchonelloidella*, *Sphenorhynchia asymmetrica*, and *Kutchirhynchia*. In the Oxfordian, the dominant genera are *Bihenithyris*, *K. jooraensis*, *G. nobilis*, *Sphenorhynchia*, and *Rhynchonelloidella*. In the Kimmeridgian, terebratulids are absent but the large rhynchonellid *Gibbirhynchia nobilis* is sparsely present.

In Kutch, Bathonian strata contain *Kutchithyris acutiplicata*, *K. propinqua*, *K. euryptycha*, *K. planiconvexa*, *K. katametopa*, *C. karuna*, *C. jooraensis*, *C. pulcherrima*, *C. rugosa*, *Flabellothyris dichotoma*, *Eudesia multicostata*, *Kutchirhynchia kutchensis*, and *Rhactorhynchia pseudoinconstans*. In the Callovian, *Kutchithyris breviplicata*, *K. mitra*, *K. ingluviosa*, *K. dhosaensis*, *K. pyroidea*, *K. propinqua*, *K. euryptycha*, *Aulacothyris* sp., *Gibbirhynchia nobilis*, *Rhynchonelloidella*, *Sphenorhynchia asymmetrica*, *Kutchirhynchia* and *Rhactorhynchia* occur. The Oxfordian brachiopod fauna of Kutch is dominated by five species of *Kutchithyris* i.e., *K. pyroidea*, *K. jooraensis*, *K. ingluviosa*, *K. dhosaensis*, and *K.*

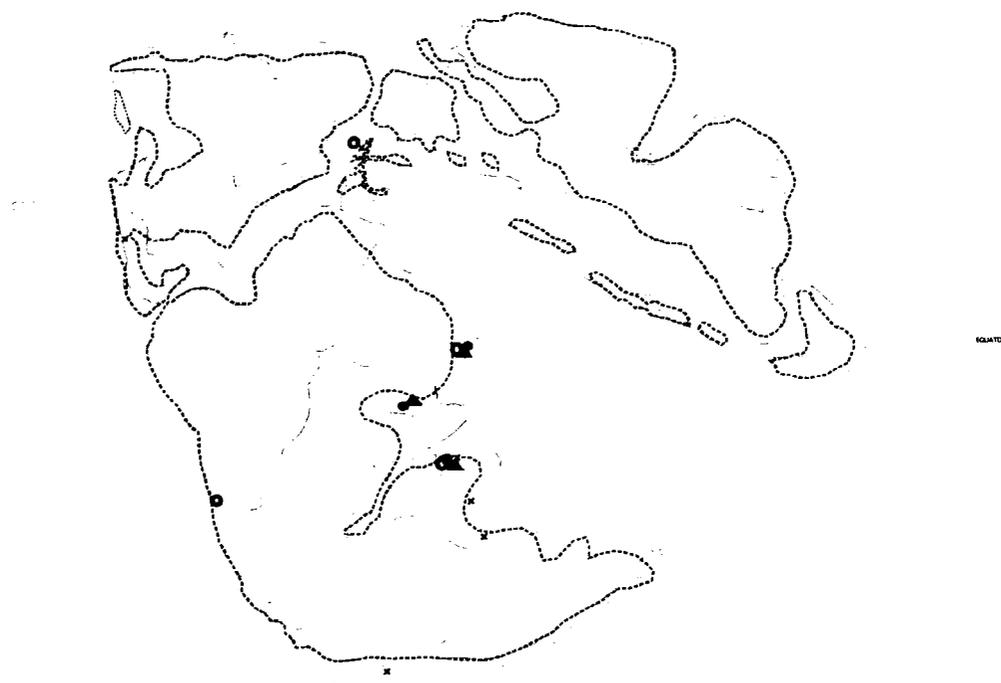


Fig. 1. Distribution of *Plectoidothyris* (circle), *Bihenithyris* (triangle), *Somalithyris* (sphere) and *Kutchithyris* (small ellipse), *Cryptorhynchia* (cross) in the Middle-Upper Jurassic.

euryptycha, as well as by *Rhynchonelloidella* and *Sphenorhynchia*. In the Kimmeridgian–Tithonian *Somalithyris* and *Acanthorhynchia* are present in Kutch and Jaisalmer in a chocolate brown oolitic limestone.

Interestingly, the brachiopod distribution shows that though Kutch and Jaisalmer were adjacent basins the brachiopod faunas considerably differed in the Bathonian but became similar from the Callovian onwards. This may indicate a separation of the basins during Bathonian times, which due to the rise in sea level at the end of the Bathonian probably became connected in the Callovian.

The brachiopod genera in Kutch are more endemic. *Kutchithyris* appeared in the Middle Bathonian of Kutch without any obvious ancestor and speciated quickly to monopolize the space of the newly emerging basin with its 12 species for a span of 13.5 m.y., continuing to the Oxfordian (MUKHERJEE 2007). In the Jaisalmer Basin some of these species are present in the Callovian. *Kutchithyris* has also been recorded from Pamir, England, New Zealand, Madagascar, and Israel – all from the Middle Jurassic. *Cryptorhynchia*, a Middle Jurassic rhynchonellid brachiopod, is abundant in the Bathonian sediments of Kutch. The oldest species, *C. karuna* and *C. jhooraensis*, are known from the Middle Bathonian of Kutch and gave rise to two Upper Bathonian species,

C. pulcherrima and *C. rugosa* (MUKHERJEE et al. 2002). The genus had a very quick dispersal and has a wide biogeographic distribution, *C. pulcherrima* is present in the Upper Bathonian of Burma, the Pamirs, and New Zealand, and another species, *C. bearensis*, has been recorded in the Upper Bathonian of Mexico. The genus has also been recorded in the Bathonian strata of Jaisalmer (Fig. 1).

The terebratulide fauna of Jaisalmer consists of cosmopolitan taxa that have come from other parts of the Indo–Madagascan Province (*Bihenithyris* and *Somalithyris*) or even the European Province (*Plectoidothyris*).

References

- BISWAS, S. K. 1991. Stratigraphy and sedimentary evolution of the Mesozoic basin of Kutch, western India, p.74–103, In *Sedimentary basins of India: tectonic context*, S. K. TANDON, C. C. PANT & S. M. CASSHYAP, eds. Gyanodaya Prakashan, Nainital.
- FÜRSICH, F.T., CALLOMON, J. H., PANDEY, D.K. & JAITLEY, A. K. 2004. Environments and faunal patterns in the Kachchh rift basin, western India, during the Jurassic. – *Rivista Italiana di Paleontologia e Stratigrafia*, 110: 181–190.
- MUKHERJEE, D. 2007. A taxonomic and phylogenetic study of *Kutchithyris* – a Jurassic terebratulide from Kutch, India. – *Journal of Asian Earth Sciences* 30 (2007): 213–237.
- MUKHERJEE, D., BARDHAN, S. & GHOSH, D.N. 2002. Significance of new species of *Cryptorhynchia* (Brachiopoda) from the Middle Jurassic of Kutch, India. – *Alcheringa* 26: 209–231.

Life in a Jurassic shelf lagoon: The Kamar-e-Mehdi Formation of east-central Iran

YANHONG PAN¹ * & FRANZ T. FÜRSICH²

¹Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, East Beijing Road 39, 210008 Nanjing, China; E-mail: yhpan@nigpas.ac.cn

²Fachgruppe Paläoumwelt, GeoZentrum Nordbayern, Friedrich-Alexander University Erlangen, Loewenichstrasse 28, D 91054 Erlangen, Germany; E-mail: franz.fuersich@fau.de

*Corresponding author

The Callovian-Oxfordian Kamar-e-Mehdi Formation of east-central Iran is an extensive carbonate shelf lagoon, up to 100 km wide and about 500 km long, that formed behind a large carbonate platform, the Esfandiar Limestone Formation (WILMSEN et al. 2010). The carbonate system developed on a tilted fault block, the Tabas Block, which is sandwiched between the Yazd Block in the west and the Lut Block in the east. The three blocks together form the Central-East Iranian Microcontinent (CEIM) which, during the Jurassic, was situated at the southern margin of Eurasia and experienced extensional tectonics due to subduction of the Neotethys. Sediments of the shelf lagoon, the carbonate platform, and of the slope forming the eastern flank of the fault block (Qal-eh Dokhtar Formation) are lithostratigraphically grouped in the Esfandiar Subgroup of the Late Bajocian - Tithonian Magu Group (WILMSEN et al. 2003).

The sediments of the shelf lagoon are mainly low-energy, fine-grained carbonates (mudstones, wackestones, floatstones) with rare intercalations of grainstones and rudstones and contain several levels with meter-sized patch reefs. Occasional thin intercalations of fine-grained sandstones are derived from the uplifted Yazd Block in the west and exhibit signs of storm-induced sedimentation such as a sharp erosional base, parallel lamination often followed by oscillation ripples, current ripple lamination, and hummocky cross-stratification. Parts of the carbonates are organised in several-meter-thick cycles which are characterised by an upward decrease of clay content and an increase in the degree of cementation and benthic macrofauna. Towards the top of the formation, mudstones with gypsum needles

and a 40-m-thick package of gypsum with mudstone and dolostone intercalations occur. The formation is overlain by evaporites of the Magu Gypsum Formation.

The Kamar-e Mehdi Formation contains a rich, moderately diverse macrofauna, strongly dominated by bivalves, which are represented by around 70 taxa (FÜRSICH & PAN 2014). The remaining fossils groups (gastropods, brachiopods, crinoids, calcisponges, serpulids, and corals) are comparatively rare, except where they form elements of patch reefs. These patch reefs are usually 1-5 m across and up to 1.5 m high. Frame-builders are either the oyster *Nanogyra*, calcisponges and *Nanogyra*, the oyster *Actinostreon*, the sclerosponge *Neuropora* and branching corals, corals, or microbialites with some corals. The latter variety is locally common in the lower part of the formation, which has been singled out as the Echellon Limestone Member. In this member, patch reefs may reach up to 12 m in height. Within the microbial crusts *Tubiphytes* is a common element.

Ammonites (perisphinctids) are extremely rare and belemnites are absent. Up-section, the diversity and abundance of the faunal elements decreases drastically.

The benthic macrofauna is dominated by small shallow-infaunal bivalves such as *Nicaniella*, *Corbulomima*, and *Protocardia* and by rarer, large deep-burrowing bivalves such as *Pholadomya*, *Ceratomya*, and *Homomya*, which occasionally are preserved in growth position. Occasionally, the small bivalves form shell pavements, in which the disarticulated valves are generally convex-up oriented. More conspicuous are shell concentrations (pavements and thin shell beds) of epibyssate

(*Pseudopecten*, *Camptonectes*, *Eligmus*), endobyssate (*Gervillella*), and cementing taxa (*Actinostreon*, *Nanogyra*), which typically occur at the top of the carbonate cycles. As both, byssate and cementing taxa require some hard substrate for anchorage they apparently colonised the lagoonal floor when a certain amount of secondary hard substrates in form of shell debris or complete shells of infaunal elements were available.

Individual carbonate cycles start with marl or silty marl followed by calcareous marlstones/silty marlstones which contain a softground fauna composed of small shallow- and large deep-infaunal bivalves. Towards the top the clay and silt content decreases as apparently did the sedimentation rate. Winnowing by currents produced autochthonous shell pavements. Pauci- to monospecific pavements indicate some degree of sorting and lateral transport (parautochthonous shell pavements). The secondary hard substrates were colonised by epifaunal taxa. Most conspicuous are two large pectinids, *Pseudopecten tipperi* and a new species of *Camptonectes*, which after winnowing formed laterally extensive thin shell beds on top of the cycles.

Environmental factors governing the distribution of the benthic fauna were salinity, which in the upper part of the formation led to increasing environmental stress, and the

substrate consistency, which was soft to soupy throughout much of the sedimentary record of the formation.

Palaeobiogeographically, the overwhelming majority of the bivalves are known also from other areas of the northern shelf of the Neotethys such as the epicontinental seas of Europe. Exceptions are the bivalves *Agrawalimya*, so far known only from the Callovian of Kachchh, western India, *Eligmus*, an element of tropical areas such as the Arabian Peninsula and Sinai but occasionally spreading south to Kachchh and north to southern and western Europe (Sardinia, Normandy), and *Neoburmesia*, hitherto known only from Japan. Two of the most common taxa thriving in the waters of the shelf lagoon, *Pseudopecten tipperi* and *Camptonectes* sp. nov., are the only endemic elements of the bivalve fauna.

References

- FÜRSICH, F.T. & PAN, Y.-H. 2014. Callovian-Oxfordian (Jurassic) bivalves from the Kamar-e-Mehdi Formation of east-central Iran. *Beringeria* (in press).
- WILMSEN, M., FÜRSICH, F.T. & SEYED-EMAMI, K. 2003. Revised lithostratigraphy of the Middle and Upper Jurassic Magu Group of the northwestern Tabas Block, east-central Iran. – *Newsletters on Stratigraphy* 39: 143–156.
- WILMSEN, M., FÜRSICH, F.T., SEYED-EMAMI, K., MAJIDIFARD, M.R. & ZAMANI PEYDARAM, M. 2010. Facies analysis of a large-scale Jurassic shelf-lagoon: the Kamar-e-Mehdi Formation of east-central Iran. – *Facies* 56: 59–87.

A review of *Virgatosphinctes densiplicatus* (WAAGEN) from the Tithonian beds of Kachchh Basin, west India

DHIRENDRA K. PANDEY & SNEHA BHAUMIK*

Department of Geology, University of Rajasthan, Jaipur 302 004, India; E-mail: dhirendrap@hotmail.com

*Corresponding author

The variability in the ornamentation of Early Tithonian *Virgatosphinctes densiplicatus* (WAAGEN, 1875) from the Umia Ammonite bed (SPATH 1933: 865) of the Kateswar and Lakhapar sections has been analysed. All these ammonites exhibit biplicate ribbing on the inner whorls (ribs branching at mid lateral height) and virgatotome ribbing on the outer whorls. Occasionally, one of the secondaries ris in virgatotome ribs appears free, but close examination of the virgatotome ribbing revealed that ribs initially bifurcate at one-third of lateral height and subsequently at mid lateral height. The primary ribs are thin and closely spaced on the inner whorls and gradually become thicker and sparser. The maximum diameter of the investigated specimens measured 126 mm.

Virgatosphinctes densiplicatus (WAAGEN) and *Virgatosphinctes communis* SPATH are

the closest comparable species. However, *V. communis* differs from *densiplicatus* in having longer primary ribs. Additionally, *V. communis* exhibits oblique folds on the smooth lateral surface near the aperture, whereas such oblique folds are absent in *V. densiplicatus*.

References

- SPATH, L.F. 1927-1933. Revision of the Jurassic cephalopod fauna of Kachh (Cutch). Parts I-VI. – Memoirs of the Geological Survey of India, Palaeontologia Indica, new series 9, 2: part I, 1–71, pls. 1–7 [1927]; part II, 72–161, pls. 8–19 [1928a]; part III, 162–278, pls. 20–47 [1928b]; part IV, 279–550, pls. 48–102 [1931a]; part V, 551–658, pls. 103–124 [1931b]; part VI, 659–945, pls. 125–130 [1933].
- WAAGEN, W. 1873-1875. Jurassic fauna of Kutch. The Cephalopoda. – Memoirs of the Geological Survey of India, Palaeontologia Indica, series 9, 1: part I, 1–22, pls. 1–4 [1873]; part II, 23–76, pls. 5–14 [1875a]; part III, 77–106, pls. 15–24 [1875b]; part IV, 107–247, pls. 25–60 [1875c].

Sequence stratigraphic framework of the Oxfordian to Tithonian sediments (Baisakhi Formation) in the Jaisalmer Basin

DHIRENDRA K. PANDEY & DHARAMVEER POONIYA*

Department of Geology, University of Rajasthan, Jaipur 302 004, India; E-mail: dhirendrap@hotmail.com

**Corresponding author*

Seven sections through the Oxfordian – Tithonian Baisakhi Formation in the Jaisalmer Basin have been interpreted for construction of a sequence stratigraphic framework. In all, within these sections 35 parasequences grouped into three depositional sequences (TST-HST/FSST) have been recognized. At least in two cases the maximum flooding surface (MFS) has found superimposed on the transgressive surface. These parasequences belong to a continuous sequence representing shoreface, the deepest part of the basin, to foreshore, shallower parts of the basin. During deposition of the Tithonian part of the sequence the southern part of the basin witnessed shallow, nearshore or foreshore to fluvial depositional environments and, consequently, several depositional gaps and less distinct parasequences.

The chronological order of the parasequences has been established on the basis of ammonites (Oxfordian *Dichotomosphinctes* sp. and Kimmeridgian *Torquatisphinctes alterniplicatus* (WAAGEN) or *Torquatisphinctes* n.sp.) and the most logical facies correlation. Unfortunately, no marker bed has been recognized. However, the record of at least two brackish-water phases helped in understanding depositional settings along onshore – offshore transects during these time intervals.

In general, the Kimmeridgian – Tithonian part of Baisakhi Formation exhibits a general coarsening-upward trend and a change from lower shoreface to fluvial environments. The at least three sequence cycles that are represented by the succession correspond to a still higher, i.e. second-order sequence cycle.

Record of a condensed late Early to Middle Callovian horizon (Rehmanni-Obtusicosites zones) from the eastern part of the Jaisalmer Basin, western India

DHIRENDRA K. PANDEY & NARENDRA SWAMI*

Department of Geology, University of Rajasthan, Jaipur 302 004, India; E-mail: dhirendrap@hotmail.com

*Corresponding author

Condensed horizon recorded in the Oxfordian of the neighbouring Kachchh Basin has been found quite useful in the intrabasinal stratigraphic correlation (ALBERTI et al. 2013). Bioturbation, concentration of high diversity of biotic elements, reworking and mixing of fauna are common features observed in the condensed horizons. Condensed successions are commonly deposited during transgressions and are associated with „maximum flooding surfaces“ and therefore may form important sequence stratigraphic markers. The condensed horizon recorded in the present work from the eastern part of the Jaisalmer Basin (1km west of the Kanod village) lithostratigraphically belongs to Kuldhar Member of the Jaisalmer Formation. It is characterized by bioturbated calcareous highly fossiliferous siltstone with reworked ammonites (*Eucycloceras eucyclum* (WAAGEN), *Idiocycloceras periophinetoides* (SPATH), *Obtusicosites obtusica* (WAAGEN), *Kinkeliniceras kinkelini* (DACQUE), *Hubertoceras aff. mutans* (WAAGEN), *Sivajiceras paramorphum* (WAAGEN), *S. aureum* SPATH, *S. besairiei* COLLIGNON). The other biotic elements recorded from this horizon are bivalves (*Plagiostoma*, *Lopha-marshi*, Oysters), brachiopods (Terebratulids, large Rhynchonellids), belemnites and trace fossils. The reworking is evident from bored and encrusted concretions, weathered ammonite fragments encrusted with oysters and serpulids.

This 65 cm thick condensed horizon is underlain by 12 cm thick bioclastic mud- to packstone bed with hardground surface, which may correspond to Late Bathonian upper part of the Bada Bag Member at the Kuldhar section (PANDEY et al. 2012) and is overlain by 100 cm thick gypsiferous shale yielding hectoceratids (upper part of Callovian Kuldhar Member, probably representing Upper

Callovian Athleta Zone). Based on ammonite association, consisting ammonite assemblages of “Rehmanni zone” sensu SPATH (1933), *Anceps* and *Obtusicosites* zones sensu KRISHNA & OJHA (1996, 200), this condensed horizon has been assigned to late Early Callovian to Middle Callovian age.

The coeval sediment recorded from the Kuldhar river section is much thicker (measured > 15 m) from where at least *Macrocephalites transitorius* assemblage (Early Callovian), *Subkossmatia opis* assemblage (late Early Callovian), *Reineckeia anceps* assemblage (early Middle Callovian) and *Callotia gigantea* assemblage (late Middle Callovian) have been recorded by KRISHNA (1987). This implies that the eastern margin of the basin presents more erosional and reworking events.

References

- ALBERTI, M., FÜRSICH, F. T. & PANDEY, D.K. 2013. Deciphering condensed sequences: A case study from the Oxfordian (Upper Jurassic) Dhosa Oolite member of the Kachchh Basin, western India. – *Sedimentology* 60 (2): 574–598.
- KRISHNA, J. 1987. An overview of the Mesozoic stratigraphy of Kachchh and Jaisalmer basins. – *Journal of the Palaeontological Society of India*, 32: 136–149.
- KRISHNA, J. & OJHA, J.R. 1996. The Callovian ammonoid chronology in Kachchh (India). In: *Advances in Jurassic Research* (Ed., Riccardi, A.C.). *GeoResearch Forum*, 1-2: 151–166.
- KRISHNA, J. & OJHA, J.R. 2000. The Intrabasinal Correlation in the Middle Jurassic Callovian Stage of Kachchh (Gujarat) and Ammonoid-Foraminifer Integration. – *Geophytology* 28 (1&2): 101–120.
- PANDEY, D.K. CHOUDHARY, S, TEJ BAHADUR, SWAMI, N. & SHA, J. 2012b. A review of the Lower – lowermost Upper Jurassic lithostratigraphy of the Jaisalmer Basin, western Rajasthan, India - an implication on biostratigraphy. – *Volumina Jurassica* 10: 61–82.
- SPATH, L.F. 1927-1933. Revision of the Jurassic cephalopod fauna of Kachh (Cutch). Parts I-VI. – *Memoirs of the Geological Survey of India, Palaeontologia Indica*, new series 9 (2): 1–945.

Table 1. Lithostratigraphic divisions of the Jhura Dome section (BISWAS 1980).

Formation	Member	Description
Jumara	IV (20 m)	Dhosa Oolite Member: Green oolite marlstone bands alternating with beds of green shale and topped by conglomeratic band
	III (106 m)	Green, gypsiferous shale with fossiliferous marl, ferruginous and white marlstone bands
	II (50 m)	Green, gypsiferous shale with fossiliferous white marlstone and red ferruginous bands. Green, hard, sandy fossiliferous marlstone
	I (90 m)	Thick, greenish to yellow-grey, laminated, gypsiferous, argillaceous shale with thin red nodular hematite bands and numerous grey marlstone and yellowish white limestone bands
Jhurio	Member G (72 m)	Well bedded and jointed white, grey, or cream-coloured limestone
	Member F (20 m)	Thick Golden oolite bands are intercalated with thinly bedded yellow limestone
	Member E (45 m)	Golden oolite-thick beds
	Member D (40 m)	Khaki-coloured laminated calcareous shale with lenses of crystalline calcite
	Member C (15 m)	Golden oolite-thick beds, when weathered brick-red
	Member B (25 m)	Grey, khaki-coloured, calcareous, laminated silty shales
	Member A (19 m)	Limestone and minor shale

informal members (Table 1) by BISWAS (1991). The Middle Jurassic succession of the Jhura Dome (Jhurio and Jumara formations) consist of carbonate and mixed siliciclastic-carbonate sediments and attain thickness is about 600 m.

Clastic (oolitic) carbonate rocks are present at four different stratigraphic levels in the succession; based on lithological characteristics, associated physical and biogenic structures, textures, body fossil content, and type of bed contact, the succession exhibits six sedimentary facies and four subfacies namely, (1) Limestone Facies – (LF); (Badi Limestone Subfacies – BLSF, White Nodular Well Bedded Limestone Subfacies – NWWLSF); (2) Conglomerate Facies – CF, (3) Calcareous Silty Shale Facies – CSSLF, (4) Oolitic Limestone Facies – OLF (Golden Oolite Subfacies – GOSF and Dhosa Oolite Subfacies – DOSF), (5) Rippled Calcareous Sandstone-Shale Facies – RMCSSF, and (6) Greenish-grey Shale Facies – GGSF. The majority of the facies are highly fossiliferous and bioturbated ; certain bands

Table 2. Ethology and toponomy of trace fossils from the Jhura Dome.

of various facies such as DOSF, RMCSSF etc. are rich in ammonites, belemnites, brachiopods, and bivalves while CF and GGSF, and some part of the RMCSSL and DOSF are found to be devoid of trace fossils.

A total of 71 ichnospecies and 37 ichnogenera were identified with some indistinct forms. All identified ichnospecies have been tabulated (Table 2) and grouped into different ethological and toponomical categories based on their behavioural and preservational patterns. Trace fossils such a *Rhizocorallium uraliense*, *Parahaentzschelina ardelia*, *Phoebichnus trochoides*, *Pilichnus dichotomus*, *Phymatoderma* isp., *Cosmorhapha carpathica*, *Chondrites recurvus*, and a number of *Zoophycus* species are reported for the first time from the sedimentary succession of the Jhura Dome. *Zoophycus* is the most conspicuous feature of the Dhosa Oolite subfacies.

The analysis of trace fossils revealed six ichno-assemblages, eighteen ichno-guilds and three ichnofacies. Six ichno-assemblages (*Protovirgularia* IA, *Zoophycos-Chondrites* IA, *Rhizocorallium-Pilichnus* IA, *Ophiomorpha* IA, *Thalassinoides-Palaeophycus* IA, and *Taenidium-Keckia* IA) have been distinguished on the basis of their occurrence and association with other ichnotaxa which provided important information on palaeoenvironment, bathymetry, wave and current energy, food availability, oxygen conditions and substrate consistency.

Eighteen ichnoguilds are recognized, which indicate similar feeding behaviour and occupy a similar tier or location within the substrate (BROMLEY 1990). They include the *Arenicolites* IG, *Calycraterion* IG, *Chondrites* IG, *Diplocraterion* IG, *Gyrochorte* IG, *Keckia* IG, *Margaritichnus* IG, *Ophiomorpha* IG, *Palaeophycus* IG, *Parahaentzschelina* IG, *Phoebichnus* IG, *Planolites* IG, *Protovirgularia* IG, *Rhizocorallium* IG, *Skolithos* IG, *Taenidium* IG, *Thalassinoides* IG, and *Zoophycus* IG. Each ichno-guilds provides details on the substrate condition, level of tiering, diversity, density, degree of bioturbation, associated ichnotaxa, ichnofacies, lithofacies, and probable depositional environment.

Three Seilacherian ichnofacies have been identified: *Skolithos* Ichnofacies (shoreface);

Ichnogenera / Ichnospecies

1. *Ancorichnus ancorichnus*
2. *Arenicolites carbonarius*
3. *Beaconites antarcticus*
4. *Beaconites coronus*
5. *Bergaueria* isp.
6. *Biformites* isp.
7. *Chondrites intricatus*
8. *Chondrites* isp.
9. *Chondrites patulus*
10. *Chondrites recurvus*
11. *Chondrites targionii*
12. *Cochlichnus anguineus*
13. *Cosmorhapha carpathica*
14. *Calycraterion* isp.
15. *Calycraterion samsonowiczi*
16. *Didymaulichnus* isp.
17. *Diplocraterion habichi*
18. *Gordia marina*
19. *Gyrochorte comosa*
20. *Gyrolithes polonicus*
21. *Keckia annulata*
22. *Laevicyclus mongraensis*
23. *Lockeia ornata*
24. *Lockeia siliquaria*
25. *Margaritichnus reptilis*
26. *Monocraterion tentaculatum*
27. *Ophiomorpha nodosa*
28. *Ophiomorpha recta*
29. *Palaeophycus annulatus*
30. *Palaeophycus heberti*
31. *Palaeophycus striatus*
32. *Palaeophycus tubularis*
33. *Parahaentzschelinia ardelia*
34. *Phoebichnus trochoides*
35. *Phycodes circinnatum*
36. *Phycodes curvipalatum*
37. *Phycodes palmatum*
38. *Phycodes pedum*
39. *Phymatoderma* isp.
40. *Pilichnus dichotomus*
41. *Planolites annularis*
42. *Planolites beverleyensis*
43. *Planolites* isp.
44. *Planolites montanus*
45. *Protovirgularia dichotoma*
46. *Rhizocorallium irregulare*
47. *Rhizocorallium jenense*
48. *Rhizocorallium uraliense*
49. *Sabularia ramosa*
50. *Scolicia strozzii*
51. *Skolithos linearis*
52. *Skolithos verticalis*
53. *Taenidium cameroneensis*
54. *Taenidium satanassi*
55. *Taenidium serpentinum*
56. *Thalassinoides foedus*
57. *Thalassinoides horizontalis*
58. *Thalassinoides paradoxicus*
59. *Thalassinoides suevicus*
60. *Urohelminthoidea dertonensis*
61. *Zoophycus brianteus*
62. *Zoophycus caudagalli*
63. *Zoophycus circinnatus*
64. *Zoophycus insignis*
65. *Zoophycus laminatus*
66. *Zoophycus villae*
67. *Zoophycus* Type A
68. *Zoophycus* Type B
69. *Zoophycus* Type C
70. *Zoophycus* Type D
71. *Zoophycus* Type E

Ethology

1. Crawling (Repichnia)
2. Dwelling (Domichnia)
3. Grazing (Pascichnia)
4. Grazing (Pascichnia)
5. Dwelling (Domichnia)
6. Dwelling and feeding
7. Feeding (Fodinichnia)
8. Feeding (Fodinichnia)
9. Feeding (Fodinichnia)
10. Feeding (Fodinichnia)
11. Feeding (Fodinichnia)
12. Crawling (Repichnia)
13. Grazing (Pascichnia)
14. Dwelling (Domichnia)
15. Dwelling (Domichnia)
16. Crawling (Repichnia)
17. Dwelling and feeding
18. Crawling (Repichnia)
19. Grazing (Pascichnia)
20. Feeding (Fodinichnia)
21. Grazing (Pascichnia)
22. Dwelling (Domichnia)
23. Resting (Cubichnia)
24. Resting (Cubichnia)
25. Dwelling (Domichnia)
26. Dwelling (Domichnia)
27. Dwelling (Domichnia)
28. Dwelling (Domichnia)
29. Crawling and feeding
30. Crawling and feeding
31. Crawling and feeding
32. Crawling and feeding
33. Feeding (Fodinichnia)
34. Feeding (Fodinichnia)
35. Feeding (Fodinichnia)
36. Feeding (Fodinichnia)
37. Feeding (Fodinichnia)
38. Feeding (Fodinichnia)
39. Feeding (Fodinichnia)
40. Feeding (Fodinichnia)
41. Crawling and feeding
42. Crawling and feeding
43. Crawling and feeding
44. Crawling and feeding
45. Crawling (Repichnia)
46. Dwelling and feeding
47. Dwelling and feeding
48. Dwelling and feeding
49. Feeding (Fodinichnia)
50. Crawling (Repichnia)
51. Dwelling (Domichnia)
52. Dwelling (Domichnia)
53. Crawling and feeding
54. Crawling and feeding
55. Crawling and feeding
56. Dwelling and feeding
57. Dwelling and feeding
58. Dwelling and feeding
59. Dwelling and feeding
60. Grazing (Pascichnia)
61. Feeding (Fodinichnia)
62. Feeding (Fodinichnia)
63. Feeding (Fodinichnia)
64. Feeding (Fodinichnia)
65. Feeding (Fodinichnia)
66. Feeding (Fodinichnia)
67. Feeding (Fodinichnia)
68. Feeding (Fodinichnia)
69. Feeding (Fodinichnia)
70. Feeding (Fodinichnia)
71. Feeding (Fodinichnia)

Toponymy

1. Endichnial
2. Endichnial
3. Epichnial
4. Epichnial
5. Epichnial
6. Endichnial
7. Endichnial
8. Endichnial
9. Endichnial
10. Endichnial
11. Endichnial
12. Epichnial
13. Epichnial
14. Epichnial
15. Epichnial
16. Epichnial
17. Endichnial
18. Epichnial
19. Epichnial
20. Endichnial
21. Epichnial
22. Endichnial
23. Epichnial
24. Epichnial
25. Endichnial
26. Endichnial
27. Endichnial
28. Endichnial
29. Endichnial
30. Endichnial
31. Endichnial
32. Endichnial
33. Endichnial
34. Endichnial
35. Endichnial
36. Endichnial
37. Endichnial
38. Endichnial
39. Endichnial
40. Epichnial
41. Endichnial
42. Endichnial
43. Endichnial
44. Endichnial
45. Epichnial
46. Endichnial
47. Endichnial
48. Endichnial
49. Epichnial
50. Hypichnial
51. Endichnial
52. Endichnial
53. Endichnial
54. Endichnial
55. Endichnial
56. Hypichnial and epichnial
57. Hypichnial and epichnial
58. Hypichnial and epichnial
59. Hypichnial and epichnial
60. Hypichnial
61. Endichnial
62. Endichnial
63. Endichnial
64. Endichnial
65. Endichnial
66. Endichnial
67. Endichnial
68. Endichnial
69. Endichnial
70. Endichnial
71. Endichnial

Cruziana Ichnofacies (lower shoreface – offshore) and Zoophycus Ichnofacies (shelf). An idealized shoreface model of ichnofacies was applied for better understanding of various depositional environments corresponding to different ichnofacies (PEMBERTON et al. 1992). The collected information has been integrated in working out the depositional environments for the sedimentary succession of the Jhura Dome which revealed seven distinctive depositional settings; Shelfal below SWWB, Transition to Lower Shoreface, Upper Offshore to Lower Offshore, Lower Shoreface above FWWB, Lower Offshore to Shelf, Lower Shoreface to Middle Shoreface, and Upper Offshore.

The presence of intraformational conglomerates is typical of storm-generated facies; DOSF and GOSF (=clastic limestones) suggest extensive sediment reworking, agitated, moderate to high energy conditions in shallow marine (shoreface-offshore) environments and occasionally witnessed storm conditions (wave ripples). A sudden increase or decrease in terrigenous influx (siliciclastic sedimentation) is responsible for kick-off or development of

carbonate facies, respectively. Trace fossils have also produced similar response and their diversity and abundance was controlled by the different depositional settings. The sedimentary facies and their corresponding sedimentary structures, trace fossils, body fossils and depositional environment is given in Table 3 for a better understanding of the relationship of trace fossil assemblages with the depositional environment.

References

- BISWAS, S.K. 1980. Mesozoic rock stratigraphy of Kutch, Gujarat. – Quarterly Journal of the Geological, Mining and Metallurgical Society of India 49:1–52 (for 1977).
- BISWAS, S.K. 1991. Stratigraphy and sedimentary evolution of the Mesozoic basin of Kutch, western India. In: TANDON, S.K., PANT, C.C. & CASSHYAP, S.M. (eds), Proceedings of Seminar on Sedimentary Basins of India, Nainital: 74–103, Gyanodaya Prakashan, Nainital.
- PEMBERTON, S.G., MACEACHERN, J.A. & FREY, R.W. 1992. Trace fossil facies models: environmental and allostratigraphic significance. In: WALKER, R.G., & JAMES, N. (eds), Facies Models: Responses to Sea Level Change, Geological Association of Canada: 47–72

Table 3. Sedimentary facies and their corresponding sedimentary structures, trace fossils, body fossils, and depositional environment.

Lithofacies	Physical sedimentary structures	Trace-fossils	Body fossils	Depositional Environment
DOs	Conglomeratic towards top; Oolites	Zo, Th, Pa, Ch, Sk, Rh, Gy	Highly fossiliferous; Ammonoids; Belemnites;	Condensed section; Upper Offshore
RMCSL	Wave ripples; Cross stratification Coarse to granules and pebbles	Op, Th, Rh, Pl, Pi, Py, Pa, Par, Mo, Ma, Le, Gy, Gyl, Go, Di, Ca, Ch, Ar, An	Highly fossiliferous; Lamellibranchia; Brachiopods Belemnites Gastropods	Lower Shoreface to Middle Shoreface
NWWLs	Thin parallel lamination; Well bedded	An, Be, Ch, Co, Cos, Ke, Lo, Pa, Ph, Pr, Sc, Th, Zo	Lamellibranchia; Brachiopods Belemnite Crinoids	Lower Offshore to Shelf
GOs	Mega ripple marks; Low angle cross stratification; Parallel lamination Oolites; pebbly towards top	Ke, Ta, Op, Sk, Rh, Ch, Pl, Pa, Pi, Di, Dy, Go, Ar, Be, Sa, Ma, Mo, Py Th	Lamellibranchia; Brachiopods Belemnite Crinoids, Corals	Lower Shoreface above FWWB
CSSL	Parallel lamination;	Rh, Ur, Th, Sc, Sa, Pl, Pi, Py, Mo, Ma, Pa, Le, Gy, Di, Ca, Ch, Bi, Be, Ar	Belemnite; Ammonoids	Upper Offshore to Lower Offshore
BLs	Parallel lamination; Bedded	Zo, Ur, Th, Rh, Op	Lamellibranchia; Brachiopods; Gastropods; Small ammonoids; Bryozoans	Shelfal below SWWB

Discovery of Early Bathonian ammonites from Kachchh, western India and their biostratigraphic implications

DEO BRAT PATHAK & BINDHYACHAL PANDEY

Department of Geology, Banaras Hindu University, Varanasi 221005, India; E-mail: dbpathak@yahoo.com, drbpandey@yahoo.co.in

The ammonite genera *Parkinsonia* and *Siemiradzka* are reported for the first time from the Indian subcontinent including the Himalayas. These genera are recorded here in association with *Prohecticoceras*, *Procerites*, and *Wagnericeras* from the famous ammonite-bearing Jurassic locality of Kachchh, western India. This finding represent the oldest ammonite-bearing levels in the Kachchh Mainland.

The present contribution is based on a fresh ammonoid collection from part of the Patcham Formation, exposed in the northwest sector of Nara dome (23° 38' 30" N, 69° 07' 55" E), about 1 km south of the village Nara, situated in the western part of Mainland Kachchh. The investigated stratigraphic section is ~16-m-thick comprising whitish grey limestone, sandy limestone with shale/silt/marl interbeds and is underlain and overlain by volcanic rock. The ammonites have been collected in-situ from a ~1.5-m-thick highly fossiliferous, ammonoid-rich limestone bed lying ~3.5 m above the base. In contrast, all other hard bands of the succession are relatively poorly fossiliferous.

The new ammonoid assemblage includes the genera *Parkinsonia*, *Siemiradzka*, *Prohecticoceras*, *Procerites*, and *Wagnericeras* with a few other endemic forms. This assemblage is dominated by cosmopolitan genera well known from the Submediterranean province which enables to date the present section in context of the Submediterranean standard ammonoid zonal scheme and in turn allows its correlation with the Macrescens Subzone (Zizag Zone) to Recinctus Subzone (Aurigerus Zone) interval of Early Bathonian age. It is also the first definite record of the presence of Early Bathonian sediments in the Kachchh Basin. The presence of two zones in a single bed (1.5-m-thick) suggests a relatively slow rate of sedimentation and stratigraphic condensation. The sudden appearance of these Submediterranean ammonoid faunal elements in the Indian subcontinent is probably due to an expansion event during the eustatic rise in sea level at the end of the Early Bathonian, already recognized on the northern margin of the Tethys in southern Europe.

Parkinsoniids and garantianids (Late Bajocian Ammonoidea) as guide fossils and biostratigraphic indices

GIULIO PAVIA¹ * & SIXTO R. FERNANDEZ-LOPEZ²

¹*Dipartimento di Scienze della Terra, Università degli Studi di Torino, 10125 Torino, Italy; E-mail: giulio.pavia@unito.it*

²*Departamento Paleontología, Facultad Ciencias Geológicas, calle José Antonio Novais,2, Universidad Complutense de Madrid, 28040-Madrid, Spain; E-mail: sixto@ucm.es*

Taphonomic, palaeobiological and biochronological data are relevant in interpreting time-space relationships of fossiliferous rock bodies, and in understanding the palaeoenvironmental changes taking place on Earth's surface. It is assumed that the bed-by-bed order of succession shown by fossils in the stratigraphic record represents the chronological order of the producer taxa. However, a particular feature of the fossil record can condition the validity of the palaeontological interpretations. In diverse cases it cannot be assured that fossils and rocks of the same stratigraphic interval represent the same time interval or the same palaeoenvironment. In this sense, it must be stressed that the fossil record can supply information on palaeoenvironments and processes that have left no traces in the stratigraphic record (FERNANDEZ-LOPEZ 2000). Consequently, palaeontological successions can display higher biochronological and geochronological completeness than lithostratigraphic and biostratigraphic successions. Taphonomic analyses are fundamental, as their results can furnish evidence of diachroneity within the facies and the fossil assemblages of the studied stratigraphic unit. The characterization of palaeontological units (such as the taphorecords) in a stratigraphic succession and their arrangement according to the time interval of the palaeobiological entities, which produced the recorded fossils, allow defining the palaeontological successions. The palaeontological succession can show a higher number of palaeoenvironmental, depositional, and palaeobiological events than the stratigraphic succession (PAVIA & MARTIRE 1997; PAVIA et al. 2013).

Also the palaeobiogeographic constraints have an effect on the potential of biochronostratigraphic interpretations:

appearances of innovative biota in several areas (then fossils in the stratigraphic record) may be interpreted as synchronous events if they are the effects of synchronous geographic dispersions from a common external source area. However, they are diachronous towards the source area. The appearances of innovative biota can be complementarily calibrated through the synchronicity of the transgressive/regressive changes analysed in sequence stratigraphy, too (SANDOVAL et al. 2001).

Since the latest decades of the past century, the International Subcommission on Jurassic Stratigraphy (ISJS) promoted activities to get definitions for the Global Boundary Stratotype Section and Point (GSSP) of each stage of the Jurassic System, and more recently (MORTON 2003) asserted the opportunity to locate sections that could be proposed as reference for the basal boundary of substages. The definition of the base of each chronozone is also an aspect to be pursued. Such formal definitions are feasible where successions display high chronostratigraphic completeness and stratigraphic parameters do permit this (FERNANDEZ-LOPEZ et al. 2009; PAVIA & ZUNINO 2012). It becomes hard if the succession is affected by stratigraphic and/or taphonomic condensation (FERNANDEZ-LOPEZ 2011). That is a common case in the Parkinsoni Zone, which represents the latest Chron of the Bajocian Stage. The ammonite groups involved in the topic are basically: the microconch *Parkinsonia* with the macroconch partner *Durotrigensia*, and the macroconch *Garantiana* with many allied taxa among them the microconch *Pseudogarantiana*.

Parkinsonia l.s. - The first occurrence of parkinsoniids in the West Tethyan areas looks as sudden, and it is the diagnostic criterion to define the base of the Parkinsoni Zone (RIOULT

et al. 1997) according to the record of the group of *Parkinsonia acris* as the index of the basal subzone. Citations of “parkinsoniids” recur in the literature (e.g., SCHWEIGERT et al. 2002) but their meaning need to be clarified for effective taxonomic relationships and biostratigraphic pertinence, as they commonly derive from condensed stratigraphic sections affected by taphonomic condensation with re-elaborated fossils. Personal data from the Basque-Cantabrian Basin assure the presence of re-sedimented specimens (contemporaneous to the encasing sediments) in the middle part of the Garantiana Zone (FERNANDEZ-LOPEZ 1988). Such specimens show intermediate morphological features between the genus *Caumontisphinctes* of the uppermost Niortense Zone, and the *Parkinsonia* of the basal Parkinsoni Zone. This new biochronostratigraphic information means that the origin of *Parkinsonia* has to be found in a still unknown place within the Submediterranean Province, and that the first occurrence of *Parkinsonia* is not a valid criterion to recognize the basal boundary of the Acris Subzone as it may be affected by diachroneity in terms of palaeobiogeographic

gradients between the Submediterranean and NW European provinces. New continuous biostratigraphic and palaeontological successions are needed to define the subzonal and zonal Garantiana-Parkinsoni boundary.

Garantiana l.s. – This early and middle Late Bajocian taxon developed in the Submediterranean Province and repeatedly diversified during the Garantiana Chron with largest dispersion in the NW European Province. Taxa of the dimorphic couple *Garantiana*–*Pseudogarantiana* are zonal and subzonal indexes for the Garantiana Zone throughout most of the Mediterranean-Caucasian Subrealm. Garantianids developed through evolutionary lineages according to palingenetic processes and peramorphic modifications, interrupted by paedomorphic changes. This iterative evolutionary pattern produced numerous and brief phyletic lineages with common homeomorphs that make it difficult to unravel their taxonomic “strapwork”. Moreover, the type specimens of most garantianids were elected on fossils deriving from the condensed sections of the NW European Province (e.g., DIETZE et al. 2002,

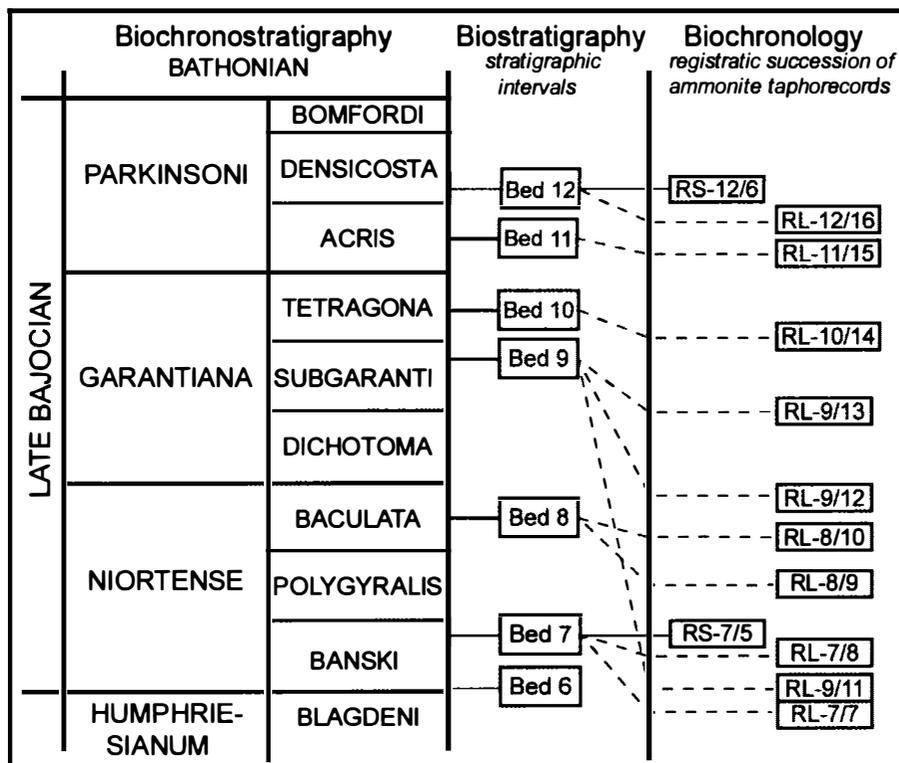


Fig. 1. The biochronological and palaeontologic succession of the Upper Bajocian of Maizet. The left column lists the geochronological divisions and the standard (sub)chronozones for the Bajocian Stage of the West Tethyan Subrealm (modified from PAVIA et al. 2013: fig. 7).

and references therein). Only the latest genus *Paragarantiana* is unambiguously recorded, as contemporaneous with the sedimentary rock bodies, from the lowermost Parkinsoni Zone

Paragarantiana is largely documented in the central sector of the Jurassic Anglo-Paris Basin, and on it we concentrated our research. Although the Bajocian sections of Calvados are condensed, repeated taphonomic analyses (PAVIA et al. 2013, and references therein) allowed aligning successive palaeontological units with biochronological meaning (Fig. 1). Our study delineates the following conclusions: (1) *Paragarantiana* derived by a proterogenetic process with paedomorphic result from garantianids, during the transition between the Garantiana and Parkinsoni zones, displaying the first occurrence in layers of the first record of *Parkinsonia* gr. *acris*; (2) such a new phyletic lineage seems to be driven by a sea-level change at the passage between the Garantiana and Parkinsoni biochrons; (3) this evolutionary event of *Paragarantiana* origination has an unequivocal and singular biochronological meaning that may be used to define the base of the Parkinsoni Zone, possibly paired with the first appearance of the *P. acris* group when its chronostratigraphic value would be ascertained.

The research was supported by the University of Torino grants (2009) and the scientific project CGL2011-23947 (MICINN).

References

- DIETZE, V., SCHWEIGERT, G., CALLOMON, J.H. & GAUTHIER, H. 2002. Garantiana- und frühe Parkinsoni-Zone (Ober-Bajocium, Mittlerer Jura) am Ipf (östliche Schwäbische Alb, SW-Deutschland) mit Bemerkungen zur Phylogenie der Ammonitengattung *Garantiana* Mascke, 1907. – Stuttgarter Beiträge zur Naturkunde B 315: 1–89.
- FERNANDEZ-LOPEZ, S. 1988. El Bajociense superior y Bathoniense inferior en Mataporquera (Santander). Ciencias de la Tierra. – Geología 11: 73–84.
- FERNANDEZ-LOPEZ, S. 2000. Ammonite taphocycles in carbonate epicontinental platforms. In: HALL, R.L. & SMITH, P.L. (eds.), Advances in Jurassic Research 2000. – GeoResearch Forum 6: 293–300.
- FERNANDEZ-LOPEZ, S.R. 2011. Taphonomic analysis and sequence stratigraphy of the Albarracinites beds (lower Bajocian, Iberian Range, Spain). An example of shallow condensed section. – Bulletin de la Société Géologique de France 182: 405–415.
- FERNANDEZ-LOPEZ, S.R., PAVIA, G., ERBA, E., GUIOMAR, M., HENRIQUES M.H., LANZA, R., MANGOLD, MORTON, N., OLIVERO, D. & TIRABOSCHI, D. 2009. Formal proposal for the Bathonian GSSP (Middle Jurassic) in the Ravin du Bès Section (Bas-Auran, SE France). – Swiss Journal of Geosciences 102: 271–295.
- MORTON, N. 2003. Meeting of Jurassic Subcommittee Mondello, Sicily. 19th September 2002. – International Subcommittee on Jurassic Stratigraphy, Newsletter 30: 3–4.
- PAVIA, G. & MARTIRE, L. 1997. The importance of taphonomic studies on biochronology: examples from the European Middle Jurassic. – Cuadernos de Geología Iberica: 153–181
- PAVIA, G. & ZUNINO, M. 2012. Ammonite assemblages and biostratigraphy at the Lower to Upper Bajocian boundary in the Digne area (SE France). Implications for the definition of the Late Bajocian GSSP. – Revue de Paléobiologie, vol. spéc. 11: 205–227.
- PAVIA, G., DEFAVERI, A., MAERTEN, L., PAVIA, M. & ZUNINO, M. 2013. Ammonite taphonomy and stratigraphy of the Bajocian at Maizet, South of Caen (Calvados, NW France). – C.R. Palevol 12: 137–148.
- RIÓULT, M., CONTINI, D., ELMI, S. & GABILLY, J. 1997. Bajocien. In: CARIOU, E. & HANTZPERGUE, P. (eds.), Biostratigraphie du Jurassique ouest-européen et méditerranéen. – Bulletin du Centre des Recherches Exploration-Production Elf-Aquitaine, Mémoire 17: 41–53.
- SANDOVAL, J.L., O'DOHERTY, L. & GUEX, J. 2001. Evolutionary rates of Jurassic ammonites in relation to sea-level fluctuations. – Palaios 16: 330–363.
- SCHWEIGERT, G., DIETZE, W. & DIETL, G. 2002. Erstnachweis der Ammoniten-Gattung *Parkinsonia* BAYLE, 1878 in der Garantiana-Zone (Tetragona Subzone). – Stuttgarter Beiträge zur Naturkunde B 320: 1–15.

A first Upper Jurassic $^{40}\text{Ar}/^{39}\text{Ar}$ date from Oxfordian ammonite-calibrated volcanic layers (bentonites) from the Rosso Ammonitico Veronese, Italy

PIERRE PELLENARD¹ *, SEBASTIEN NOMADE², LUCA MARTIRE³, FABRICE MONNA⁴ & HERVE GUILLOU²

¹*Biogéosciences, CNRS-UMR 6282, Université de Bourgogne, F-21000 Dijon, France; E-mail: Pierre.Pellenard@u-bourgogne.fr*

²*LSCE-IPSL, CNRS-UMR 8212, CEA Orme, F-91191 Gif-sur-Yvette, France; E-Mail: Sebastien.nomade@lsce.ipsl.fr; Guillou.Herve@lsce.ipsl.fr*

³*Dipartimento di Scienze della Terra, University of Torino, via Valperga Caluso 35 10125 Torino, Italy; E-mail: Luca.martire@unito.it*

⁴*ARTEHIS, CNRS-UMR 6298, Université de Bourgogne, F-21000 Dijon, France; E-Mail: Fabrice.Monna@u-bourgogne.fr*

*Corresponding author

The scarcity of interbedded volcanic units in ammonite-bearing marine successions hinders the accurate numerical calibration of the Late Jurassic Time Scale, even with the progress made in GTS2012, including improved numerical ages for stage boundaries, obtained by selecting only single-zircon U-Pb ages, recalculating $^{40}\text{Ar}/^{39}\text{Ar}$ dates, and more precise magnetostratigraphy and cyclostratigraphy (GRADSTEIN et al. 2012). In this study we focus on eight volcanic ash layers weathered into bentonites, identified by their field characteristics, mineralogy, and geochemical features that occurred in pelagic cherty limestones, the Rosso Ammonitico Veronese, from the Trento Plateau domain, north-eastern Italy, at the Serrada, Echar, and Kaberlaba sections (PELLENARD et al. 2013). In the Rosso Ammonitico Veronese, bentonites appear as continuous, centimetre-thick red or white plastic clay-rich horizons, interbedded with limestones and cherts. Mineralogical and elemental analyses were performed on all powdered samples to confirm their volcanic nature. At Kaberlaba, five bentonites are recognised. The ammonite assemblage, characteristic of the *Gregoryceras transversarium* Biozone, indicates a Middle Oxfordian age for the top of the unit where the thickest bentonite has been identified (CLARI et al. 1990; MARTIRE et al. 2006). At Echar, the same five bentonites are recognised and are overlain by three stromatolitic beds, the first of which belongs to the *G. transversarium* Biozone, with the same taxa as at Kaberlaba. At Serrada, six bentonites are recognised and are dated from

the Upper Callovian to the Middle Oxfordian (*G. transversarium* Biozone). As ammonites diagnostic of the *G. transversarium* Biozone were found just below the thickest bentonite at Kaberlaba and just above at Echar, this bentonite clearly belongs to the *G. transversarium* Biozone (Middle Oxfordian).

The laser-fusion step-heating $^{40}\text{Ar}/^{39}\text{Ar}$ method was performed on 30 small (<100 μm) transparent sanidines, carefully hand-picked under a binocular microscope after several treatments from the thickest bentonite. The apparent age spectrum obtained for sanidines is 100% concordant; all steps yield indistinguishable ages, with a well-defined plateau age of 156.1 ± 0.89 Ma (2σ full uncertainty propagation) using the optimisation model of RENNE et al. (2010, 2011) for estimating the partial decay constants of ^{40}K and $^{40}\text{Ar}^*/^{40}\text{K}$ ratio of Fish Canyon sanidine. The plateau age we obtain can be directly compared to U-Pb ages available for the Jurassic Time Scale. Nevertheless, there are no well-constrained radiometric dates, closely tied to ammonite biostratigraphy, currently available for the whole of the Upper Jurassic. Some Upper Jurassic Ar/Ar dates are integrated as secondary guides into GTS2012: (1) A suite of dates from the almost totally non-marine Morrison Fm in the USA (GRADSTEIN et al. 2004; OGG et al. 2008); (2) dates from Oxfordian tuffs intercalated with terrestrial sediments in China (CHANG et al. 2009); (3) dates from ocean-floor basalt veins in the Pacific (GRADSTEIN et al. 2012). A single Re/Os date is available from ammonite-bearing

marine sedimentary successions in the Lower Kimmeridgian (SELBY 2007). As a consequence, the Late Jurassic Time Scale derives mainly from the Pacific seafloor-spreading numerical model of the M-sequence magnetic polarity pattern and from limited recent cyclostratigraphic studies (GRADSTEIN et al. 2012). The age proposed here, well constrained within the standard Jurassic biostratigraphic zonation, provides the first accurate and reliable numerical age currently available for the Late Jurassic Time Scale (PELLENARD et al. 2013). This Middle Oxfordian date is in better agreement with GTS2004 boundaries than with the current GTS2012. This precise new tie-point can be used to anchor floating cyclostratigraphy and magnetostratigraphy, thus contributing to the improvement of seafloor-spreading models and, above all, will aid in the calibration of the Late Jurassic time scale.

References

- CHANG, S., ZHANG, H., RENNE, P. & FANG, Y. 2009. High-precision $^{40}\text{Ar}/^{39}\text{Ar}$ age constraints on the basal Lanqi Formation and its implications for the origin of angiosperm plants. – *Earth and Planetary Science Letters* 279: 212–221.
- CLARI, P.A., MARTIRE, L. & PAVIA, G. 1990. L'unità Selciferà del Rosso Ammonitico Veronese (Alpi Meridionali). – In: PALLINI, G. et al. (eds.), *Atti Convegno "Fossili, Evoluzione, Ambiente"*: Pergola II 1987: 151–162.
- GRADSTEIN, F.M., OGG, J.G. & SMITH, A.G. 2004. *A Geologic Time Scale 2004*. 589 pp., Cambridge University Press, Cambridge.
- GRADSTEIN, F.M., OGG, J.G., SCHMITZ, M.D. & OGG, G.M. 2012. *The Geologic Time Scale 2012*. 1144 pp., Elsevier, Amsterdam.
- MARTIRE, L., CLARI, P., LOZAR, F. & PAVIA, G. 2006. The Rosso Ammonitico Veronese (Middle-Upper Jurassic of the Trento Plateau): a proposal of lithostratigraphic ordering and formalization. – *Rivista Italiana di Paleontologia e Stratigrafia* 112: 227–250.
- OGG, J.G., OGG, G. & GRADSTEIN, F.M. 2008. *The concise Geological Time Scale*. 177 pp., Cambridge University Press, Cambridge.
- PELLENARD, P., NOMADE, S., MARTIRE, L., DE OLIVEIRA RAMALHO, F., MONNA, F. & GUILLOU, H. 2013. The first $^{40}\text{Ar}/^{39}\text{Ar}$ date from Oxfordian ammonite-calibrated volcanic layers (bentonites) as a tie-point for the Late Jurassic. – *Geological Magazine*, in press.
- RENNE, P.R., MUNDIL, R., BALCO, G., MIN, K. & MUDWIG, K.R. 2011. Response to the comment by W.H. SCHWARZ et al. on „Joint determination of ^{40}K decay constants and $^{40}\text{Ar}/^{40}\text{K}$ for the Fish Canyon sanidine standard, and improved accuracy for Ar-40/Ar-39 geochronology“ by P.R. RENNE et al. (2010). – *Geochimica et Cosmochimica Acta* 75: 5097–5100.
- RENNE, P.R., MUNDIL, R., BALCO, G., MIN, K. & MUDWIG, K.R. 2010. Joint determination of ^{40}K decay constants and $^{40}\text{Ar}/^{40}\text{K}$ for the Fish Canyon sanidine standard; and improved accuracy for Ar-40/Ar-39 geochronology. – *Geochimica et Cosmochimica Acta* 74: 5349–5367.
- SELBY, D. 2007. Direct Rhenium-Osmium age of the Oxfordian-Kimmeridgian boundary, Staffin Bay, Isle of Skye, U.K., and the Late Jurassic time scale. – *Norwegian Journal of Geology* 47: 291–299.

Integrated stratigraphy of the potential candidate Oxfordian GSSP at Thuoux and Saint-Pierre d'Argençon (France)

PIERRE PELLENARD¹ *, ANNACHIARA BARTOLINI², SLAH BOULILA³, PIERRE-YVES COLLIN¹, DOMINIQUE FORTWENGLER¹, BRUNO GALBRUN³, SILVIA GARDIN⁴, VINCENT HUULT⁵, EMILIA HURET⁶, DIDIER MARCHAND⁷ & JACQUES THIERRY¹

¹UMR CNRS 6282 Biogéosciences, Université de Bourgogne, 6 Bd Gabriel, 21000 Dijon, France; E-mail: pierre.pellenard@u-bourgogne.fr; pierre-yves.collin@u-bourgogne.fr; dominique.fortwengler@wanadoo.fr; jaques-thierry2@wanadoo.fr

²Muséum National d'Histoire Naturelle, UMR 7207 CR2P „Centre de recherche sur la Paléobiodiversité et les Paléoenvironnements“, France; E-mail: bartolini@mnhn.fr

³Université Paris 6, UMR 7193 IStEP „Institut des Sciences de la Terre-Paris“, Paris, France; E-mail: slah.boulila@upmc.fr; bruno.galbrun@upmc.fr

⁴Université Paris 6, UMR 7207 CR2P „Centre de recherche sur la Paléobiodiversité et les Paléoenvironnements“, Paris, France; E-mail: silvia.gardin@upmc.fr

⁵UMR CNRS 7359 Géoressources, Université de Lorraine, BP 239, 54506 Vandœuvre-lès-Nancy Cedex, France; E-mail: vincent.huault@g2r.uhp-nancy.fr

⁶ANDRA, Parc de la Croix-Blanche, 1-7 rue Jean Monnet, 92298 Châtenay-Malabry, France; E-mail: Emilia.Huret@andra.fr

⁷8a, avenue Ste Claire, 06100 Nice, France; E-mail: didoux.marchand@gmail.com

*Corresponding author

In Western European basins, the Callovian–Oxfordian transition is commonly marked by hiatuses or condensed levels. The scarcity of available ammonite-rich continuous sedimentary successions, allowing precise ammonite biostratigraphy and integrating ammonite taxa from various palaeobiogeographical provinces, renders difficult the choice of a reliable section to define a Global boundary Stratotype Section and Point (GSSP) for the Middle-Late Jurassic transition. In this context, the Redcliff Point – Ham Cliff section (Weymouth, UK) was proposed as a candidate for the Callovian–Oxfordian boundary GSSP, while the Sournon section (Subalpine Basin, SE France) was selected as an alternative (PAGE et al. 2008). Here we propose other potential sections as a candidate GSSP for the Callovian–Oxfordian boundary at Thuoux and Saint-Pierre d'Argençon (Subalpine Basin, SE France).

Numerous well-exposed outcrops in the Diois, Baronnies, and the Buëch valley have been studied over several decades for the Middle–Late Jurassic transition, including biostratigraphic, sedimentological, and tectonic aspects. In many sections of this domain, numerous well-preserved ammonites provide

an accurate biostratigraphy (FORTWENGLER et al. 2012). The Thuoux and Saint-Pierre d'Argençon sections consist of several tens of metres of shales and calcareous shales, with occasional nodular rusty or buff-coloured carbonate beds, characteristic of the “Terres Noires” Formation. The Callovian–Oxfordian boundary is well exposed in both sections and all ammonite biohorizons and subzones of the uppermost Callovian Lamberti and basal Oxfordian Mariae Zones can be clearly identified.

At Thuoux, the biostratigraphic framework is precisely based on the following succession of different ammonite species and genera. Within the Lamberti Zone – Lamberti subzone and the Mariae Zone – Scarboroughense Subzone, which bracket the boundary, the corresponding biohorizons are clearly identified: (1) The upper part of the Callovian (lamberti horizon) is characterised by scarce *Kosmoceras* and *Distichoceras* and always the clear presence of *Quenstedtoceras lamberti* (SOWERBY), *Hecticoceras punctatum* LAHUSEN and *Poculisphinctes poculum* (LECKENBY). (2) The uppermost part of the Callovian (paucicostatum horizon) is characterised by the total disappearance of *Kosmoceratidae* and

the co-occurrence of the latest *Quenstedtoceras* cf. *lamberti* (Sow.) with the first *Cardioceras paucicostatum* LANGE. In the upper part of that horizon, we notice abundant *Hecticoceras paulowi* (DE TSYTOVITCH) and the first appearance of *Peltoceratoides eugenii* (RASPAIL). (3) The basal Oxfordian is characterised by the isochronous first appearance of true *Cardioceras scarburgense* (YOUNG & BIRD), *Hecticoceras (Brightia) thuouxensis* FORTWENGLER et al. and *Peltoceratoides eugenii* morpho *eugenii*. This fauna characterises the thuouxensis horizon, the first biohorizon of the Scarburgense Subzone. (4) Above, several shell ornamentation changes are used to characterise the basal Oxfordian: the secondary ribs of *Peltoceratoides eugenii* suddenly bifurcate lower on the flanks, and Hecticoceratinae macroconchs have softer ornamentation. (5) The first morphs close to *C. woodhamense* ARKELL appear at the top of the Scarburgense Subzone. This species never co-exists with *C. scarburgense*.

The potential of nannofossil biohorizons to be useful proxies for the Callovian–Oxfordian boundary has been tested by a quantitative analysis and biometric measurements of key taxa. Results indicate that the marker species *Stephanolithion bigoti maximum*, defined as having “measurements exceeding 6x3µm”, is not present in the boundary interval, although an increase in size reaching 5.50/5.60 µm of rim length occurs from the Paucicostatum Subzone, in coincidence with a positive carbon isotope excursion. Thus, the recognition and utility of *S. bigoti maximum* as a marker for dating and correlating the Callovian–Oxfordian boundary interval depends only on accurate biometric measurements. The Callovian–Oxfordian boundary is well defined in palynology by the occurrence of *Wanaea fimbriata*. Ongoing investigations of dinoflagellate cyst assemblages in the Thuoux and Saint-Pierre d’Argençon sections should provide deciding factors in the placement of the GSSP for the Middle–Late Jurassic transition.

The marlstone bulk-carbonate $\delta^{13}\text{C}_{\text{carb}}$ record at the Thuoux section shows marked fluctuations, with values from 0 ‰ to 2 ‰. Although the values are quite scattered in some intervals, significant trends across the MLJ (Middle–Late Jurassic) boundary are still well discernable. This general pattern of the $\delta^{13}\text{C}_{\text{carb}}$

curve does not correlate with carbonate content and oxygen-isotope values, therefore mirroring, at least in part, the primary environmental signal. The ~ 1,5 ‰ increasing $\delta^{13}\text{C}_{\text{carb}}$ trend around the Callovian/Oxfordian boundary has already been documented in other sections and boreholes in France, Switzerland and elsewhere (PELLENARD et al., 2013). The $\delta^{13}\text{C}_{\text{carb}}$ positive shift to maximal values can thus be used as an auxiliary marker of the Callovian/Oxfordian (and MLJ) boundary.

High-resolution analysis of magnetic susceptibility and field spectral gamma ray measurements were performed on 700-m-thick Early-Middle Oxfordian marine marls of the Terres Noires Formation. Sub-Milankovitch to Milankovitch cycles are clearly identified, with the long-term eccentricity (405 kyr and 2 myr) being the most prominent. The 405 kyr cycle was used as a high-resolution geochronometer for astronomical calibration of this poorly constrained interval of Late Jurassic time. The astronomical calibration of the Mariae Zone indicates a duration of ~2.2 myr in this basin (BOULILA et al. 2010). New high-resolution magnetic susceptibility analysis (every 8 cm) and spectral gamma ray measurements (every 12 cm) of the Thuoux and Saint-Pierre d’Argençon sections spanning the Callovian–Oxfordian transition will allow astronomical calibration of the associated ammonite sub-zones and horizons, and assessment of variations in sedimentation rate.

References

- BOULILA, S., GALBRUN, B., HINNOV, L.A., COLLIN, P.-Y., OGG, J.G., FORTWENGLER, D. & MARCHAND, D. 2010. Milankovitch and sub-Milankovitch forcing of the Oxfordian (Late Jurassic) Terres Noires Formation (SE France) and global implications. – *Basin Research* 22: 717–732.
- FORTWENGLER, D., MARCHAND, D., BONNOT, A., JARDAT, R. & RAYNAUD, D. 2012. Proposal for the Thuoux section as a candidate for the GSSP of the base of the Oxfordian stage. – *Carnets de Géologie (Notebooks on Geology)*, CG2012A06: 117–136.
- PAGE, K.N., MELÉNDEZ, G., HART, M.B., PRICE, G.D., WRIGHT, J.K., BOWN, P. & BELLO, J. 2009. Integrated stratigraphical study of the candidate Oxfordian Global Stratotype Section and Point (GSSP) at Redcliff Point, Weymouth, Dorset, UK. – *Volumina Jurassica* 7: 101–111.
- PELLENARD, P., TRAMOY, R., PUCÉAT, E., HURET, H., MARTINEZ, M., BRUNEAU, L. & THIERRY, J. 2013. Carbon cycle and palaeoenvironmental changes at the Middle-Late Jurassic transition from the Paris Basin (France). – *Marine and Petroleum Geology*, in press.

Evolution of Volgian–Valanginian microphytoplankton communities in the Olenyok River region, North Siberia

E. B. PESTCHEVITSKAYA

Institute of Petroleum Geology and Geophysics, Novosibirsk 630090; E-mail: paleodinocyst@gmail.com

A palynological study of the Volgian–Valanginian section from the Olenyok River basin provides new data on the evolution of Siberian dinoflagellate communities in Late Jurassic and Early Cretaceous times. Ammonite and foraminiferal zones in the Volgian and Berriasian give us additional stratigraphic control of the dinoflagellate succession (NIKITENKO et al. 2012).

Taxonomic changes in dinoflagellate assemblages allow the definition of five dinoflagellate zones. All assemblages include some taxa, which provide interregional correlation. The correlative events are as follows: (1) The *Athigmatocysta glabra* – *Circulodinium compta* – *Cometodinium habibii* Zone (Lower Volgian). *Occisucysta ?monoheuriskos*, *Leptodinium subtile*, *L. simplex*, and *L. mirabile* are common in the Late Tithonian of North America; *Occisucysta balios* and *Scriniodinium inritibile* disappear in the Late Kimmeridgian of Western Europe. (2) The *Scriniodinium campanula* – *Trichodinium ciliatum*–*Occisucysta wiersbowskii* Zone (upper part of the Lower Volgian – lower part of the Middle Volgian). the appearance of *Occisucysta wierzbowskii* and *Scriniodinium campanula* has also been defined in the Early Volgian of Poland; the disappearance of *Scriniodinium inritibile* and *Occisucysta balios* has also been identified in the Late Kimmeridgian of Western Europe and the Middle Volgian of the Russian Platform (PESTCHEVITSKAYA et al. 2011). (3) The *Gochteodinia villosa* – *Dingodinium ?spinosum* – *Bourkidinium* sp. Zone (upper part of the Middle Volgian – lower part of the Late Volgian). The extinction of *Gonyaulacysta dualis* has also been recognised in the middle part of the Middle Volgian in the Nordvik section of North Siberia (NIKITENKO et al. 2008); the appearance of *Dingodinium ?spinosum* and *Gochteodinia villosa*, has been correlated with the Portlandian of Western Europe and the Middle Volgian of

the Russian Platform (PESTCHEVITSKAYA et al. 2011; HARDING et al. 2011); the appearance of *Bourkidinium* has also been identified in the Late Tithonian of Western Europe (BOOROVÁ et al. 1999) and the Middle Volgian of the Russian Platform (RIDING et al. 1999). (4) The *Batioladinium varigranorum* – *Circulodinium distinctum* – *Circulodinium colliveri* Zone (uppermost Volgian – Lower Berriasian). First finds of *Circulodinium colliveri* are also reported from the Berriasian of Canada and Antarctica; the appearance of *Circulodinium distinctum* has been defined in the Berriasian of Siberia, Canada, Greenland and England; the appearance of *Tehamadinium dodekovae* is defined in France as Berriasian (PESTCHEVITSKAYA et al. 2011). (5) The Pareodinioideae – *Cassiculosphaeridia reticulata* – *Cyclonephelium cuculliforme* Zone. The diversity of pareodinioid forms, *Barbatocysta* – *Sentusidinium* and *Escharisphaeridia* – *Batiacasphaera* groups are also typical of other regions of Siberia; the appearance of *Cassiculosphaeridia reticulata* has also been defined as Late Berriasian in Siberia and the Subpolar Urals; the appearance of *Cyclonephelium cuculliforme* has also been reported from the Late Berriasian of North Siberia and Arctic Canada. Dinoflagellates become rare in the Valanginian. An important feature is the appearance of *Muderongia crucis*, as its first occurrence has been defined in other regions of Siberia in the upper part of the Lower Valanginian (PESTCHEVITSKAYA 2010).

The established biostratigraphic succession and biofacies analysis of dinoflagellate communities allow the reconstruction of transgressive-regressive (T-R) changes of the North Siberian palaeo-basin in the Olenyok River region during the Volgian, Berriasian, and Valanginian. Essential taxonomic changes in dinoflagellate communities and quantitative fluctuations of the microphytoplankton in general indicate that Volgian-Valanginian

deposits were formed in the marginal zone of the palaeo-basin influenced by frequent T-R events. Shallow water environments in the Early Volgian are confirmed by the lower quantity of microphytoplankton (8% in relation to the terrestrial palynomorphs). However, the diversity of dinoflagellates suggests normal marine conditions. The transgression occurred at the end of the Early Volgian. Dinoflagellate associations became very rich and diverse. They contained numerous taxa of the families Gonyaulacaceae and Pareodiniaceae (56%), a feature that is often regarded as an indicator of the neritic zone. The Middle to Late Volgian and the beginning of the Berriasian were characterized by unstable environments leading to frequent changes in the taxonomic composition of dinoflagellate communities and quantitative fluctuations of different groups of microphytoplankton. The percentage of microphytoplankton varied to a great extent (12-57% in relation to the terrestrial palynomorphs). The diversity of dinoflagellates was reduced, but remained rather high which is typical for shallower areas of the neritic zone. The increased percentage of dinoflagellates with simple morphology and of the family Pareodiniaceae possibly point to climate cooling. During that time, microphytoplankton associations were periodically dominated by prasinophytes of the genera *Leiosphaeridia* and *Tasmanites* that is often interpreted as evidence of stagnant, anoxic conditions. The regression began in the Late Berriasian and became stronger in the Early Valanginian. It is confirmed by taxonomic changes of the microphytoplankton. Its quantity was reduced in the Late Berriasian, but dinoflagellate diversity remained rather high indicating stable, fully marine conditions. Sharp reduction of the microphytoplankton percentage (3-9%) occurred in the Early Valanginian. The prasinophyte *Leiosphaeridia* is the most abundant taxon here. Dinoflagellates are rare, including *Sentusidinium*, *Apteodinium*, *Cribroperidinium*, *Circulodinium*, and *Batioladinium*.

Thus, the palynological study of the Volgian–Valanginian succession in the section from the Olenyok River region shows that taxonomic changes in the microphytoplankton communities depend on both local environments and evolutionary events, which

are also recognised in different regions of Europe, Canada, and Antarctica and can be regarded as reliable correlative markers. The established biostratigraphic succession of dinoflagellate zones provides the stratigraphic basis for the analysis of local T-R events in the Volgian–Valanginian and the reconstruction of the dynamic of the North Siberian palaeobasin in the Olenyok River region.

Projects RAS 23, 28 and IGSP 608.

References

- BOOROVÁ, D., LOBITZER, H., SKUPIEN, P. & VAŠÍČEK, Z. 1999. Biostratigraphy and facies of Upper Jurassic-Lower Cretaceous pelagic carbonate sediments (Oberalm-, Schrambach- and Roßfeld-Formation) in the Northern Calcareous Alps, South of Salzburg. – *Abhandlungen der Geologischen Bundesanstalt* 56: 273–318.
- HARDING, I.C., SMITH, G.A., RIDING, J.B. & WIMBLEDON, W.A.P. 2011. Inter-regional correlation of Jurassic/Cretaceous boundary strata based on the Tithonian-Valanginian dinoflagellate cyst biostratigraphy of the Volga Basin, western Russia. – *Review of Palaeobotany and Palynology* 167: 82–116.
- HUNT, C.O. 2004. Palynostratigraphy of the classic Portland and Purbeck sequences of Dorset, southern England, and the correlation of Jurassic-Cretaceous boundary beds in the Tethyan and Boreal realms. In: BEAUDOIN, A.B. & HEAD, M.J. (eds.), *The palynology and micropalaeontology of boundaries*. – *Geological Society of London Special Publication* 230: 175–187.
- NIKITENKO, B.L., PESTCHEVITSKAYA, E.B., LEBEDEVA, N.K. & ILYINA, V.I. 2008. Micropalaeontological and palynological analyses across the Jurassic-Cretaceous boundary on Nordvik Peninsular, Northeast Siberia. – *Newsletters on Stratigraphy* 42: 181–222.
- NIKITENKO, B.L., PESTCHEVITSKAYA, E.B., KHAFAEVA, S.N. & KNYAZEV, V.G. 2012. Preliminary data on the biostratigraphy and biofacies of Volgian-Valanginian section from the Olenyok river region (North Siberia). In: VISHNEVSKAYA, V.S. (ed.), *Contemporary micropalaeontology*. – *Proceeding of XV Russian micropalaeontological conference*: 19–22, Gelendzhik, Kuban University [in Russian].
- PESTCHEVITSKAYA, E.B. 2010. Dinocysts and palynostratigraphy of the Lower Cretaceous in Siberia: 230 p., Novosibirsk, Geo.
- PESTCHEVITSKAYA, E.B. 2007. Dinocyst biostratigraphy of the Lower Cretaceous in North Siberia. – *Stratigraphy and Geological Correlation* 15: 577–609.
- PESTCHEVITSKAYA, E., LEBEDEVA, N. & RYBOKON, A. 2011. Uppermost Jurassic and lowermost Cretaceous dinocyst successions of Siberia, Subarctic Urals and Russian Platform and their interregional correlation. – *Geologica Carpathica* 62: 189–202.
- RIDING, J.B., FEDOROVA, V.A. & ILYINA, V.I. 1999. Jurassic and lowermost Cretaceous dinoflagellate cyst biostratigraphy of the Russian Platform and Northern Siberia, Russia. – *AAPS Contribution series* 36: 1-184.

Marine (black) and marginal-marine (green) Toarcian shales in Europe – carbon isotope consistency, TOC inconsistency

GRZEGORZ PIEŃKOWSKI¹ * & MARTA HODBOD²

¹Polish Geological Institute – National State Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland; E-mail: grzegorz.pienkowski@pgi.gov.pl

²Polish Geological Institute – National State Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland; E-mail: marta.hodbod@pgi.gov.pl

*Corresponding author

A black shale is a black/dark grey mudstone rich in total organic carbon – TOC (>5% by weight) generally formed in anoxic marine bottom waters, usually connected with Oceanic Anoxic Events (OAE), including the well-documented Toarcian Oceanic Anoxic Event (T-OAE), one of the largest (~–6‰) in Phanerozoic times. They were formed when a high rate of organic burial globally over a brief interval of time has led to the deposition of organic-rich sediments. Many parts of Europe contain prime targets for shale gas exploration, one of these is the Posidonia Shale (Early Toarcian, ~183 Ma ago) of northern Germany and approximately coeval black shales from the Paris Basin (France) and Cleveland Basin (England). At the same time, in the Polish Basin, poorly consolidated green/grey mudstones, claystones and siltstones (“verdine” facies) with subordinate sandstone intercalations (Ciechocinek Formation) were deposited in a large embayment/lagoon. Deposition of both black and green shales in early Toarcian times is associated with abrupt and large-magnitude changes in the global carbon cycle (Carbon Isotope Excursions – CIE), which appear to be a recurrent phenomenon during greenhouse periods of Earth’s history. Early Toarcian carbon-isotope data from terrestrial organic matter of the Polish Basin (phytocolist separates) show that the shift to light carbon isotope values in the woody organic matter, and therefore also in atmospheric carbon dioxide, occurred in major steps, similarly as in the oceans. The steps identified in green shales in Poland were correlated with those identified from marine organic matter (black shales), where they have previously been attributed to 100 kyr eccentricity forcing of climate. However,

whereas there is a perfect correlation between CIE steps in marine and marginal-marine/non-marine settings, the correlation is directly opposite when the TOC content is compared. Contrary to the epicontinental open marine basins, where more negative $\delta^{13}\text{C}$ values mean higher TOC content, in the Polish Basin there is an opposite correlation: the more positive the $\delta^{13}\text{C}$ values, the higher the TOC content. In the Polish Basin, strata richest in TOC predate the T-OAE. Palynofacies reflect the sea-level changes (shore proximity) and climate changes inferred from kaolinite content, megaspore frequency and CIE steps. Of particular note is the dinoflagellate peak associated with a flooding surface, slightly preceding the T-OAE onset, which reflects a bloom of plankton, most probably associated with major climate-oceanographic change. Each 100-kyr cycle in carbon-isotope values was characterized by increasingly severe palaeoclimatic changes, culminating in extremely hot and humid conditions (high abundance of megaspores and fungal spores), co-incident with the peak of the final-most negative carbon-isotope excursion and TOC-rich, black shale deposition in West Europe. In the marginal-marine Polish Basin these extreme greenhouse conditions are related to the lowest values of TOC. Productivity in this brackish-marine waters (inferred from P_2O_5 content) was only slightly diminishing during the T-OAE, mostly due to increasing freshwater influx (gradual disappearance of dinoflagellates) and shallowing of the basin. Depletion of TOC in green shales should be then explained by preservational conditions, related to an intensified hydrologic cycle and runoff, resulting in shallowing, destruction of the

halocline and a well-oxygenated bottom. Of note is a very sensitive reaction of these processes to changes in $\delta^{13}\text{C}$ values.

References

HESSELBO, S.P. & PIEŃKOWSKI, G. 2011. Stepwise atmospheric carbon isotope excursion during the Early Jurassic Oceanic Anoxic Event. – *Earth and Planetary Science Letters* 301: 365–372.

End-Triassic biota crisis and earliest Jurassic recovery in continental strata of Poland in relation to rapid climatic reversals associated with CAMP volcanism

GRZEGORZ PIEŃKOWSKI¹ *, GRZEGORZ NIEDŹWIEDZKI² & PAWEŁ BRAŃSKI³

¹Polish Geological Institute – National State Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland; E-mail: grzegorz.pienkowski@pgi.gov.pl

²Subdepartment of Evolution and Development, Department of Organismal Biology, Evolutionary Biology Centre, Uppsala University, Norbyvägen 18A, 752 36 Uppsala, Sweden; E-mail: grzegorz.niedzwiedzki@ebc.uu.se

³Polish Geological Institute – National State Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland; E-mail: pawel.branski@pgi.gov.pl

*Corresponding author

Eight climatic events indicated by the kaolinite/illite ratio, Chemical Alteration Index, colour of sediments, and palynomorphs can be distinguished in the transitional Triassic – Jurassic (T-J, c. 201 mya) continental strata of Poland. The first climatic humidification turnover, evidenced by shift from smectite to kaolinite-dominated mudrocks, coincides with the earlier ('precursor') Rhaetian negative $\delta^{13}\text{C}_{\text{org}}$ excursion, which means that the beginning of climate perturbations predated the oldest known CAMP flood basalts by some 100–200 kyr. The global, late Rhaetian 'initial' negative $\delta^{13}\text{C}_{\text{org}}$ excursion is divided into two 'sub-peaks' (KORTE & KOZUR 2011) corresponding to hot and humid events, separated by a cooler/drier event. Based on calculation of the duration of the whole 'initial' bi-partite CIE (10,000 to 20,000 years; RUHL et al. 2011), our study shows that these changes are of too high a frequency to be linked with astronomical forcing, but they could be easily associated with episodes of CAMP eruptions. This is further supported by differences of certain geochemical and palynological properties (Os isotope system disturbances as well as darkening of miospores and, circumstantially, PAHs content. Between the 'initial' excursion and the T-J boundary zone, next five climatic fluctuations are inferred from the changing kaolinite-illite ratio, the last two are also associated with Os isotope system perturbations, polycyclic aromatic hydrocarbon (PAH) releases, 'spore peak' and darkened miospores. A series of periodic atmospheric loading by CO_2 , CH_4 or, alternatively, by SO_2 ,

sulphate aerosols, and toxic compounds is inferred to have caused this series of rapid climatic reversals and resulting extinction of many less adapted forms. Our conclusion is that the extinction period is more prolonged than the some 20,000 years duration of the 'initial' CIE. Just above the palynofloral extinction level, appearance of new forms started the Jurassic palynofloral recovery. Tetrapod evolution events at the end Triassic/earliest Jurassic were related with extinction of the Pseudosuchia, Dicynodontia, Capitosauroidae, Plagiosauridae, and Rhynchosauria, while appearance of a highly-diversified tetrapod ichnofauna in the earliest Jurassic strata indicates a rapid recovery and refill of ecological niches.

Obtained values of initial $^{187}\text{Os}/^{186}\text{Os}$ between 2.905 and 4.873 and very low iridium content lend no support for an asteroid impact at the T-J boundary event, although one cannot exclude a hypothetical comet impact or 'comet shower', which would not leave any geochemical traces behind. However, CAMP-related volcanic volatiles causing frequent climate disturbances and influencing in many ways the ecosystem seem to be a much more substantiated cause for the end-Triassic extinction, while relative stabilization of climate in Hettangian times allowed the biota recovery (PIEŃKOWSKI et al. 2012).

This paper is part of a project, which has been financed by the Polish National Science Centre, granted on the basis of decision no. DEC-2012/06/M/ST10/00478. G.N. is currently funded by a Wallenberg Scholarship grant awarded to P.E. Ahlberg (Uppsala University).

References

- KORTE, C. & KOZUR, W. 2011. Bio- and chemostratigraphic assessment of carbon isotope records across the Triassic-Jurassic boundary at Csóvár quarry (Hungary) and Kendlbachgraben (Austria) and implications for global correlations. – Bulletin of the Geological Society of Denmark 59: 101–115
- PIEŃKOWSKI, G., NIEDŹWIEDZKI, G. & WAKSMUNDZKA, M. 2012. Sedimentological, palynological, and geochemical studies of the terrestrial Triassic-Jurassic boundary in north-western Poland. – Geological Magazine 149: 308–332.
- RUHL, M., BONIS, R.N., REICHART, G.J., SINNINGHE DAMSTÉ, J.S. & KÜRSCHNER, W.M. 2011. Atmospheric carbon injection linked to end-Triassic mass extinction. – Science 333: 430–434.

New high-resolution geochemistry of Sinemurian marine sections in British Columbia and Nevada

SARAH J. PORTER^{1,2} *, PAUL L. SMITH¹, ANDREW H. CARUTHERS¹, PENGFEI HOU¹, DARREN R. GRÖCKE² & DAVID SELBY²

¹*Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver V6T 1Z4, Canada; E-mail: sporter@eos.ubc.ca; psmith@eos.ubc.ca; caruthers.andrew@gmail.com; phou@eos.ubc.ca*

²*Department of Earth Sciences, Durham University, Sciences Laboratories, Durham DH1 3LE, UK; E-mail: d.r.grocke@durham.ac.uk; david.selby@durham.ac.uk*

**Corresponding author*

Understanding marine depositional environments throughout geological time allows us to evaluate past changes in ocean chemistry. Using powerful geochemical tools such as carbon and osmium (Os) isotopes, we are able to trace temporal alterations in the balance of inputs to the global oceans. As such, significant input from meteorite impact, continental weathering and mantle-derived fluxes can be identified and distinguished (e.g., COHEN et al. 1999; PEUCKER-EHRENBRINK & RAVIZZA 2000).

This study focuses on two Sinemurian (~199.8 – 190.3 Ma; GRADSTEIN et al. 2012) marine sites from North America: Five Card Draw (FCD), Nevada, USA and Last Creek (LC), British Columbia, Canada. At each location, two stratigraphic sections were sampled and analysed. Our first Five Card Draw section (FCDI) spans ~110 m of the Sinemurian from the Involutum Zone through to the Harbledownense Zone. Five Card Draw is the type section for the North American Sinemurian zonation scheme (TAYLOR et al. 2001), and following thorough biostratigraphic correlation with this site, the chosen study areas are ideally suited for geochemical analysis and comparison.

Herein we present high-resolution carbon isotope data and rhenium-osmium (Re-Os) data from these sections, with a view to understanding seawater chemistry and environments of deposition during this stage of the Jurassic. Of particular interest are sections FCDI and LCII within the upper Leslei Zone. At this level, both sections exhibit significantly different carbon isotope profiles, with $\delta^{13}\text{C}$

values at FCDI remaining relatively continuous at ~ -25 to -26 per mil, contrasting with those at LCII that shift gradually from ~ -27 per mil to -24 per mil. Further, the gradual positive trend observed at LCII corresponds to a comparable and coeval positive shift seen in shales in Dorset, UK (JENKYN & WEEDON 2013). This suggests that the LCII sediments record a potentially global carbon isotope signal at this time that may reflect an increase in global ocean primary productivity. Why, then, is this signal not also observed at FCD? Using Os isotopes we are able to quantitatively demonstrate that both sections were deposited under contrasting depositional conditions (open ocean vs. partially restricted with significant input from continental weathering), and further, that this is what is likely to have dictated the differences observed between the two carbon isotope profiles.

References

- COHEN, A.S., COE, A.L., BARTLETT, J.M. & HAWKESWORTH, C.J. 1999. Precise Re-Os ages of organic-rich mudrocks and the Os isotope composition of Jurassic seawater. – *Earth and Planetary Science Letters* 167: 159–173.
- GRADSTEIN, F.M., OGG, J.G., SCHMITZ, M.D. & OGG, G.M. 2012. *The Geological Time Scale 2012*. Elsevier BV, Amsterdam.
- JENKYN, H.C. & WEEDON, G.P. 2013. Chemostratigraphy (CaCO_3 , TOC, $\delta^{13}\text{C}_{\text{org}}$) of Sinemurian (Lower Jurassic) black shales from the Wessex Basin, Dorset and palaeoenvironmental implications. – *Newsletters on Stratigraphy* 46: 1–21.
- PEUCKER-EHRENBRINK, B. & RAVIZZA, G. 2000. The marine osmium isotope record. – *Terra Nova* 12: 205–219.
- TAYLOR, D.G., GUÉX, J. & RAKUS, M. 2001. Hettangian and Sinemurian ammonoid zonation for the Western Cordillera of North America. – *Bulletin de la Société vaudoise des sciences naturelles* 87: 381–421.

An overview of Upper Gondwana fossil floral assemblages of the Kachchh Basin, India

NEERU PRAKASH

Birbal Sahni Institute of Palaeobotany, 53, University Road, Lucknow, India; E-mail: neerup_in@yahoo.com

Kachchh is a pericratonic and pericontinental rift basin. The Mesozoic sedimentary horizons owe their formation to rifting along the major Precambrian lineaments in the western India – East Africa divergent plate region prior to fragmentation of the Gondwana Superplate (KRISHNA 1987). The thick stratigraphic succession is well developed and floristically rich. These successions have been categorized on the basis of lithology, stratigraphy, and palaeontological records into the Jhurio, Jumara, Jhuran, and Bhuj formations, their age ranging from Bathonian to Albian (BISWAS 1971, 1999).

The complete Upper Gondwana succession is exposed in the Mainland, whereas the older Mesozoic succession (Bathonian to Callovian) is exposed in the northern 'Island belt' as well as in eastern Kachchh (Washtawa/Khandir Formation and Wagad sandstone; BISWAS & DESPANDE 1983). The Bhuj Formation lies directly on the Katrol beds with apparent conformity and is exposed near Bhuj. It comprises ferruginous coarse sandstone, white sandstone with interlaminated sandy shale, while finely mottled pink, red, white, and yellow coloured beds are cross-bedded and friable.

The extraordinarily well preserved, rich and diversified palaeofloral assemblage is recorded from strata exposed in various localities around Bhuj and the Bhuj–Lakhpat road (BOSE & BANERJI 1984). The fossils are preserved in form of impressions and compressions and show excellent morphological and anatomical details. The presentation illustrates a typical Upper Gondwana flora consisting of various plant groups such as bryophytes, pteridophytes, pteridosperms, cycads, Bennettitales, and conifers. Its diversity and composition is compared with contemporaneous deposits of India and other Gondwana continents. The flora comprises thalli, fronds, leafy twigs, and cone scales. The following floral elements have been found:

Bryophytes: Represented by sterile thallus e.g., *Thalites*, *Hepaticites*.

Pteridophytes: Represented by *Isoetites*, *Sellaginellites*, *Phlebopteris*, *Matonidium*, *Coniopteris*, *Cladophlebis*, *Gleichenites*, *Hausmannia*, and *Dictyophyllum*.

Pteridosperms: Sterile leaf of *Pachypteris* and *Sagenopteris*; the fruit *Caytonia*.

Bennettitales: Sterile leaves; e.g., *Ptilophyllum*, *Pterophyllum*, *Anomozamites*, *Ctenozamites*, *Pseudectenites*, *Nilssoniopteris*, *Otozamites*, ? *Bucklandia*, as well as *Williamsonia* flower and bract scale, *Cycadolepis*.

Cycads: Sterile leaves showing variations in shape and size are recorded by genera such as *Cycadites* and *Taeniopteris*.

Conifers: Represented by abundant sterile twigs of *Pagiophyllum*, *Brachyphyllum*, *Elatocladus*, *Allocladus* and cone scales of *Araucarites*.

Cone: *Conites*.

In addition to these, some unclassified forms such as *Kachchhia*, *Rajmahalia*, and *Lorumformophyllum* are reported.

The fossil flora from Kachchh exhibit two types of floral assemblages within the basin:

Type-1 flora is dominated by a number of species of the genus *Pachypteris* along with other plant groups: the Pteridophytes *Cladophlebis*, *Linguifolium*, *Sagenopteris* cf. *colpodes*, species of *Taeniopteris* (*Pentoxylalae*), *Nilssoniopteris*, *Pterophyllum*, *Otozamites*, *Ptilophyllum*, (Bennettitales), *Elatocladus*, *Pagiophyllum*, and *Brachyphyllum* (conifers). (The taxa have been recorded from Rudra Mata dam site, Chawad, Gadsisa, and Kakadbbhit, representing the Jhuran Formation).

Type-2 flora is dominated by *Ptilophyllum* along with conifer remains such as *Brachyphyllum*, *Pagiophyllum*, and *Allocladus*. The genus *Isoetites* is also commonly recorded from here (forms recorded from Trambau, Sukhpur, Bhajodi, and Dharesi represent the

Bhuj Formation).

The overall fossil floral assemblage is dominated by Cycadales and conifers and shows close affiliation with the flora reported from the Jabalpur Formation. However, Bennettitales are commonly known and dominant in one of the two types of floral assemblage reported from the Rajmahal Formation of Rajmahal Hills with rare conifers, while the other type of flora represented by dominant conifers followed by pteridophytes and Pentoxylales with extremely rare bennettitalean remains has been reported from Nipania of the Rajmahal Hills, Jharkhand. The phytogeographical correlation with contemporaneous floral assemblages of Western Australia and Antarctica suggests its floral affinity at the generic level. Due to close the juxtaposition and contiguous position of Western Australia with the northern extension of the Indian subcontinent or greater India

during Jurassic times, the floral similarities are strong mostly at the generic and in some cases even at the species level (MCLOUGHLIN & POTT 2009).

References

- BISWAS, S.K. 1971 Note on Geology of Kutch. Quarterly Journal of the Geological. – Mining and Metallurgical Society of India 43: 223–235.
- BISWAS, S.K. 1999. Review on the evolution of rift basins in India during Gondwana with special reference to western Indian basins and their hydrocarbon prospects. – Proceedings of the Indian National Science Academy 65: 261–283.
- BISWAS, S.K. & DESPANDE, S.V. 1983 Geology and hydrocarbon prospects of Kutch, Saurashtra and Narmada basins. In: BHANDARI, L.L. et al. (eds.), Petroliferous basins of India: 111–126.
- KRISHNA, J. 1987. An overview of the Mesozoic stratigraphy of Kachchh and Jaisalmer Basins. – Journal of the Palaeontological Society of India 32: 136–149.
- MCLOUGHLIN, S. & POTT, C. 2009. The Jurassic flora of Western Australia. – Geologiska Föreningen i Stockholm Förhandlingar 131: 113–136.

When did the twain meet? The epeiric Ethiopian Gulf with the Western Indian craton; Coccoliths, the beacon of light!

JYOTSANA RAI

Birbal Sahni Institute of Palaeobotany, 53 University Road, 226007, Lucknow, India; E-mail: Jyotsana@yahoo.com

The Kachchh Basin is a sedimentary basin situated on the southwestern fringe of India and is formed during Early-Middle Jurassic times by the southern extension of the Neo-Tethys at a palaeolatitude of 33°S. After a phase of terrestrial sedimentation in the Late Triassic, marine sedimentation started during Early Jurassic time. The oldest marine sedimentary rocks called Kaladongar Formation are exposed in Kuar Bet of the Pachchham Island. The lowest unit of the Kaladongar Formation, called Dingi Hill Member, has for the first time been precisely dated by a moderately diversified and well preserved calcareous nannofossil assemblage. The assemblage includes marker species of *Biscutum finchii*, *Bussonius prinsii*, *Crucirhabdus primulus* and *Discorhabdus criotus* straddling the Pliensbachian–Toarcian interval boundary (NJ5 to NJ7). This nannofossil find suggests that after the rifting of the western margin of the Indian plate, the first epeiric transgressive event via an arm of the southern Tethys known as the Ethiopian Gulf in the Kachchh Basin occurred during the Pliensbachian–Toarcian boundary interval (at 183 Ma), ca. ~11.4 million years earlier than the ammonite-based (*Calliphylloceras heterophylloides*) Early Bajocian or older (~171.6 Ma) record by PANDEY et al. (2013) and the ?Early Bajocian (~171.6 Ma) coral-based record (the *Amphiastraea-Isastraea* assemblage) by PANDEY et al. (2002).

The record of *Lotharingius* sp. and *Triscutum sullivanii* within the present assemblage also

tentatively suggests an upward extension of the age into the latest Toarcian (~175.6 Ma) for these earliest Kachchh sediments. Reworked nannofossils of Early Jurassic age (Pliensbachian – Toarcian) are consistently found in Callovian – Oxfordian age nannofossil assemblages at Jara, Jumara, and Habo domes and in the Wagad Uplift (RAI & JAIN submitted). Though the provenance has not yet been recovered, it is envisaged that both the global eustatic sea-level rise and local tectonics are responsible for this Pliensbachian–Toarcian boundary interval inundation of the Kachchh Basin (RAI & JAIN 2012).

References

- PANDEY, D.K., LATHUILIÈRE, B., FÜRSICH, F.T. & KULDEEP, S. 2002. The oldest cyathophorid coral (Scleractinia) from siliciclastic environments of the Kachchh Basin, western India. – *Paläontologische Zeitschrift* 76: 347–356.
- PANDEY, B., PATHAK, D.B. & KRISHNA, J. 2013. *Calliphylloceras heterophylloides* (Oppel, 1856) from the basal most Jurassic succession of Sadhara Dome, Kachchh, India. – *Journal of the Palaeontological Society of India* 58: 61–65.
- RAI, J. & JAIN, S. 2012. Early Jurassic Gondwanaland breakup – a nannofossil story. National Level Field based Workshop on Geology of Kachchh Basin, western India: Present status and Future perspectives. Abstracts: 84–85, Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj.
- RAI, J. & JAIN, S. submitted. Pliensbachian nannofossil assemblage from Kachchh: Implications on the earliest Jurassic transgressive event on the western Indian margin. – *Zitteliana*.

Integrated nannofossil-dinoflagellate cyst – ammonoid biostratigraphy from Wagad area, Kachchh, Western India

JYOTSANA RAI¹, SURABHI GARG¹, MRIDUL GUPTA¹, ABHA SINGH¹, DHIRENDRA K. PANDEY² & RAHUL GARG¹

¹*Birbal Sahni Institute of Palaeobotany, 53, University Road, Lucknow, India*

²*Geology Department, University of Rajasthan, Jaipur, India*

The entire Kachchh Basin is marked by six major uplifts one of them being Wagad. The Wagad uplift is bounded by a high angle normal fault to its south, while all the other uplifts are bounded by either high angle faults or flexure zones to their north.

The Wagad region is stratigraphically divided into the Washtawa, Kanthkot, and Gamdau formations in ascending order. The Kanthkot Formation is further divided into three members, the lower Patasar Shale Member, the middle Fort Sandstone Member, and the upper Adhoi Member. The type section of the Patasar Shale Member is exposed near the Patasar tank in western Wagad. It is from this locality that calcareous nannofossil and dinoflagellate data are presented herein. The shales occur above the datable fossiliferous Kantkote Ammonite Beds of the upper Washtawa Formation and below the unfossiliferous sandstones of the Fort Sandstone Member. There is a gradual increase in the thickness of the Patasar Shale Member from East to West (DESAI & MERH 1975).

At Patasar tank apparently barren exposures of Patasar shales are exposed as cliff section comprising more than 50 m. They are grey to dark grey in colour, soft, gypsiferous in the lower part and greenish grey to khaki, silty in the upper part. The upper part is often marked by flaggy, yellowish brown siltstone alternations. These shales are continuously exposed eastward towards Nara, where the upper part gradually grades into friable sandstones.

In all, 12 representative samples (denoted as PTS) were collected, out of which six (PTS-2, PTS-3, PTS-4, PTS-5, PTS-11, and PTS-12) were productive and contain a highly diverse, moderately preserved nannofossil assemblage. The assemblage contains *Axopodorhabdus cylindratus*, *Biscutum dubium*, *B. dorsetensis*, *B. novum*, *Cretarhabdus conicus*, *Crepidolithus perforata*, *Cyclagelosphaera margerelli*,

Diazomatolithus lehmanii, *Discorhabdus corollatus*, *D. criotus*, *D. striatus*, *D. ignotus*, *Ethmorhabdus gallicus*, *Hexapodorhabdus cuvillieri*, *Lotharingius vellatus*, *L. crucicentralis*, *L. barozii*, *L. haufii*, *Octopodorhabdus decussatus*, *O. praevisus*, *Podorhabdus grassei*, *Retecapsa octofenestrata*, *Stauroolithites lumina*, *Stephanolithion bigotii*, *S. speciosum octum*, *S. hexum*, *Triscutum beaminsterense*, *T. sulliviani*, *T. tiziense*, *T. expansum*, *Tubirhabdus patulus*, *Umbria granulosa*, *Watznaueria britannica*, *W. barnesae*, *W. manivitiaie*, and *Zeugorhabdotus erectus*. *Crucirhabdus primulus*, *Magaganella protensa*, *Diductius constans*, and *Parhabdolithus liasicus* recorded with the assemblage are considered as reworked Early Jurassic nannofossils.

The presence of *L. velatus* in older PTS-2 and PTS-3, *L. crucicentralis* in PTS-3, and *C. perforata* in PTS-5 suggests a Late Oxfordian – Early Kimmeridgian age for the assemblage, the boundary between the two stages lying most likely in sample PTS-4. *Stephanolithion bigotii bigotii* is found throughout the section. Patasar Shale samples have also yielded a rich and well preserved dinoflagellate cyst assemblage. The occurrence of *Aldorfia dictyota*, *Dingodinium jurassicum*, *D. tuberosum*, *Endoscrinium luridum*, *Gonyaulacysta jurassica*, *Prolixosphaeridium capitatum*, *Rigaudella aemula*, *Scrinioidinium crystallinum* and *Tubotuberella apatela* attests a Late Oxfordian – Early Kimmeridgian age for the Patasar shales at Patasar tank. The assemblage shows affinity with both Boreal and Austral dinoflagellate cyst assemblages. However, the ammonite data suggests that the Patasar Shale Member questionably belongs to the ?Grossouvrei Subzone of the Upper Bifurcatus Zone of Middle Oxfordian age on the basis of a single specimen of *Perisphinctes cf. besairiei* (PANDEY et al. 2012).

References

- DESAI, G. & MERH, S.S. 1975. Western Wagad Mesozoic sediments and their depositional environments. – Symposium on Sediment, Sedimentation & Sedimentary Environment, University of Delhi: 313–322.
- PANDEY, D.K., ALBERTI, M. & FÜRSICH, F.T. 2012. Ammonites of the genus *Perisphinctes* WAAGEN, 1869 from the Oxfordian of Kachchh, western India. – *Revue de Paléobiologie* 31: 483–587.

Nannofossil biostratigraphy of the Chari Formation, Jumara Dome, Kachchh, western India

JYOTSANA RAI¹, MRIDUL GUPTA¹, SURABHI GARG¹, ABHA SINGH¹, SREEPAT JAIN² & DHIRENDRA K. PANDEY³

¹*Birbal Sahni Institute of Palaeobotany, 53, University Road, Lucknow- 226007, India; E-mail: Jyotsana_rai@yahoo.com*

²*DG-2, Flat no. 51C, SFS Flats, Vikaspuri, New Delhi-110018*

³*Department of Geology, University of Rajasthan, Jaipur*

The Kachchh Basin, situated on the western margin of the Indian plate, was formed in the Late Triassic following the rifting between India and Africa. Lithostratigraphically, the Jurassic rocks of the basin are classified into Patcham, Chari, Katrol, and Umia formations (in ascending order; WAAGEN 1873-75) and were subsequently redesignated by BISWAS (1977) as Jhurio, Jumara, Jhuran, and Bhuj formations, respectively, with details of stratigraphic type sections. The boundaries between these two lithostratigraphic schemes are the same for the first three formations but the boundaries of the Katrol–Umia and Jhuran–Bhuj formations differ. Among different domal exposures in the Kachchh mainland, the Jumara Dome (N 23°40', E 69°06') is the type section of the Jumara Formation of BISWAS (1977), located nearly 80 km NW of Bhuj. The Jurassic succession exposed at the Jumara Dome belongs mainly to the Jhurio, Patcham, Chari (Jumara) and Katrol (Jhuran) formations (FÜRSICH et al 2001).

The Middle Jurassic marine succession of Kachchh is globally known for its abundant datable macro- as well as microfossils. In this study an attempt is made to date the Jhurio, Patcham and Chari formations rocks in the Jumara Dome by their calcareous nannofossil assemblages. In all, 17 samples were collected out of which 15 (nine from the Jumara and six from the Jhurio and Patcham formations) were found productive. The Chari Formation is capped by the Dhosa Oolite Member (constituting several bands), an important marker bed. The calcareous nannofossil assemblage at Jumara is well diversified and moderately preserved with pronounced etching in Bathonian-age nannofossils of the Jhurio and Patcham formations as well as the Oxfordian-age nannofossils recovered from calcareous

sandy shales underlying the Dhosa Oolite.

The Bathonian assemblage recovered from the Jhurio Formation is represented by *Axopodorhabdus cylindratus*, *Cyclagelosphaera margerelii*, *Calyculus* sp., *Diazomatolithus lehmanii*, *Discorhabdus criotus*, *Ethmorhabdus gallicus*, *Carinolithus magharensis*, *Lotharingius haufii*, *L. crucicentralis*, *L. sigillatus*, *L. velatus*, *Octopodorhabdus deccusatus*, *Staurolithites* sp., *Watznaueria barnesae*, *W. britannica*, *W. manivitae*, and *Zeugorhabdotus erectus*. The presence of *W. manivitae* (FAD marks the base of NJ 10= Lower Bajocian) and *Carinolithus magharensis* [LAD marks Middle Bathonian= NJ 11 (part)] suggests an age of the upper part of the Jhurio Formation straddling between the Lower Bajocian and Middle Bathonian (MATTIOLI & ERBA 1999). Ammonite data have also suggested a Middle Bathonian age for the lowest sediments exposed in the Jumara Dome (JAIN 1995, 2002; JAIN & PANDEY 2000).

The Callovian-age nannofossil assemblage includes *Anfractus harrisonii*, *Ansulasphaera helvetica*, *Axopodorhabdus atavus*, *A. cylindratus*, *Biscutum depravatus*, *B. dorsentensis*, *B. dubium*, *B. finchii*, *B. grande*, *B. novum*, *B. profundum*, *B. striatum*, *Bussonius leufensis*, *Carinolithus magharensis*, *Crepidolithus crassus*, *C. granulatus*, *C. perforata*, *C. pleinsbachensis*, *Cretarhabdus conicus*, *Crucirhabdus primulus*, *Cyclagelosphaera margerelii*, *Diazomatolithus lehmanii*, *Discorhabdus criotus*, *Discorhabdus corollatus*, *D. ignotus*, *D. striatus*, *Diductus constans*, *Ethmorhabdus gallicus*, *Faviconus multicolumnatus*, *Hexapodorhabdus cuvillieri*, *Lotharingius contractus*, *L. crucicentralis*, *L. haufii*, *L. sigillatus*, *L. velatus*, *Magaganella protensa*, *Mitrolithuselegans*, *Octopodorhabdus deccusatus*, *O. praevisus*, *Podorhabdus grassei*, *Pseudoconus enigma*, *Parhabdolithus liasicus*, *Perissocyclus*

noeliae, *Retecapsa incompta*, *R. schizobrachiata*, *Rhagodiscus nebulosus*, *Schizosphaerella punctulata*, *Stephanolithion bigotii bigotii*, *S. hexum*, *S. speciosum octum*, *Staurolithites lumina*, *S. quadriarculla*, *S. stradneri*, *Similiscutum orbiculus*, *Thurmannolithion claratum*, *Triscutum beaminsterensis*, *T. sullivanii*, *T. tiziense*, *Tubirhabdus patulus*, *Umbria granulosa*, *Watznaueria barnesae*, *W. britannica*, *W. contracta*, *W. manivitae*, *W. ovata*, *Zeugorhabdotus erectus*, and *Z. fluxus*. The presence of *Ansulasphaera helvetica*, *C. perforata*, *Cretarhabdus conicus*, *D. striatus*, *Faviconus multicolumnatus*, *L. crucicentralis*, *Stephanolithion bigotii bigotii*, *S. hexum*, and *S. speciosum octum* constricts the Jumara Formation up to the first band of the Dhosa Oolite to the NJ13 NF Zone of BOWN et al. (1988) of the Middle to latest Callovian.

Additionally, as elsewhere (RAI 2006, 2007; RAI & JAIN 2012), some Early Jurassic reworked forms of *Crepidolithus plienschbachensis*, *Mitrolithus elegans*, *Parhabdolithus liasicus*, *Triscutum sullivanii*, and *T. tiziense* are also recorded in the Bathonian–Oxfordian succession of Jumara.

References

- BISWAS, S.K. 1977. Mesozoic rock-stratigraphy of Kutch, Gujarat. – Quarterly Journal of the Geological Mineralogical and Metallurgical Society of India 49 (3-4): 1–51.
- BOWN, P.R., COOPER, M.K.E & LORD, A.R. 1988. A calcareous nannofossil biozonation scheme for the Early to Mid Mesozoic. Newsletters on Stratigraphy 20: 91–114.
- FÜRSICH, F. T., PANDEY, D.K., CALLOMON, J. H. JAITLY, A. K. & SINGH, I. B. 2001. Marker beds in the Jurassic of the Kachchh Basin, western India: their depositional environment and sequence-stratigraphic significance. – Journal of The Palaeontological Society of India 46: 176–198.
- JAIN, S. 1995. Biostratigraphical and paleoecological studies of Middle Jurassic (Upper Bathonian-Lower Callovian) beds exposed in Jumara Dome, Kachchh, Western India. – Unpublished Thesis, 202 pp.
- JAIN, S. 2002. Middle Jurassic ammonite biozonation in western India: Global implications. – Geological Society of America, Annual Meeting, Colorado. Paper No. 141-10, 34.
- JAIN, S. & PANDEY, D.K. 2000. Middle Jurassic ammonite biozonation in Kachchh, western India. – Bulletin of the Indian Geologists Association 33: 1–12.
- MATTIOLI, E. & ERBA, E. 1999. Synthesis of calcareous nannofossil events in Tethyan Lower and Middle Jurassic successions. – Rivista Italiana di Paleontologia et Stratigrafia 105: 343–376.
- RAI, J. 2006. Reworked Plienschbachian–Aalenian nannofossils from Jara Dome, Kutch: Early Jurassic palaeobiogeography of western India. – In: XIth International Nannoplankton Association, Nebraska, U.S.A.: 84–85.
- RAI, J. 2007. Early Jurassic calcareous nannofossils from Patcham Island, Kutch, western India. – In: XXIIth Indian Colloquium on Micropalaeontology and Stratigraphy, Nov. 16-17, 2007, B.S.I.P., Lucknow: 143.
- RAI, J. & JAIN S. 2012. Early Jurassic Gondwanaland breakup – a nannofossil story. – DST Sponsored Field Workshop and Brainstorming Session on 'Geology of Kachchh Basin, Western India: Present Status and Future Perspectives', 26th to 29th January 2012, Kachchh University, Bhuj, Kachchh (Abstract).
- WAAGEN, W. 1873-75. Jurassic fauna of Kutch. The Cephalopoda. – Memoirs of the Geological Survey of India. Palaeontologica Indica, New Series 9 (1-4): 1–247.

Middle-Jurassic age calcareous nannofossils from Habo Dome, Kachchh, western India

JYOTSANA RAI¹, S. J. PATEL², ABHA SINGH¹ *, MRIDUL GUPTA¹, SURABHI GARG¹, BISWAJEET THAKUR¹ & HITENDRA SHUKLA³

¹Department of Microplankton, Birbal Sahni Institute of Palaeobotany, 53, University Road, Lucknow-226007, India; E-mail: jyotsana_rai@yahoo.com

²Department of Geology, M.S. University of Baroda, vadodara- 390 002, India

³Department of Geology, Bundelkhand University, Jhansi, India

*Corresponding author

Habo Dome, the biggest inlier domal structure (ca. 320 m in height) is situated in the northern Mainland of Kachchh. The geographical extent of the Habo Hill is roughly elliptical (E-W 16 km, N-S 6 km). The rugged topography with its highest peaks is situated roughly on the longer axis of the hill. The southern slopes are flat, gentle, extensive and monotonous, whereas the northern ones are steep and short.

The Mesozoic rocks exposed in Habo Dome are Bathonian to Kimmeridgian in age and have been divided into Patcham, Jumara, and Jhuran formations (BISWAS 1977; FÜRSICH et al. 2001). In Habo Dome the upper part of the Patcham Formation crops out only at one place in the northern flank of the hill, south of Dhrang Village. In Habo hill the maximum thickness of the exposed upper part of Patcham Formation is ca. 16.6 m, and it consists of thinly bedded yellowish brown, black and dirty white limestone interbedded with thin calcareous shales. The black limestone is bioturbated and contains abundant *Chondrites* and resting traces (*Lockeia*; PATEL et al. 2008).

The Patcham Formation is conformably overlain by the thick argillaceous Jumara (Chari) Formation. The formation is exposed on the periphery of inliers. Being soft, it usually gives rise to a greenish-grey undulating landscape of low relief and hard bands occasionally forming cuestas. The formation is characterized by monotonous olive-grey, gypsiferous, laminated shales with thin, red ferruginous bands, alternating beds of limestone, and occasional sandstone inter-beds. The middle part of Jumara Formation consists of three to four thick bands of sandstone. This unit is characterized by planar and trough cross-lamination with abundant trace

fossils. At certain levels conglomerates, shell beds, and coral fragments are seen. Abundant traces (*Laevicyclus*, *Fucopsis*, *Spongeliomorpha*, *Ophiomorpha*, *Rhizocorallium*, *Halymenidium* etc.) are observed (PATEL et al. 2008). Above the sandstone thick grey shale is capped by thin, prominent, hard, fossiliferous oolitic limestone bands (sandy oo-micrites), called 'Dhosa Oolite member'; it is the best marker bed in the Kachchh Basin. The member consists of three to four hard bands, rich in megafossils especially ammonoids (*Perisphinctes* (*Arisphinctes*) cf. *colei*, *Perisphinctes* (A.) aff. *cotovuiformis*, *Perisphinctes* (A.) *kheraensis*, *Perisphinctes* (A.) cf. *trifidus*), belemnites, brachiopods, gastropods, and bivalves. The topmost layer of the Dhosa Oolite is an intraformational conglomerate and contains both reworked pebbles and boulders of oolitic limestone with abundant large-sized reworked ammonites and belemnites (ALBERTI et al. 2011, 2013).

The samples collected from the Patcham, Jumara and Jhuran formations of the Habo Dome were analysed for calcareous nannofossil productivity. The nannofossil assemblages are well diversified and moderately preserved. Samples from the Patcham Formation in the core of the Dome have yielded *Watznaueria barnesae*, *W. britannica*, *Cyclagelosphaera margerelii*, *Lothringuis contractus*, *Discorhabdus striatus*, and *L. velatus*. The assemblage is dated Upper Bathonian–Lower Callovian in age (Fig.1).

The Jumara Formation has yielded well preserved and moderately diversified nannofossil assemblages. The assemblage contains *Crepidolithus perforata*, *Cretarhabdus conicus*, *Cyclagelosphaera margerelii*, *Diazmatolithus lehmanni*, *Discorhabdus*

striatus, *Ethmorhabdus gallicus*, *Faviconus multicolumnatus*, *Lotharinguis contractus*, *L. crucicentralis*, *L. sigillatus*, *Stradnarlithus* sp., *Stephanolithion bigotii*, *Stephanolithion* sp., *Triscutum expanses*, *Tubirhabdus patulus*, *Watznaueria barnesae*, *W. britannica*, *Zegrhabdutus erectus*, and *Z. fluxus*. In various zonation schemes the presence of *Lotharinguis crucicentralis* (LAD indicates base of NJ 15a of the Middle Oxfordian (DE KAENEL & BERGEN 1996) to NJ 15b of Late Oxfordian (BOWN et al. 1988), *Stephanolithion bigotii bigotii* (FAD is from the upper part of the Lower Callovian), *Crepidolithus perforata* (range Lower Callovian to Lower Volgian fide BOWN 1998) and *Discorhabdus striatus* (LAD NJ 15a Middle Oxfordian; BOWN 1998) and FAD of *F. multicolumnatus* (= base of NJ 15b of Upper Oxfordian; BOWN 1998). Thus the samples from Upper Jumara Formation underlying the Dhosa Oolite are dated Late Callovian-Oxfordian (Fig.1).

Samples from the Jhuran Formation contain *Staurolithites quadriarcula*, *Cretarhabdus conicus*, *C. margerelii*, *W. britannica*, *W. barnesae*, *L. sigillatus*, *S. bigotii bigotii* (LAD in NJ 16 of BOWN et al. 1988 coinciding with NJ 20A of BRALOWER et al. 1989 of Middle Tithonian age), and *Triscutum beaminsterensis* (LAD indicates upper Lower Kimmeridgian). The age of the base of the Jhuran Formation is thus constrained from the Divisum (NJ 15, Upper Lower Kimmeridgian) to the Lower Fallauxi Tethyan ammonite Zone (NJ 20A Zone of BRALOWER et al. 1989, corresponding to the Middle Upper Volgian NJ 16 Zone of BOWN et al. 1988) (Fig.1).

The abundance of *Zegrhabdotus* spp. (5 µm) usually increases in upwelling zones and is thus considered as a good palaeo-fertility indicator (STREET & BOWN 2000). These authors also suggested *W. barnesae* is abundant during periods of more muddy deposition, while *Zegrhabdotus* spp. is more common during carbonate deposition.

On the basis of limited nannofossil marker taxa the Bathonian-Callovian, Callovian-Oxfordian, and the Oxfordian-Kimmeridgian boundaries are delineated from the upper Patcham, Jumara, and lower Jhuran formations exposed in Habo Dome. This nannofossil data is tagged with known ammonite data. Integrated calcareous nannofossil-ammonite studies may

serve as standard for the Indo-Pacific province. Identification of marker taxa (both cosmopolitan and substitute) and assignment to nanno-zones due to diachronous nature of some markers in various zonal schemes are taken into account (BRALOWER et al. 1989; DE KAENEL & BERGEN 1996; BOWN & COOPER 1998; MATTIOLI & ERBA 1999).

References

- ALBERTI, MATTHIAS, FÜRSICH, FRANZ T. & PANDEY, DHIRENDRA K. 2013. Deciphering condensed sequences: A case study from the Oxfordian (Upper Jurassic) Dhosa Oolite member of the Kachchh Basin, western India. – *Sedimentology* 60 (2): 574–598
- ALBERTI, M., PANDEY, DHIRENDRA K. & FÜRSICH, F.T. 2011. Ammonites of the genus *Peltoceratoides* SPATH, 1924 from the Oxfordian of Kachchh, western India. – *Neues Jahrbuch für Geologie und Paläontologie* 262: 1–18.
- BISWAS, S.K. 1977. Mesozoic rock-stratigraphy of Kutch, Gujarat. – *Quarterly Journal of the Geological, Mineralogical and Metallurgical Society of India* 49 (3-4): 1–51.
- BOWN, P.R. 1998. Calcareous nannofossil biostratigraphy, British Micropalaeontological Society Publication Series: 315 pp., Chapman and Hall, Dordrecht.
- BOWN, P.R. & COOPER, M.E.K. 1998. Jurassic. In: BOWN, P.R. (ed.), *Calcareous nannofossil biostratigraphy*. – British Micropalaeontological Society Publication Series: 38–85, Chapman and Hall, Dordrecht.
- BOWN, P.R., COOPER, M.K.E & LORD, A.R. 1988. A calcareous nannofossil biozonation scheme for the Early to Mid Mesozoic. – *Newsletters on Stratigraphy* 20: 91–114.
- BRALOWER, T., MONECHI, S. & THIERSTEIN, H.R. 1989. Calcareous nannofossil zonation of the Jurassic-Cretaceous boundary interval and correlations with the Geomagnetic Polarity Timescale. – *Marine Micropalaeontology* 14: 153–235.
- DE KAENEL, E. & BERGEN, J.A. 1996. Mesozoic calcareous nannofossil biostratigraphy from sites 897,899, and 901, Iberia abyssal plain: new biostratigraphic evidence. – *Proceedings of the Ocean Drilling Program, Scientific Results* 149: 27–59.
- FÜRSICH, F. T., PANDEY, D.K., CALLOMON, J. H. JAITLEY, A. K. & SINGH, I. B. 2001. Marker beds in the Jurassic of the Kachchh Basin, western India: their depositional environment and sequence-stratigraphic significance. – *Journal of The Palaeontological Society of India* 46: 176–198.
- MATTIOLI, E. & ERBA, E. 1999. Synthesis of calcareous nannofossil events in Tethyan Lower and Middle Jurassic successions. – *Rivista italiana di Paleontologia e Stratigrafia* 105: 343–376.
- PATEL, S.J., DESAI, B.G., VAIDYA, A.D. & SHUKLA, R. 2008. Middle Jurassic trace fossils from Habo Dome, Mainland Kachchh, Western India. – *Journal of the Geological Society of India* 71: 345–362.
- STREET, C. & BOWN, P.R. 2000. Palaeobiogeography of Early Cretaceous (Berriasian-Barremian) calcareous nannoplankton. – *Marine Micropalaeontology* 39: 265–291.

Continental Jurassic of peninsular India – A floristic and stratigraphic riddle

ANNAMRAJU RAJANIKANTH* & CHOPPARAPU CHINNAPPA

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India; E-mail: annamraju rajanikanth@gmail.com; chinnabsip@gmail.com

**Corresponding author*

Terrigenous facies of peninsular India, initiated by a glacial episode and culminating in a lithologic hiatus, is grouped under the Gondwana Supergroup (VENKATACHAL et al. 1993). Post-Gondwana deposits, often associated with Ptilophyllum Flora and at times with marine intercalations, have been variously assigned Early, Middle or Late Jurassic or Early Cretaceous ages (FEISTMANTEL 1887; FOX 1931; SPATH 1933; ARKELL 1956; SASTRY et al. 1979; DATTA et al. 1983; BANERJI 1990; MITRA 1993; SEN GUPTA 1994; RAJANIKANTH et al. 2000; LAKSHMINARAYANA 2002; VIJAYA & PRASAD 2001; PANDEY & CHOUDHARY 2007; DUTTA 2002; MUKHOPADHYAY et al. 2010). Subsequent researches separated coastal 'Gondwana' litho-units from the purview of Gondwana (PRASAD & PUNDIR 1999; RAJANIKANTH 2010). Age reassignments of the Rajmahal basalt (Mc DOUGALL & McELHINNY 1970) opened a new paradigm of early Cretaceous floristics and litho-units comprising the Ptilophyllum Flora in both intra- and pericratonic sedimentary basins. Thus the traditional Jurassic age connotation of the Ptilophyllum Flora (Upper Gondwana) shifted to the Early Cretaceous. This view is supported by a non-deposition phase (hiatus/erosion) of Jurassic sediments in peninsular India (VENKATACHALA & MAHESHWARI 1991). This created an uncertainty over the placing of non-marine Jurassic litho-units distributed in the Pranhita-Godavari/Krishna-Godavari, South Rewa, Jaisalmer, and Rajmahal basins. A reassessment of the floristic and stratigraphic evidence is required to understand the status of continental Jurassic in peninsular India. Macro- and micro-palaeobotany of Kota (Pranhita-Godavari/Krishna-Godavari, Maharashtra, Andhra Pradesh), Hartala/Bandhogarh (South Rewa, Madhya Pradesh), Lathi (Jaisalmer, Rajasthan) and Dubrajpur (Rajmahal, Bihar/

Jharkhand/West Bengal) (see Figs 1 and 2) litho-units provide stratigraphic, phytogeographic, and phytoevolutionary inferences.

The present communication aims to re-evaluate plant fossil data and their limitations for inferring an unequivocal age. An analysis of the macro-palaeobotanical evidence in the Kota succession reflects preponderance of conifers followed by pteridophytes and Bennettitales. Pteridospermales, Cycadales, and Ginkgoales are poorly represented. These floral components are closely comparable with floral evidence from Rajmahal (Early Cretaceous), which may suggest the reassessment of its Jurassic age based on Kota macro-plant evidence (RAJANIKANTH & SUKH-DEV 1989). Micro-palaeobotanical evidence shows a dominance of pteridophytes followed by gymnosperms and bryophytes. Moreover the age assignment ranges from early Jurassic to early Cretaceous (VIJAYA & PRASAD 2001). This long-ranging chronological

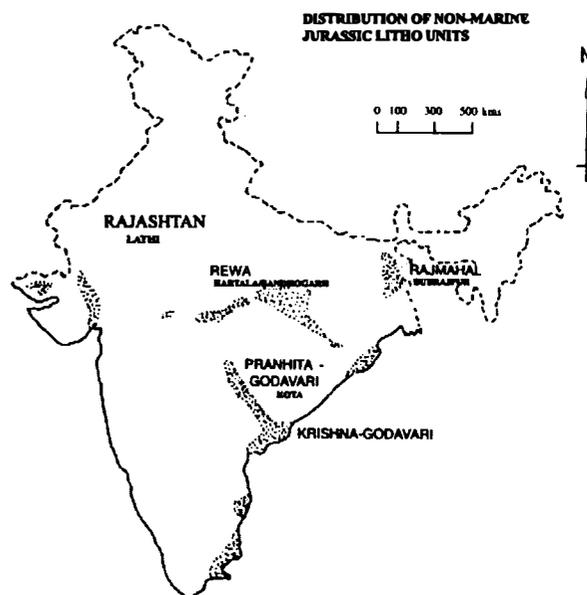


Fig. 1. Showing geographic distribution of non marine Jurassic litho-units in India.

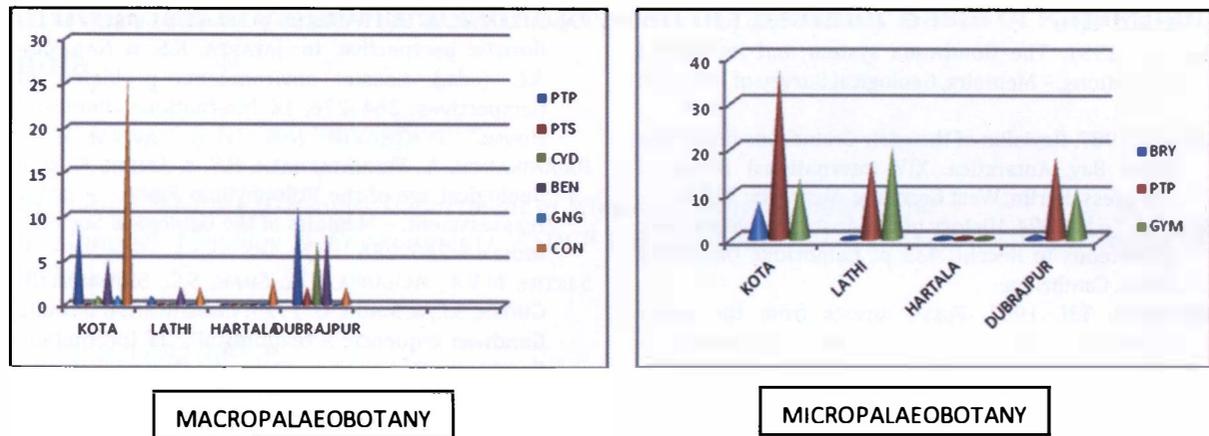


Fig. 2. Distribution of macro- and micro-plant relics in non-marine Jurassic litho-units of India; Legend: BRY: Bryophytes, BEN: Bennettitales, CON: Coniferales, CYD: Cycadales, GNG: Ginkgoales, GYM: Gymnosperms, PTP: Pteridophytes, PTS: Pteridospermales.

inference negates the exact stratigraphic status of the Kota succession. A critical reassessment of lithologic and faunal data is suggested. Moreover the extent of the Kota succession has been extended from the intra-cratonic Pranhita-Godavari Basin to the peri-cratonic (coastal 'Gondwana') Krishna-Godavari Basin, and an unconformity with the overlying Gangapur and Raghavapuram (Early Cretaceous) succession has been suggested. Both macro- and micro-palaeobotanical evidence of these two units are dated as early Cretaceous and the Kota evidence, too, may signal an early Cretaceous age connotation.

Macro- and micro-palaeobotanical information of Hartala/Bandhogarh (South Rewa) is poorly/hardly known and its age assessment is questionable (PAL 1984; SUKHDEV 1988). The Lathi Formation (Jaisalmer Basin), represented by conifer wood taxa and Bennettitales, bears no stratigraphic affinity (BONDE 2010; SHARAM et al. 2002). Micro-palaeobotanical data is suggestive of a dominance of gymnosperms followed by pteridophytes (SRIVASTAVA 1966). Further data is needed for stratigraphic and age conclusions (PANDEY & CHOWDHURY 2007).

The Dubrajpur macro-palaeobotanical data consist of pteridophytes, Bennettitales, Cycadales, pteridosperms, and conifers in order of decreasing abundance (BANERJI 1990). Significant floral components suggest an early Cretaceous affinity. Sub-surface micro-palaeobotanical data, in contrast, exhibit a dominance of pteridophytes followed by gymnosperms and bryophytes and suggest a

Jurassic to early Cretaceous age (VIJAYA & ROY 2000; TRIPATHI 2000). The later age connotation seems rational since the assemblage zones are comparable with other micro-palaeobotanical evidence from various intra- and peri-cratonic early Cretaceous basins. Macro- and micro-palaeobotanical evidences found in Jurassic strata of continents adjoining India (Antarctica, Australia, Africa), too, are subjected to age reassignments (JEFFERSON 1982; GEE 1987; HILL 1994; BOSE et al. 2000; PHILIPPE et al. 2004). The problem of continental Jurassic in India should be reassessed in the light of occurrence of cosmopolitan taxa (plant relics) and wide historical geographic distribution of faunal evidence and the possibility of facies variations given a different chronological limitation.

References

- ARKELL, W.J. 1956. *Jurassic Geology of the World*. 806 p., Oliver and Boyd Ltd., London.
- BANERJI, J. 1990. Plant fossils from Dubrajpur Formation, Bihar and their significance in stratigraphy. - *Palaeobotanist* 38: 122-130.
- BONDE, S.D. 2010. A new genus of podocarpaceous wood from the Lathi Formation (Early Jurassic) of Rajasthan, India. - *Geophytology* 38:19-24.
- BOSE, M.N., TAYLOR, E.L. & TAYLOR, T.N. 1990. Gondwana floras of India and Antarctica- a survey and appraisal. In: TAYLOR, T.N. & TAYLOR, E.L. (eds.), *Antarctic palaeobiology: its role in the reconstruction of Gondwana*: 18-148, Springer, New York.
- DATTA, N.R., MITRA, N.D. & BANDYOPADHYAY, S.K. 1983. Recent trends in the study of Gondwana basins of peninsula and extra peninsula, India. - *Petroleum Asia Journal* 6: 9-169.
- DUTTA, P. 2002. Gondwana lithostratigraphy of peninsular India. *Gondwana Research* 5: 540-553.
- FEISTMANTEL, O. 1879. Upper Gondwana flora of the outliers on the Madras coast. - *Palaentologia Indica*

- 1: 202–234.
- FOX, C.S. 1931. The Gondwana system and its related formations. – *Memoirs, Geological Survey of India* 58: 1–241.
- GEE, C.T. 1987. Revision of the early Cretaceous flora from Hope Bay, Antarctica. XIV International Botanical Congress, Berlin, West Germany, Abstracts: 333.
- HILL, R.S. (ed.) 1994. History of the Australian vegetation: Cretaceous to Recent. 433 p., Cambridge University Press, Cambridge.
- JEFFERSON, T.H. 1982. Fossil forests from the lower Cretaceous of Alexander Island, Antarctica. – *Palaeontology* 30: 233–249.
- LAKSHMINARAYANA, G. 2002. Evolution in basin fill style during the Mesozoic Gondwana continental breakup in the Godavari Triple Junction- SE India. – *Gondwana Research* 5: 227–244.
- MC DOUGALL, I. & MC ELHINNY, M.W. 1970. The Rajmahal traps of India – K-Ar ages and palaeomagnetism. – *Earth and Planetary Science Letters* 9: 371–378.
- MUKHOPADHYAY, G., MUKHOPADHYAY, S.K., ROYCHOWDHURY, M. & PARUI, P.K. 2010. Stratigraphic correlation between different Gondwana basins of India. – *Journal of the Geological Society of India* 76: 251–266.
- PAL, P.K. 1984. Fragmentary plant remains from the Hartala Hill, South Rewa Gondwana Basin, India. – *Palaeobotanist* 32: 126–129.
- PANDEY, D.K. & CHOWDHARY, S. 2007. Sequence stratigraphic framework of Lower to Lower Middle Jurassic sediments of the Jaisalmer Basin, India. – *Beringeria* 37: 121–131.
- PHILIPPE, M., BAMFORD, M., MC LOUGHLIN, S., ALVES, L.S.R., FALCON LANG, H.J., GNAEDINGER, S., OTTONE, E.G., POLE, M., RAJANIKANTH, A., SHOEMAKER, R.E., TORRES, T. & ZAMUNER, A. 2004. Biogeographic analysis of Jurassic–early Cretaceous wood assemblages from Gondwana. – *Review of Palaeobotany and Palynology* 129: 141–173.
- PRASAD, B. & PUNDIR, B.S. 1999. Biostratigraphy of the exposed Gondwana and Cretaceous rocks of Krishna-Godavari Basin, India. – *Journal of the Paleontological Society of India* 44: 91–117.
- RAJANIKANTH, A. & SUKH-DEV 1989. The Kota Formation: Fossil flora and stratigraphy. – *Geophytology* 19: 52–64.
- RAJANIKANTH, A. 2010. Status of coastal Gondwana – A floristic perspective. In: JAYAPPA, K.S. & NARAYANA, A.C. (eds.), *Coastal environments problems and perspectives*: 264–276, IK International Publishing House.
- RAJANIKANTH, A., VENKATACHALA, B.S. & ASHOK, K. 2000. Geological age of the Ptilophyllum Flora – A critical reassessment. – *Memoirs of the Geological Society of India* 46: 245–256.
- SASTRY, M.V.A., ACHARYA, S.K., SHAH, S.C., SATSANGI, P.P., GHOSH, S.C. & SINGH, G. 1979. Classification of Indian Gondwana sequence: A reappraisal. – IV International Gondwana Symposium, India, Geological Survey of India 2: 502–507.
- SEN GUPTA. 1994. Does continental Jurassic sequence occur in India. – *Proceedings, 9th Gondwana Symposium, Hyderabad* 1: 299–309
- SHARMA, B.D. & TRIPATHI, R.P. 2002. Petrified conifer woods from Lathi Formation (Jurassic), Rajasthan, India. – *Geophytology* 30: 27–30.
- SPATH, L.F. 1933. Revisions of the Jurassic cephalopod fauna of Kutch. – *Memoir of the Geological Survey of India, Palaeontologia Indica* 9: 659–945.
- SRIVASTAVA, S.K. 1966. Jurassic microflora from Rajasthan, India. – *Micropalaeontology* 12: 87–103.
- SUKH-DEV 1988. Floristic zones in the Mesozoic formations and their relative age. – *Palaeobotanist* 36: 161–167.
- TRIPATHI, A. 2000. Palynological events during late Triassic-Early Jurassic time in India. – *Palaeobotanist* 49: 309–408.
- VENKATACHALA, B.S. & MAHEHWARI, H.K. 1991. Indian Gondwana redefined. In: *Indian Gondwana*. – Geological Society of India, Bangalore, Special Publication: 81–87.
- VENKATACHALA, B.S., MAHESHWARI, H.K. & RAJANIKANTH, A. 1993. The Gondwana Supergroup. – *Gondwana Geological Magazine, Special Volume*: 80–92.
- VIJAYA & PRASAD, G.V.R. 2001. Age of the Kota Formation, Pranhita Godavari Valley, India. A palynological approach. – *Journal of the Palaeontological Society of India* 46: 77–93.
- VIJAYA & ROY, A. 2000. Late hour Jurassic palynomorph assemblage in the Dubrajpur sediments, Birbhum district, West Bengal, India. – *Palaeobotanist* 49: 41–49.

An overview of yellow Limestone deposit of Jaisalmer Basin of Rajasthan, India

T. S. RANAWAT¹ & NEERAJ SRIVASTAVA² *

¹*Additional Director (Geology), Department of Mine & Geology, Udaipur, India*

²*Sr. Manager (Geology & Environment), ASDCP Ltd., Udaipur, India; E-mail: neeraj.shrivastava@golcha.com*

*Corresponding author

The Mesozoic rocks are well exposed in the Jaisalmer basin of Rajasthan. It is classified as Lathi, Jaisalmer, Baisakhi, Bhadasar, Pariwar and Habur formations (DAS GUPTA 1975; KRISHNA 1987; PANDEY et al. 2012). The rocks of these formations are mainly represented by limestone, sandstone and shale. Out of these formations Lathi, Jaisalmer, Baisakhi and Badasar formations belong to Jurassic age. The yellow limestone is mainly confined in the Jaisalmer Formation (AGARWAL et al. 1988; DMG 2004; IBM 2011). The yellow limestone is occurring in Jaisalmer, Bada Bag, Moolsagar, Kanod, Amarsagar, Chundi, Bhagata, Manria, etc. areas and widespread in more than 5.4 million sq. meters. It contains 42 to 51% calcium oxide and having thickness of hardly about 3 mts. The strike of the bed is N15°E and dipping at an angle of 4° to 5° in north western direction. The total estimated resource of yellow limestone is about 8.2 million tons. The yellow limestone is massive and partly crystalline with pink colour bands at some places. Fossiliferous bands are also very common (MUDE et al. 2012). Under microscope it shows presence of well rounded quartz grains in the calcareous cement.

The mining of the yellow limestone is continuing from last several decades. It is quarried in blocks of 50 to 60 cms length, 30 to 40 cms in width and thickness of about 30 cms is sawed into tiles and used as yellow marble after polishing. It has been used since ancient time for construction of fort, temples and various other building purposes. In recent

times its use has increased manifold mainly in interior flooring, wall claddings, monuments, cobble stones and for decorative purpose. With the increasing demand of this decorative stone in the world market the deposit of yellow limestone is precious for us and it should be scientifically mine to get maximum recovery because this deposit is having tremendous scope to earn foreign exchange and emerged as a valuable asset for ornamental stone industry.

References

- AGARWAL, S.C., BHATNAGAR P. & KHABYA, N. 1988. Limestone deposit of Rajasthan. Publication of Department of Mines and Geology, Udaipur.
- DASHORA, R.S. & BHARGAVA, K.D. 1971. Investigation of yellow limestone and other economic minerals in Jaisalmer area. Report of field season 1970-71, Department of Mines and Geology, Udaipur.
- DAS GUPTA S.K. 1975. A revision of the Mesozoic-Tertiary Stratigraphy of the Jaisalmer Basin, Rajasthan. - Indian Journal of Earth Sciences, 2 (1): 77-94.
- DMG. 2004. Mineral directory of Rajasthan. Publication of Department of Mines and Geology, Udaipur.
- IBM. 2011. Indian Mineral Yearbook. Publication of Indian Bureau of Mines, Nagpur.
- KRISHNA, J. 1987. An overview of the Mesozoic stratigraphy of Kachchh and Jaisalmer basin. - Journal of the Paleontological society of India 32: 136-149.
- PANDEY, D.K. CHOUDHARY, S., TEJ BAHADUR, SWAMI, N. & SHA, J. 2012b. A review of the Lower - lowermost Upper Jurassic lithostratigraphy of the Jaisalmer Basin, western Rajasthan, India - an implication on biostratigraphy. - Volumina Jurassica 10: 61-82
- MUDE, S.N., JAGTAP, S.A., KUNDAL, P., SARKAR, P.K. & KUNDAL, M.P. 2012. Paleoenvironmental significance of ichnofossils from the Mesozoic Jaisalmer Basin, Rajasthan, north western India. - Proceedings of the International Academy of Ecology and Environmental Sciences.

Limit of Upper Bathonian-Lower Callovian in Ankilizato region (Morondava Basin)

HASINA NIRINA RANDRIANALY & ARMAND RASOAMIARAMANANA

Department of Paleontology and Biologic Anthropology, Faculty of Sciences, University of Antananarivo, Madagascar; E-mail: rhasinanirina@gmail.com

In the Ankilizato area of the Morondava Basin Bathonian–Callovian strata are well exposed and richly fossiliferous. Studies of the macro- and microfossils have been carried out in order to characterize more precisely the Upper Bathonian–Lower Callovian succession. According to this work, the Bathonian is characterized by thin-bedded oolitic and

bioclastic limestones containing a rich benthic macrofauna. A transgressive phase started in Early Callovian which is indicated by Bathonian sediments found reworked in the Lower Callovian strata, marked by a combination of Bathonian and Callovian faunas, and marly clay deposits with abundant macrocephalitids and phylloceratids.

Stable isotopes of foraminifera and ostracods for interpreting the Toarcian Oceanic Anoxic Event at the South Iberian palaeomargin

MATÍAS REOLID

Departamento de Geología, Universidad de Jaén, 2307 Spain; Email: mreolid@ujaen.es

The Early Toarcian Oceanic Anoxic Event (T-OAE) is recognized as one of the most important environmental changes during the Mesozoic, with a dramatic impact on marine biota revealed by a significant mass extinction event in benthic and pelagic groups. The sedimentary record of the T-OAE is characterized by organic-rich sediments ("black shales") associated with a distinct negative excursion in $\delta^{13}\text{C}$ recorded in organic matter, marine carbonates, brachiopods, belemnites, and fossil wood (e.g. JENKYN & CLAYTON 1997; HESSELBO et al. 2007; SUAN et al. 2008). Several environmental changes may have been involved in the mass extinction event, mainly affecting benthic organisms, such as general anoxia, the enhancement of greenhouse conditions and a warming trend, or sea-level changes (e.g., HALLAM 1986; WIGNALL et al. 2005; GÓMEZ & GOY 2011). The $\delta^{13}\text{C}$ of foraminiferal shells reflects the carbon isotopic composition of the dissolved inorganic carbon (DIC) in sea-water in which the shell calcified. It is, however, not in isotopic equilibrium with sea-water, because biogenic calcification is relatively rapid resulting in kinetic isotope fractionation. Still, the stratigraphic trends of $\delta^{13}\text{C}$ composition of calcitic foraminifera do reflect the $\delta^{13}\text{C}$ fluctuations of the ambient DIC.

This work focuses on the analysis of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ from whole rock and tests of selected foraminifera (*Lenticulina* and *Dentalina*) and ostracods from Lower Toarcian marls and marly limestones of the South Iberian Palaeomargin (Western Tethys), as well as on the comparison with geochemical redox and palaeoproductivity proxies with the aim to improve knowledge of the processes and the environmental effects of the Toarcian Oceanic Anoxic Event. The selected outcrop is a pelagic section called Fuente Vidriera (FV). It is of special interest for interpreting the Early Toarcian Oceanic Anoxic Event at the westernmost end of the Tethys, characterized by a complex palaeogeography and by being relatively isolated from open

oceanic influences.

In the FV section, a bed-by-bed geochemical analysis was conducted in the 30-m-thick rhythmic succession of soft and hard marlstones with a total of 24 sample levels selected for a detailed analysis of stable isotopes (oxygen and carbon). Analyses of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ (at the University of Michigan) were applied on bulk samples and shells of different genera of foraminifera (*Lenticulina* and *Dentalina*) and ostracods. A total of 364 specimens were investigated in 140 analyses.

The analysis of the abundance and diversity of foraminiferal assemblages throughout the section indicates an important diminution in the number of foraminifera per gram and of the α -diversity at the base of Serpentinum Zone. The $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values obtained from whole samples do not exhibit a clear trend or isotopic excursion.

The $\delta^{13}\text{C}$ of *Dentalina*, *Lenticulina*, and ostracods show a negative isotopic excursion at the base of the Serpentinum Zone, more accentuated in the case of *Lenticulina*. The $\delta^{13}\text{C}$ values subsequently recovered. In general, $\delta^{13}\text{C}_{Lenticulina}$ values are lower than $\delta^{13}\text{C}_{Dentalina}$ values and no clear pattern is observed according to test size. Values of $\delta^{13}\text{C}_{Lenticulina}$ and $\delta^{13}\text{C}_{Dentalina}$ are usually lower than $\delta^{13}\text{C}$ from bulk samples. With respect to $\delta^{18}\text{O}$, values of both *Dentalina* and *Lenticulina* show minor fluctuations, $\delta^{18}\text{O}_{Dentalina}$ being lower than $\delta^{18}\text{O}_{Lenticulina}$. No relationship is observed with the test size of the foraminifera. Redox (Cr/Al, Ni/Al, V/Al, and U/Th) and palaeoproductivity proxies (Sr/Al, U/Al, P/Ti and TOC) show a peak at the base of the Serpentinum Zone.

This data allow the interpretation of environmental conditions during the Early Toarcian and the characterization of redox and paleoproductivity conditions in the water column and pore-water of shallow to deep infaunal microhabitats, with special attention to the T-OAE. Microhabitat affected the $\delta^{13}\text{C}$

values, $\delta^{13}\text{C}_{\text{Lenticulina}}$ being generally lower than $\delta^{13}\text{C}_{\text{Dentalina}}$ due to the more depleted ^{13}C values of the pore-water in deep infaunal microhabitats. The lowest values of $\delta^{13}\text{C}$ (lower part of the Serpentinum Zone) occurred during suboxic conditions indicated by redox proxies, low diversity and abundance of foraminifera, and higher TOC values. The fine-grained, organic-rich sediments favoured depletion in ^{13}C of pore-water-dissolved inorganic carbon compared to that of the bottom water, a feature more accentuated during suboxic conditions. The $\delta^{13}\text{C}$ values of potential deep infauna (*Lenticulina*) reflect the oxygen restricted conditions better than the shallow infauna (*Dentalina*) and the whole sediment. With respect to $\delta^{18}\text{O}$, values from bulk samples fluctuate more strongly and exhibit lower values than $\delta^{18}\text{O}_{\text{Dentalina}}$ and $\delta^{18}\text{O}_{\text{Lenticulina}}$. The stratigraphic differences between $\delta^{18}\text{O}_{\text{Dentalina}}$ and $\delta^{18}\text{O}_{\text{Lenticulina}}$ correspond to vital effects because no important fluctuations in temperature occurred in the bottom waters as deduced from the absence of peaks and stratigraphic trends in the studied interval. The $\delta^{18}\text{O}$ values do not allow interpretation of temperature changes related to the Toarcian

Oceanic Anoxic Event in this part of the palaeomargin.

References

- GÓMEZ, J.J. & GOY, A. 2011. Warming-driven mass extinction in the Early Toarcian (Early Jurassic) of northern and central Spain. Correlation with other time-equivalent European sections. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 306: 176–195.
- HALLAM, A. 1986. The Pliensbachian and Tithonian extinction events. – *Nature* 319: 765–768.
- HESSELBO, S.P., JENKYN, H.C., DUARTE, L.V. & OLIVEIRA, L.C.V. 2007. Carbon isotope record of the Early Jurassic (Toarcian) Oceanic Anoxic Event from fossil wood and marine carbonate (Lusitanian Basin, Portugal). – *Earth and Planetary Science Letters* 253: 455–470.
- JENKYN, H.C. & CLAYTON, C.K. 1997. Lower Jurassic epicontinental carbonates and mudstones from England and Wales: chemostratigraphic signals and the early Toarcian anoxic event. – *Sedimentology* 44: 687–706.
- SUAN, G., PITTET, B., BOUR, I., MATTIOLI, E., DUARTE, L.V. & MAILLIOT, S. 2008. Duration of the Early Toarcian carbon isotope excursion deduced from spectral analysis: Consequence for its possible causes. – *Earth and Planetary Science Letters* 267: 666–679.
- WIGNALL, P.B., NEWTON, R.J. & LITTLE, C.T.S. 2005. The timing of paleoenvironmental change and cause-and-effect relationships during the Early Jurassic mass extinction in Europe. – *American Journal of Science* 305: 1014–1032.

Ecostratigraphy of foraminiferal assemblages and geochemistry for approaching the incidence of Early Toarcian environmental changes at the North Gondwana palaeomargin (Traras Mountains, Algeria)

MATÍAS REOLID¹ *, ABBAS MAROK² & ABBÈS SEBANE³

¹Departamento de Geología, Universidad de Jaén, 23071 Jaén, Spain; E-mail: mreolid@ujaen.es

²Département des Sciences de la Terre et de l'Univers, Université Abou-Bekr Belkaid, 13000 Tlemcen, Algeria

³Département des Sciences de la Terre, Université d'Es-Sénia, 31000 Oran, Algeria

*Corresponding author

The Early Toarcian was characterised by important environmental changes and a mass extinction event usually interpreted as a global Toarcian Oceanic Anoxic Event (T-OAE). This mass extinction event had a significant impact on many marine organisms (bivalves, brachiopods, foraminifera, ostracods, ammonites and dinoflagellates). The stronger incidence of the T-OAE is documented at the boundary of the subboreal *Tenuicostatum-Falciferum* zones and the Submediterranean and Mediterranean *Polymorphum-Serpentinum* zones and *Polymorphum-Levisoni* zones. In the Traras Mountains (Tlemcen Domain, Northern Algeria), the T-OAE remains scarcely studied. The selected Mellala section is one of the very few examples of continuous and monotonous hemipelagic sedimentation (marls and marly limestones, 50 m thick) through the Pliensbachian-Toarcian boundary (ELMI et al. 2009).

The aim of this research involves the ecostratigraphic analyses of foraminiferal assemblages for determining the response to ecosedimentary dynamics during the Early Toarcian, complemented with the analyses of geochemical proxies and C and O stable isotopes.

This research uses the ammonoid biozonation proposed by ELMI et al. (2009) for the Mellala section. The foraminiferal assemblages were analysed from 43 marly sample levels. The ecostratigraphic analysis was focused on the stratigraphic fluctuations of the composition of foraminiferal assemblages. TOC, geochemical proxies (redox proxies Co/Al, Cu/Al, Cr/Al, and V/Al; and palaeoproductivity proxies Ba/Al, and P/Ti) and $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ were

analysed from 16 samples.

The observed benthic foraminiferal assemblages are dominated by the suborder Lagenina, with minor content of Textulariina, Miliolina, and Spirillinina, comprising 17 genera and 26 species. The ecostratigraphic analysis of the foraminiferal assemblages along the studied succession reveals four well differentiated stratigraphic intervals:

The end of the Pliensbachian is characterised by a foraminiferal assemblage dominated by potentially deep infaunal forms (mainly *Lenticulina gottingensis*). The presence of epifauna and shallow infauna as well as the number of species and the α -diversity (> 3.0) suggest good oxygen and nutrient availability in the infaunal microhabitats. The high number of calcareous species corresponding to K-strategists (*Dentalina*, *Lingulina*, *Marginulina*, *Vaginulina*, *Saracenaria*, *Falsopalmula*, *Marginulinopsis*, and *Planularia* and *Spirillina*) and the presence of agglutinated forms point to a stable and constant benthic environment.

The beginning of the Toarcian shows significant changes in foraminiferal assemblages with respect to the uppermost Pliensbachian. At the Pliensbachian-Toarcian boundary six species disappear (*Saracenaria sublaevis*, *Falsopalmula insignis* and *Marginulinopsis speciosa*, *Spirillina infima*, *Ammobaculites agglutinans*, and *A. fontinensis*). The general trend is the decrease of the proportion of epifauna indicating more adverse conditions compared with the end of the Pliensbachian. The *Polymorphum* Zone reveals a decrease of shallow infauna and epifauna, and an increase in the proportions of potentially deep infauna. The last record of agglutinated foraminifera is in

the Mirabile Subzone pointing to environmental changes in the epifaunal microhabitat. In the epifauna only *Ophthalmidium* appears as a new genus in the Polymorphum Zone. *Lingulina tenera* and *L. pupa* are especially abundant. Three new species of nodosariids appear at the base of the Toarcian; *Lenticulina toarcense*, *Planularia preobonensis*, and *Ichtyolaria sulcata*. The most abundant foraminifer is *Lenticulina toarcense* (43% of the assemblage). The dominance of *Lenticulina toarcense* and its inferred opportunist behaviour confirm a perturbation in the palaeoecological parameters at the sea-bottom. The presence of *Planularia preobonensis* marks the late normal phase of the foraminiferal development (SEBANE et al. 2007) that immediately preceded the crisis related to the anoxic event that occurred during the early Levisoni Chron. The Polymorphum Zone is characterised by an initial decrease in the diversity of benthic foraminifera and subsequent irregular fluctuations in the values, which could be interpreted as changes in the palaeoenvironmental conditions resulting in instability. Redox and palaeo-productivity proxies in the Polymorphum Zone exhibit important fluctuations in the Semicelatum Subzone with local maximum values of Co/Al, Cr/Al, and V/Al suggesting a decrease in the degree of oxygenation and an increase in the precipitation of these redox-sensitive elements. Local increase of P/Ti could be correlated with an increase in productivity; however, Ba/Al does not corroborate this interpretation.

A negative excursion of $\delta^{13}\text{C}$ is recorded in the Polymorphum/Levisoni zonal boundary. The beginning of the Levisoni Zone is characterised by the disappearance of epifaunal

forms, probably related to increasing stress conditions. The proportions of the opportunist *Lenticulina toarcense* increase in the Levisoni Zone (mean value of 58%) being the dominant species. The most significant information is the reduced diversity (4 species and α -diversity <1). At 1.30 m above the Polymorphum/Levisoni zonal boundary microfossils are almost absent and only two species were found (*Lenticulina toarcense* and *Lingulina tenera*). These data suggest more unfavourable conditions at the sea floor. Probably the Polymorphum/Levisoni zonal boundary constitutes an episode of restricting conditions resulting in suboxic waters at the sea floor as indicated by the maximum values of redox proxies (Co/Al, Cu/Al, Cr/Al, and V/Al). However, it was not an anoxic event as has been described from other localities for this time interval due the values of these ratios, the low values of TOC and the absence of an azoic interval with respect to the benthic assemblages.

The upper part of the Levisoni Zone is more calcareous with an increasing shallow infauna and decreasing potentially deep infauna. The α -diversity index and the increasing number of species indicate more favorable conditions.

References

- ELMI, S., MAROK, A., SEBANE, A. & ALMÉRAS, Y. 2009. Importance of the Mellala section (Traras Mountains, northwestern Algeria) for the correlation of the Pliensbachian-Toarcian boundary. - *Volumina Jurassica* 7: 37-45.
- SEBANE, A., MAROK, A. & ELMI, S. 2007. Évolution des peuplements de foraminifères pendant la crise toarcienne à l'exemple des données des Monts des Ksour (Atlas Saharien Occidental, Algérie). - *Comptes Rendus Palevolution* 6: 189-196.

The Early Toarcian Oceanic Anoxic Event in the External Subbetic (South Iberian Palaeomargin, westernmost Tethys): geochemistry, nannofossils, and ichnology of the La Cerradura section

MATÍAS REOLID¹ *, EMANUELA MATTIOLI², LUIS M. NIETO¹ & FRANCISCO J. RODRÍGUEZ-TOVAR³

¹*Departamento de Geología and CEAET, Universidad de Jaén, 23071 Jaén, Spain; Email: mreolid@ujaen.es*

²*Laboratoire de Géologie de Lyon, UMR 5276 CNRS, Université Lyon 1, ENS Lyon, 69622 Villeurbanne, France*

³*Departamento de Estratigrafía y Paleontología, Universidad de Granada, 18071 Granada, Spain*

*Corresponding author

The Toarcian Oceanic Anoxic Event (T-OAE) is one of the most important environmental changes during the Mesozoic with a dramatic impact on the marine assemblages. The record of T-OAE is characterized by a crisis of carbonate production, an increase of organic matter content of sediments, and a negative excursion of $\delta^{13}\text{C}$ (e.g. JENKYN & CLAYTON 1997; HERMOSO et al. 2009). There is a great geographic variability of the T-OAE concerning the organic matter content and degree of oxygenation of the sea-bottom. The aim of this work is the analysis of geochemical data, calcareous nannofossils, and ichnofossils in the very well exposed La Cerradura section (Subbetic, South Iberian Palaeomargin, westernmost Tethys) that allow to interpret the environmental conditions at the sea-bottom and in the water column.

The La Cerradura section is located at a slope of the motorway A-44, km 57. The studied interval consists of 27 m of marl-limestone rhythmites ranging from the Algovianum Zone (Upper Pliensbachian) to the Polymorphum Zone (Lower Toarcian) and 11 m of dark marls of the Serpentinum Zone (Lower Toarcian).

The marl-limestone rhythmites are very rich in belemnites and ammonoids with *Canavaria*, *Emaciatceras*, *Fontanelliceras*, *Lioceratoides*, *Neolioceratoides*, *Protogrammoceras*, and *Tauromeniceras* (Upper Pliensbachian) and *Dactylioceras* (Polymorphum Zone; Lower Toarcian), rendering a fine biostratigraphy possible. The top of the marl-limestone rhythmites is an ammonite-rich horizon (*Dactylioceras commune* and *D. polymorphum*). The limestone layers are mudstones with an diverse trace-fossil assemblage consisting of

Chondrites (small and large), *Palaeophycus*, *Planolites*, *Teichichnus*, *Thalassinoides*, and *Trichichnus*. The fill of trace fossils is occasionally rich in organic matter. Foraminifera (mainly *Lagenina* suborder) and ostracods are common.

The marly interval is characterized by the absence of ammonoids. The foraminifera and ostracods are very scarce or absent in the first two meters of these marls. The trace fossil assemblage reveals a drastic decrease in diversity just above the top of the marl-limestone rhythmites where the CO_3Ca content decreases to minimum values in the section (19%), followed by a gradual recovery showing an increase in diversity from 3 m above the top of the marl-limestone rhythmites.

The nannofossil assemblage of La Cerradura is of Tethyan affinity with a dominance of *Mitrolithus jansae* and *Schizosphaerella* mainly in the marl-limestone rhythmites of the Pliensbachian, whilst *Crepidolithus crassus* that has a N Tethyan affinity is very scarce. The First Occurrence of *Carinolithus superbus* occurs 60 cm over the last surface of the marl-limestone rhythmites and defines the NJT 6 that normally contains the T-OAE (MATTIOLI et al. 2009). As ammonites are lacking in the interval, we are able to precisely date the base of the T-OAE negative excursion by means of the NJT 6 nannofossil zone. We can thus demonstrate that the T-OAE is synchronous with many other Tethyan settings (MATTIOLI et al. 2009). Absolute abundances are very high, comprising between 0.5 E9 and 1.5 E9 specimens per gram of rock. However, abundances dramatically drop in the interval between samples 31 and

27, where the relative abundance of *M. jansae* also decreases. A similar trend is observed in several western Tethyan sections (MATTIOLI et al. 2008, 2009). *Orthogonoides hamiltoniae*, an incertae sedis that normally is recorded during the levels enriched in organic matter, is common in the interval between 4 and 5 m above the top of the marl-limestone rhythmites.

Geochemical data indicates an abrupt change related to the beginning of the marly interval. The CaCO₃ (%) dramatically decreases with lowest values at the base of the marls (1 m over the marl-limestone rhythmites) in coincidence with relatively higher values of total organic carbon (TOC, 0.4 wt.%). However, this value is low compared with central and north Europe records. The values of δ¹³C in the rhythmites (Upper Pliensbachian to Polymorphum Zone) are around 1.20‰, and a negative excursion of δ¹³C (0.8‰) occurs from the top to 1 m above the rhythmite (0.21‰). From this level onwards δ¹³C increases to the top of the marls (reaching 2.47‰). The authigenic U and the Total Sulphur (TS) exhibit the highest values just above the marl-limestone rhythmites. The content of Cu, U, and Th also increases in the same interval. In SEM, small pyrite framboids (~4 μm) are also recorded in the lower part of the marl interval.

The carbon cycle perturbation related to the T-OAE is clearly recorded in the La Cerradura section by the decrease in CO₃Ca and the negative excursion of δ¹³C at the base of the Serpentinum Zone, NJT 6 nannofossil zone. The trace fossil assemblage from the marl-limestones rhythmites (Upper Pliensbachian Algovianum Zone to Lower Toarcian Polymorphum Zone) reflects favourable oxygen conditions (oxic to slightly disoxic) for macrobenthic trace-makers. A decrease in diversity or absence of foraminifera and trace fossils at the base of

the Serpentinum Zone confirm the adverse conditions at the sea floor probably related to anoxic-suboxic conditions. Environmental conditions were unfavourable for the development of calcareous nannoplankton also in the surface waters, as attested by the drop in absolute abundances. Furthermore, the deep photic zone seemed to have been particularly hostile to phytoplankton, as shown by the main decrease in the relative abundance of the deep-dwelling *M. jansae*, probably related to the sporadic upward migration of the anoxic zone in the water column (further attested by the presence of small pyrite framboids). Increasing values of Cu, U, Th, TS, TOC, and U aut., as well as the record of pyrite framboids < 5 μm size confirm anoxia (probably affecting the water column at any time). The First Occurrence of *Carinolithus superbus* in this section is recorded in the interval where geochemical signals indicate restricted oxygen conditions. This event also permits effective correlations with other Tethyan settings where the T-OAE has been recorded.

References

- HERMOSO, M., MINOLETTI, F., LE CALLONNEC, L., JENKYN, H.C., HESSELBO, S.P., RICKABY, R.E.M., RENARD, M., DE RAFAELIS, M. & EMMANUEL, L. 2009. Global and local forcing of Early Toarcian seawater chemistry: A comparative study of different paleoceanographic settings (Paris and Lusitanian basins). – *Paleoceanography* 24: PA4208.
- JENKYN, H.C. & CLAYTON, C.J. 1997. Lower Jurassic epicontinental carbonates and mudstones from England and Wales: chemostratigraphic signals and the early Toarcian anoxic event. – *Sedimentology* 44: 687–706.
- MATTIOLI, E., PITTET, B., PETITPIERRE, L. & MAILLIOT, S. 2009. Dramatic decrease of the pelagic carbonate production by nannoplankton across the Early Toarcian Anoxic Event (T-OAE). – *Global and Planetary Changes* 65: 134–145.

Preliminary report on the ammonite fauna and stratigraphy of the Beckeri Zone (Upper Kimmeridgian) of the southern Crimea (Ukraine)

MIKHAIL A. ROGOV

Geological Institute of RAS, Moscow, 119017, Russia; E-mail: russianjurassic@gmail.com

Upper Jurassic strata of Crimea (Ukraine) are mainly represented by shallow-water reef facies, characterized by significant thickness (up to few kilometers), complex tectonics, and rare ammonite records. Only recently Upper Kimmeridgian ammonite-bearing beds were discovered in the eastern Crimea (ARKADIEV & ROGOV 2006), while new records of microfossils suggested that this substage also could be recognized in the southern Crimea (ANIKEYEVA & ZHABINA 2009). A new section, containing rich ammonite assemblages of the uppermost Kimmeridgian, has been discovered recently between Chelebi and Foros mountains near to Foros settlement, southernmost Crimea by the amateur palaeontologist Aleksei Kudryavtsev. This section is represented by a folded marlstone succession with a total thickness ca. 30 m. Ammonites occur in abundance in the lowermost part of this section and become relatively uncommon upwards. Belemnites and bivalves are very rare. Terebratulid brachiopods are relatively numerous in the lowermost part of the section only (beds 59-66), but were not found above.

The following assemblages could be recognized, from youngest to oldest:

(1) Ataxioceratid ammonite, resembling *Lithacoceras*, and *Berckhemeria* sp. were collected from bed 15, suggesting an earliest Tithonian age.

(2) Beds 26-41 are characterized by ammonite assemblages consisting mainly of *Subplanites*-like microconchiate ataxioceratids or leiostrocan ammonites, belonging to the genera *Sowerbyceras*, *Haploceras*, and *Protetragonites*. At least two ataxioceratid-dominated and two leiostrocan-dominated assemblages could be recognized here. The age of these assemblages could not yet be determined precisely, but lies close to the Kimmeridgian-Tithonian boundary.

(3) Slightly below, in bed 44, *Neochetoceras* ex gr. *rebouletianum* (FONT.) and *Silicisphinctes* sp. were collected. These ammonites indicate

a latest Beckeri Zone age (~ *rebouletianum* horizon or closeby level).

(4) A rich ammonite assemblage has been collected from bed 59. It includes, along with phylloceratids (*Pseudophylloceras* and *Sowerbyceras*), a few *Ochetoceras semimutatum* (FONT.) and small-sized ataxioceratids resembling *Virgataxioceras minutum* (BERCKH.) This assemblage could be dated as belonging to the Setatum Subzone of the Beckeri Zone.

(5) Ammonites were most abundant (more than 100 specimens were collected) in bed 66. The ammonite assemblage is dominated by *Taramelliceras* cf. *compsum* (OPP.), which includes more than 70% of all ammonite records. In addition to this species *Sowerbyceras* are relatively common here, while other ammonites (*Euvirgalithacoceras* (?) *tantalus* (HERBICH) and indeterminate ataxioceratids, *Aulacostephanus* (*Aulacostephanoceras*) cf. *jasonoides* (PAVL.), *Pseudophylloceras* sp., *Sutneria* sp. etc.) are rare. This assemblage could belong to the uppermost Subeumela or Setatum Subzone of the Beckeri Zone.

(6) Beds 72-73 in the lowermost part of the succession are characterized by a nearly homogeneous ammonite assemblage dominated by *Sowerbyceras* and including also *Haploceras* (?) sp. and *Pseudophylloceras consanguineum* (GEMM.)

The studied succession is characterized by unique ammonite assemblages of the Beckeri Zone, which strongly differ from assemblages of this age known from other areas. Aspidoceratid ammonites are here absent or extremely rare (only one small-sized *Sutneria* was recorded), while *Taramelliceras* from bed 66 is more numerous compared with any other described Kimmeridgian assemblage.

This study has been supported by RFBR grant 12-05-00380 and Program of the Presidium of RAS no.28. I am also wish to thank ALEKSEI KUDRYAVTSEV and YURI ZHUKOV, who showed me the section, provided some specimens, and helped collecting the ammonites.

References

- ANIKEYEVA, O.V. & ZHABINA, N.M. 2009. Sedimentation conditions of the Upper Jurassic deposits in the Mountain Crimea, Yalta amphitheater. In: Fossil flora and fauna of Ukraine: paleoecological and stratigraphic aspects. – Proceedings of the Institute of Geological Sciences of the NAS of Ukraine: 99–103, Kyiv [in Ukrainian].
- ARKADEV, V.V. & ROGOV, M.A. 2006. New data on Upper Kimmeridgian–Tithonian biostratigraphy and ammonites of the Eastern Crimea. – Stratigraphy and Geological Correlation 14: 185–199.

Quantitative and qualitative aspects of changes in shell size through the evolution of Volgian ammonites in the Russian Sea: Cope's rule, Lilliput effect, dimorphism, and polymorphism

MIKHAIL A. ROGOV

Geological Institute of RAS, Moscow, 119017, Russia; E-mail: russianjurassic@gmail.com

Recent advances in studies of biodiversity changes and evolution of fossil lineages through time rarely considered quantitative changes in fossil populations. Investigations of changes in size through evolution are relatively common, but mainly focus on mass-extinction time-intervals and usually do not include observations on dimorphism and polymorphism. Here I am presenting a few examples of evolution of Volgian ammonite faunas in the Russian Sea, showing quantitative and qualitative aspects of changes in shell size.

(1) Cope's rule in the evolution of Volgian ammonites

The Volgian Stage is well-known as a time when giant ammonites were common, but rate and time of size increase differ significantly within lineages. Members of the Virgatitidae family, endemic to the Subboreal Russian and Polish seas, show a gradual increase in the size of macroconchs during the Early and Middle Volgian, while the size of microconchs remains nearly constant (see also below). Larger virgatitids (megaconchs *Virgatites giganteus* and *V. rosanovi*, attaining more than 0.5 m in diameter) are known from the Virgatus Zone of the Middle Volgian just before the extinction of this family. Nearly the same pattern in shell-size changes characterized the dorsoplanitid lineage, but it started later, because Lower Volgian dorsoplanitids were uncommon on the Russian Platform and only since the beginning of the Middle Volgian these ammonites became abundant. Occasionally, the same gradual increase in shell size was recognized within successive populations of the species (*Lomonossovella lomonosovi*; see MITTA 1993). The maximum diameter of megaconchs of *Epivirgatites* at the beginning of the Nikitini Chron was slightly less than 1 m, well comparable with the size of Portlandian giants of the same age. But the upper subzone of the Nikitini Zone was characterized by a strong

reduction in size of dorsoplanitid ammonites across the Arctic and extinction of nearly all genera. First craspeditid ammonites, belonging to three geographically separated subfamilies, all show a very small size at the end of the Middle Volgian and at the very beginning of the Late Volgian (ROGOV 2013). During the Late Volgian these ammonites show different patterns in shell-size evolution, and only their Valanginian and especially Hauterivian descendants show a size of macroconchs comparable with that of the Middle Volgian age.

(2) Miniaturisation in response to stress environments and Lilliput effect as post-extinction phenomenon

Volgian ammonite faunas show few miniaturization events of different nature. In the beginning of the Early Volgian, invasion of ammonites of Submediterranean origin (*Paralingulaticeras*) led to appearance of endemic species, which are characterized by smaller size (~1/2 the size of this genus in Submediterranean faunas) and absence of ventrolateral nodes, which are typical for late growth stages in typical *Paralingulaticeras*. Such a size decrease was accompanied by a high abundance of these ammonites (up to ~60% of all ammonite records; see ROGOV 2010). Other Submediterranean ammonites in the Lower Volgian are also usually relatively small-sized (*Neochetoceras*) or represented mainly by small-sized morphotypes (dwarf macroconchs of *Schaireria*). The miniaturization event in *Paralingulaticeras* and partially in other Submediterranean taxa strongly resembles the response of cardioceratid populations in untypical environments after their southwards immigration (MATYJA & WIERZBOWSKI 2000) and could be considered as stress-related phenomenon. Another type of miniaturization event occurred in the latest Middle Volgian just after extinction of giant megaconchs. At this time the oldest *Kachpurites*, dwarf descendants

of *Laugeites* (with shell diameter of mainly ~3 cm compared with at least 8-10 cm in microconchs of *Laugeites*) are blooming. At all known localities their shells form coquinas, consisting of hundreds of specimens, while other ammonites (the last relatively small-sized *Epivirgatites*) remain uncommon. These *Kachpurites* are also characterized by evolute coiling and relatively simple ribbing (mainly fine biplicate ribs and intercalatories) and do not reveal significant size dimorphism. It should be noted that miniaturization occurred within all Boreal lineages near to the Middle/Late Volgian transition, but it was not simultaneous in the various taxa. Such a remarkable post-extinction event is easily comparable with other simplification and dwarfism in ammonites, described by GUÉX (2001) as special response to enormous stress (for review see NEVO 2011), and as "Lilliput effect" (URBANEK 1993), because these small species also show high abundance but very low diversity. Significantly, just after its appearance the genus *Kachpurites* shows very fast evolution accompanied at some levels by a very high variability. During all the time when evolution of this genus (and of the descendant genus *Garniericeras*) was rapid, these ammonites dominated in all studied populations of the Russian Sea, usually accounting for up to 80-90% of all records. Nevertheless members of *Kachpurites* mainly remained small-sized during the early part of the Fulgens Chron and even among full-grown macroconchs commonly attained only 5-6 cm in diameter, while big macroconchs (20-25 cm) were very uncommon. In the latest part of the Late Volgian (Nodiger Chron) a higher evolutionary speed was typical of members of the other craspeditid subfamily (Craspeditinae), also accompanied by size decrease at the beginning. Late Volgian ammonite faunas of all Boreal regions with a rare exception (large-sized *Chetaites* at the end of the Volgian in Northern Siberia) consisted of ammonites which were much smaller than Middle Volgian ones (ROGOV 2013).

(3) Dimorphism and polymorphism in shell size of Volgian ammonites

Recognition of dimorphism and polymorphism as well as their interpretation met some problems in the Volgian ammonites, as they are mainly lacking any mature modifications. Thus micro- and macroconchs

are here used as morphological terms only. Lower and Middle Volgian dorsoplanitids and virgatitids usually show two or three separate size groups, while specimens of intermediate size are absent or very uncommon. Virgatitid microconchs have a shell diameter of usually between 8 and 15 cm and are characterized by nearly constant type of ribbing at the body chamber and phragmocone or by changes in the rib ratio. Macroconchs show biplicate ribbing or smoothing of sculpture on the outer whorls; they are usually less numerous than microconchs. Macroconchs are also uncommon within dorsoplanitids from the Panderi Zone, while in the overlying Virgatus Zone macroconchs of the genus *Dorsoplanites* dominate. Dorsoplanitids from the Middle Volgian Nikitin Zone are mainly characterized by three size morpho-groups (microconchs, macroconchs, and big macroconchs (megaconchs)). Three size groups are also very typical of the latest Middle to Late Volgian Garniericeratinae. It should be noted that early garniericeratins (*Kachpurites*) are represented by microconchs (~3-4 cm), small macroconchs (6-7 cm) and relatively rare large macroconchs (up to 20-25 cm); the small-large macroconch ratio changed significantly within different populations. *Garniericeras*, a late member of this subfamily, shows two size groups in nearly all assemblages (microconchs and small or large macroconchs). Interpretation of the discussed polymorphism in shell size includes developmental polymorphism sensu MATYJA (1986) and/or discrete adaptive norms (see NIGMATULLIN 2012 for example of DAN in modern cephalopods) coupled with possible sexual dimorphism.

This study has been supported by RFBR grant 12-05-00380 and Program of the Presidium of RAS no. 28.

References

- GUÉX, J. 2001. Environmental stress and atavism in ammonoid evolution. – *Eçlogæ Geologicae Helvetiae* 94: 321–328.
- MATYJA, B.A. 1986. Developmental polymorphism in Oxfordian ammonites. – *Acta Geologica Polonica* 36: 37–68.
- MATYJA, B.A. & WIERZBOWSKI, A. 2000. Biological response of ammonites to changing environmental conditions: an example of Boreal *Amoeboceras* invasions into Submediterranean Province during Late Oxfordian. – *Acta geologica Polonica* 50: 45–54.
- MITTA, V.V. 1993. Ammonites and zonal stratigraphy of the Middle Volgian deposits of Central Russia. 132 p.,

- Geoprognoz, Kiev. [in Russian]
- NEVO, E. 2011. Evolution under environmental stress at macro- and microscales. – *Genome Biology and Evolution* 3: 1039–1052.
- NIGMATULLIN, CH.M. 2012. Discrete adaptive norms of cephalopods: On an example of giant squid *Dosidiscus gigas* (Ommastrephidae) from the eastern Pacific Ocean. In: LEONOVA, T.B., BARSKOV, I.S. & MITTA, V.V. (eds.), Contributions to current cephalopod research: Morphology, systematics, evolution, ecology and biostratigraphy: 42–44, PIN RAS, Moscow. [in Russian with English summary]
- ROGOV, M.A. 2010. A precise ammonite biostratigraphy through the Kimmeridgian-Volgian boundary beds in the Gorodischi section (Middle Volga area, Russia), and the base of the Volgian Stage in its type area. – *Volumina Jurassica* 8: 103–130.
- ROGOV, M.A. 2013. The end-Jurassic extinction. *Extinction. Grzimek's Animal Life Encyclopedia*: 487–495, Cengage.
- URBANEK, A. 1993. Biotic crises in the history of Upper Silurian graptoloids: a palaeobiological model. – *Historical Biology* 7: 29–50.

New data on the Lower-Upper Kimmeridgian boundary beds of southern Tatarstan, Central Russia

MIKHAIL A. ROGOV¹ *, ANDRZEJ WIERZBOWSKI², ELENA V. SHCHEPETOVA¹ & HUBERT WIERZBOWSKI³

¹Geological Institute of RAS, Moscow, 119017, Russia; E-mail: russianjurassic@gmail.com

²Polish Geological Institute-National Research Institute, Warsaw, 00-975, Poland; E-mail: andrzej.wierzowski@pgi.gov.pl

³Geological Institute of Polish Academy of Sciences, Warsaw, Poland; E-mail: hwierzbo@twarda.pan.pl

*Corresponding author

The lowermost and uppermost Kimmeridgian deposits of Central Russia are relatively widely distributed and fairly well known, while Lower-Upper Kimmeridgian boundary beds are missing or strongly condensed in nearly all sections and were not investigated in detail so far. It should be noted that the position of the Lower-Upper Kimmeridgian boundary (the base of the Mutabilis Zone) in the Subboreal succession remains the matter of discussion during the last decades. Traditional definition of this boundary by FAD of *Aulacostephanoides* is widely accepted (MESEZHNIKOV 1984; HANTZPERGUE et al. 1997, 1998). Since the transition from *Rasenioides* to *Aulacostephanoides* (*Aulacostephanites*) is very gradual with co-occurrences of specimens with or without ventral rib interruption (cf. ARKELL & CALLOMON 1963; BIRKELUND et al. 1978), English authors have proposed the FAD of *Rasenioides* (i.e., the base of the Askeptia Subzone) as the marker of the base of the Mutabilis Zone (BIRKELUND et al. 1983). The latter definition of the Lower-Upper Kimmeridgian boundary is, however, unclear in those regions, where *Rasenioides* is rare or absent (i.e. the whole Arctic, Russian Platform etc.), whereas in the Submediterranean succession the boundary in question lies within the Hypselocyclum Zone (MATYJA & WIERZBOWSKI 2000). Here we follow the older definition of the Mutabilis Zone and its lower boundary by FAD of *Aulacostephanoides*.

Ammonites from the boundary of the Cymodoce and Mutabilis zones of the Russian Platform are generally poorly known. Only a few specimens of such ammonites were figured or mentioned since the end of the 19th century and the position of all these records within succession remains unclear. Moreover,

the presence of the Mutabilis Zone has been suggested based on a single historical record of the ammonite *Aspidoceras liparum* (= *A. lallierianum* (D'ORB.) in PAVLOW 1886: pl. 9, fig. 3).

During fieldwork in 2010 and 2011 we studied key sections of the Lower-Upper Kimmeridgian boundary beds, located at the Volga river bank close to the border between the Ulyanovsk Region and the Tatarstan Province of Russia. High cliffs at the right bank of the Volga river, located along a few kilometers from Mimei to Tarkhanovskaya Pristan (HANTZPERGUE et al. 1998), are consist mainly of the Kimmeridgian and only occasionally of underlying Middle Jurassic deposits. The Kimmeridgian succession is mainly represented by grey to light-grey calcareous silty clay with a total thickness of ca. 15 m with a well visible band of dark-grey to brown oil shales having TOC contents of up to 12.4%.

The following ammonite succession could be recognized here:

(1) *Crussoliceras* spp., *Rasenioides* spp., *Amoebites* cf. *modestum* (MESEZH. & ROMM). Remains of the same assemblage with *Crussoliceras* are known also from other areas of the Russian Platform (Kostroma, Kaluga, and Moscow regions). In the Tver region (BUEV 2012) *Amoebites kitchini* (SALE.), *Rasenioides* (*Semirasenia*) *discooides* HANTZ. and *Aspidoceras binodum* (OPP.) are also found in this assemblage. The assemblage could be distinguished as the *lacertosum* horizon after the most common microconchiate species of *Crussoliceras*. Co-occurrence of Boreal, Subboreal, and Submediterranean ammonites allows correlation of this unit with the Divisum

Zone of the Submediterranean succession, the *discoides* horizon of the Subboreal Cymodoce Zone, and the Boreal Kitchini Subzone.

(2) *Amoebites* sp. nov. (*beaugrandi* auct. non SAUVAGE, 1871), *Aulacostephanoides* spp., dominated by small-sized coarsely-ribbed *Amoebites*. It roughly corresponds to "faunas" with *Amoebites* aff. *beaugrandi* of East Greenland and Spitsbergen in the Modestum Subzone of the Kitchini Zone. Unfortunately, aulacostephanid ammonites collected along with *Amoebites* are mainly represented by fragmentary preserved juveniles and their precise identification is difficult. Nevertheless, the presence of a well developed smooth band at the venter of these ammonites confirms their identification as *Aulacostephanoides*, typical of the Mutabilis Subzone of the Mutabilis Zone.

(3) Slightly above the unit with coarse-ribbed *Amoebites*, a single specimen of *Zenostephanus sachsi* (MESEZHNIKOV) has been found. This species is typical of the sachsi horizon of Spitsbergen and Franz-Josef Land and perhaps it occurs at nearly the same level in East Greenland (cf. SYKES & SURLYK 1976: fig. 7A).

(4) Overlying light-grey to grey clays (uppermost 2.8 m of clayey unit) and brownish oil shales are characterized by a nearly homogeneous ammonite assemblage, consisting of *Aulacostephanoides* sp. and aspidoceratids, accompanied by poorly preserved cardioceratid microconchs. This assemblage also belongs to the Mutabilis Subzone.

(5) The presence of *Orthaspidoceras liparum* (OPPEL) and *O. lallierianum* (D'ORB.) above the oil shales marks the base of the uppermost subzone of the Mutabilis Zone (Lallierianum Subzone) and its basal *lallierianum* horizon. The uppermost horizon of this subzone (*schilleri* horizon) is unknown from the Russian Platform.

This study has been supported by RFBR grant 12-05-00380, the Program of the Presidium of RAS no.28, and the Polish Ministry of Science and Higher Education (grant no. N N307 036537).

References

- ARKELL, W.J. & CALLOMON, J.H. 1963. Lower Kimmeridgian ammonites from the drift of Lincolnshire. – *Paleontology* 6: 216–245.
- BIRKELUND, T. & CALLOMON, J.H. 1985. The Kimmeridgian ammonite faunas of Milne Land, central East Greenland. – *Grønlands Geologiske Undersøgelse Bulletin* 153: 5–56.
- BIRKELUND, T., CALLOMON, J.H., CLAUSEN, C.K., NØHR HANSEN, H. & SALINAS, I. 1983. The Lower Kimmeridge Clay at Westbury, Wiltshire, England. – *Proceedings of the Geologists' Association* 94: 289–309.
- BIRKELUND, T., THUSU, B. & VIRGAN, J. 1978. Jurassic-Cretaceous biostratigraphy of Norway, with comments of the British Rasenia cymodoce Zone. – *Palaeontology* 21: 32–63.
- BUEV, D.V. 2012. Rare Kimmeridgian ammonites from the poorly studied section located in Tver region. In: *Palaeontology and evolution of the biodiversity in the Earth history (in museum context)*. – *Collection of scientific articles*: 119–124, GEOS, Moscow.
- HANTZPERGUE, P., ATROPS, F. & ENAY, R. 1997. Kimméridgien. In: *Biostratigraphie du Jurassique Ouest-Européen et Méditerranéen*. – *Bulletin du Centre de Recherche Elf Exploration Production* 17: 87–96.
- HANTZPERGUE, P., BAUDIN, F., MITTA, V., OLFERIEV, A. & ZAKHAROV, V. 1998. The Upper Jurassic of the Volga basin: ammonite biostratigraphy and occurrence of organic-carbon rich facies. Correlations between boreal-subboreal and submediterranean provinces. In: CRASQUIN-SOLEAU, S. & BARRIER, E. (eds.), *Peri-Tethys Memoir 4: Epicratonic basins of Peri-Tethyan platforms*. – *Mémoires du Muséum national d'histoire naturelle* 179: 9–33.
- MATYJA, B.A. & WIERZBOWSKI, A. 2000. Biostratigraphical correlation between the Subboreal Mutabilis Zone, and the Submediterranean upper Hypselocyclum – Divisum zones of the Kimmeridgian. In: HALL, R.L. & SMITH, P.L. (eds.), *Advances in Jurassic Research 2000*. – *GeoResearch Forum* 6: 129–136.
- MESEZHNIKOV, M.S. 1984. Kimmeridgian and Volgian stages of the North of the USSR. 224 p., Nedra, Leningrad [in Russian].
- PAVLOW, A.P. 1886. Les ammonites de la zone à *Aspidoceras acanthicum* de l'est de la Russie. – *Mémoires du Comité Géologique II* (3): 1–91. [in Russian]
- SYKES, R.M. & SURLYK, F. 1976. A revised ammonite zonation of the Boreal Oxfordian and its application in northeast Greenland. – *Lethaia* 9: 421–436.

***Distichoceras bicostatum* (STAHL) (Ammonoidea) from Kutch, western India; its stratigraphic and palaeoecological significance**

PINAKI ROY

Department of Geology, Durgapur Government College, Durgapur – 713214, West Bengal, India

Distichoceras bicostatum (STAHL) has been redescribed including SPATH's (1927-33) form and additional topotype. Following PALFRAMAN (1967) the taxon has been designated as a macroconchiate form. In Kutch, *D. bicostatum* occurs in the Lamberti Zone, more precisely in the uppermost white limestone bed of Upper Callovian age. Wide palaeogeographic occurrence and short temporal distribution of the species make it a useful tool for interregional stratigraphic correlation. Comparing the mode of occurrence of the Kutch species with

worldwide patterns as well as morphometric analysis imply a probable nektobenthic shallow-water mode of life of the present species.

References

SPATH, L.F. 1927-1933. Revision of the Jurassic cephalopod fauna of Kachh (Cutch). Parts I-VI. – Memoirs of the Geological Survey of India, Palaeontologia Indica, new series 9, Calcutta, 2: part I, 1-71, pls. 1-7 [1927]; part II, 72-161, pls. 8-19 [1928a]; part III, 162-278, pls. 20-47 [1928b]; part IV, 279-550, pls. 48-102 [1931a]; part V, 551-658, pls. 103-124 [1931b]; part VI, 659-945, pls. 125-130 [1933].

Integrated biostratigraphy across the Aalenian/Bajocian boundary of the Central High Atlas, Morocco

DRISS SADKI

Department of Geology, Faculty of Science, BP. 11201 Zitoune, Meknes, Morocco; Email: driss.sadki@gmail.com

The Rich area, situated in the center of the basin of the High Moroccan Atlas, presents a thick Aalenian–Bajocian succession with continuous marine sedimentation, which offers a rich and varied fauna. This section was proposed as a submediterranean auxiliary stratotype for the boundary between Aalenian and Bajocian (SADKI 1994). An integrated biostratigraphic analysis of this section is proposed from the distribution of the main palaeontological groups: ammonites, belemnites, brachiopods, bivalves, gastropods, calcareous nannofossils, foraminifera, and ostracods. This integrated biostratigraphy enables us to establish parallel scales, to serve as a comparison tool, but mostly it is an element of dating when ammonites are rare or absent.

Ammonites. – The succession of ammonite faunas of the Aalenean-Bajocian boundary interval shows six successive assemblages (SADKI & ELMÍ 1991), occasionally dominated by NW European graphoceratids, occasionally by taxa of the Mediterranean Province which also enables good correlations. This succession allows to identify different biohorizons that characterize the transition between the Aalenian and Bajocian in the Moroccan Central High Atlas (SADKI 1994). The boundary between the two stages is marked by the first appearance of *Hyperlioceras* together with numerous mediterranean elements.

Belemnites. – Belemnites are very rare, occasionally absent in the Concavum Zone and at the base of the Discites Zone. They become abundant and diverse from the top of the Discites Zone onwards where we can identify *Holcobelus*.

Brachiopods. – The Rich area has yielded Aaleno-Bajocian brachiopods, mainly zeilleriids, in marly layers. The biostratigraphic succession (SADKI & ALMÉRAS 1992), shows a faunal break between the Concavum and Discites zones. Both zones are characterized by the predominance

of zeilleriids that are comparatively close to *Rugitela hughesi* (DAVIDSON). This species is accompanied in the Concavum Zone by only a few specimens of *Lophrothyris contracta* BUCKMAN, *Acanthothyris oligocantha* BRANCO, *A. tenuispina* WAAGEN, and a shell of the genus *Loboidothyris* BUCKMAN. Apart from *Rugitela* cf. *hughesi*, also very rare in the basal part of the Bajocian, and a *Zeilleria* sp., no other brachiopods have been collected from the Discites Zone.

Bivalves. – The bivalve taxa, identified by ISTVAN SZENTE (University of Budapest, Hungary) from the Rich section, are dominated by *Palaeonucula*, indicating soft substrate and poorly oxygenated waters. Other burrowing forms such as *Trigonia*, *Astarte*, and *Nicaniella* occur only sporadically, appearing mainly in the Concavum Zone together with the supposedly pseudo-planktonic *Bositra*. These are remarkably abundant at the top of the Concavum Zone. In the Discites zone, a rare *Palaeneilo* sp. and *Grammatodon* sp. occur.

Gastropods. – Gastropods, analysed by CONTI & MONARI (2001), show an inverse distribution to that of bivalves. Their density and their diversity gradually increase up-section. In the Graphoceras concavum Biozone, we can identify *Amphitrochus abbas* (HUDLESTON), *?Discohelix subaequalis* (D'ORBIGNY), *Eucyclus ornatus* (SOWERBY), *Eucycloidea (Pseudalaria)?* cf. *etheridgii* (TAWNEY), and *Sadkia richens* (CONTI & MONARI). In the Hyperlioceras discites Biozone, we find *Amphitrochus abbas* (HUDLESTON), *Eucyclus ornatus* (SOWERBY), *Eucycloidea (Pseudalaria)? subangulata* (MÜNSTER), *Eucycloidea (Pseudalaria)?* cf. *etheridgii* (TAWNEY), *Sadkia richens* (CONTI & MONARI) and *Rhynchocerithium?* sp.

Calcareous nannofossils. – Several biohorizons of calcareous nannofossils at the Aalenian–Bajocian boundary were identified by DE KAENEL (1990) and were correlated with the ammonite zones established by SADKI et

al. (1986). The most striking pattern of events is the great number of first occurrences in the vicinity of the Aalenian–Bajocian boundary. The new occurrences are mainly species of the genus *Watznaueria*, which experienced a major diversification at that time. In this interval, several new species of *Watznaueria* make their appearance: *W. manivita*, *W. frequens* at the base of Concavum zone and *W. barnesae*, and *W. britannica* in the Discites zone.

Foraminifera and ostracods. – Foraminifera and ostracods consist of associations, generally known from the Toarcian. The major microfauna renewal is located at the Aalenian–Bajocian boundary with the disappearance of *Lenticulina orbigny*, *L. chicheryi*, *Nodosaria pulchra* and the appearance of *Lenticulina quenstedti*, *L. galeata*, and *Garantella stellata*. This association marks the Biozone B1 of the Discites Zone (AMHOUD & BOUTAKIOUT 1994).

Ostracods abound with *Kinkelinella* gr. *sermoisensis* which disappears at the end of the Aalenian.

References

AMHOUD, H. & BOUTAKIOUT, M. 1994. Les foraminifères de l'Aalénien-Bajocien inférieur dans la localité Rich-

Gourrama (Haut Atlas central; Maroc). – *Miscellanea del Servizio Geologico Nazionale de Roma* 5: 243–248.

CONTI, M.A. & MONARI, S. 2001. Middle Jurassic gastropods from the Central High Atlas, Morocco. – *Geobios* 34: 183–214.

DE KAENEL, E. 1990. Etudes biostratigraphiques fondées sur les nannofossiles calcaires. Deuxième partie: Nannofossiles calcaires du Jurassique des marges Sud et Nord de la Téthys (marge Sud: Haut-Atlas, Maroc; marge Nord: Jura, Suisse). Thèse Université de Neuchâtel, 318 p.

SADKI, D. 1994. Proposition de la région de Rich (Haut-Atlas central marocain) comme stratotype auxiliaire subméditerranéen pour la limite Aalénien-Bajocien. – *Geobios* M.S. 17: 431–440.

SADKI, D. & ALMERAS, S. 1992. Les brachiopodes aalénobajociens de la région de Rich (Haut-Atlas central, Maroc): implications biostratigraphiques et paléocologiques. – *Cahiers Université Catholique Lyon, Série Sciences* 5: 93–105.

SADKI, D. & ELMi, S. 1991. Fluctuations de la composition des peuplements d'Ammonoides en relation avec la dynamique sédimentaire au passage Aalénien-Bajocien dans le Haut-Atlas central marocain. In: MORTON, N. (ed.), *Proceedings of Conference on Aalenian and Bajocian Stratigraphy, Isle of Skye, Scotland*: 113–122.

SADKI, D., IBNOUSSINA, M. & MOUTERDE, R. 1986. Biostratigraphie des ammonites de l'Aalénien et du Bajocien inférieur dans le Haut-Atlas central (Maroc). PICG-UNESCO, 185, Marrakech 1985. – *Revue de la Faculté des Sciences de Marrakech, N.S.* 2: 443–462.

Middle Jurassic coral biohermal limestones from pelagic carbonate platforms (Pieniny Klippen Basin, Western Carpathians)

JÁN SCHLÖGL¹ *, ADAM TOMAŠOVÝCH², DARIA IVANOVA³, BERNARD LATHUILIÈRE⁴, LOIC VILLIER⁵ & MARIÁN GOLEJ²

¹*Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynska dolina, 842 15 Bratislava, Slovakia; E-mail: schlogl@nic.fns.uniba.sk*

²*Geological Institute, Slovak Academy of Sciences, Dúbravská cesta 9, SK-840 05 Bratislava, Slovakia; E-mail: geoltoma@savba.sk, geolmgol@savba.sk*

³*Department of Paleontology, Stratigraphy & Sedimentology, Geological Institute, Bulgarian Academy of Sciences 24, Acad. G. Bonchev Str., 1113 Sofia, Bulgaria; E-mail: dariaiiv@geology.bas.bg*

⁴*UMR Georessources n°7359 Université de Lorraine, Campus Aiguillettes- BP 70239, F 54506 Vandoeuvre lès Nancy Cedex, France; E-mail: bernard.lathuiliere@univ-lorraine.fr*

⁵*UMR CNRS 7207, Centre de recherche sur la paléobiodiversité et les paléoenvironnements, Université Pierre et Marie Curie, T.46-56, 5e étage, case 104, 4, place Jussieu, 75252 Paris cedex 05, France; E-mail: loic.villier@upmc.fr*

**Corresponding author*

Unique, several decametres-thick coral reefs (Vrsatec Formation) that developed on the Czorsztyn pelagic carbonate platform (eastern part of the Pieniny Klippen Belt – PKB, Western Carpathians) in the Penninic Ocean were assigned to the Oxfordian by MIŠÍK (1979), KOCHANOVA (1979), SIBLIK (1979), and MORYCOWA & MIŠÍK (2005) on the basis of their bivalve and coral fauna. SCHLÖGL et al. (2006) revised the local stratigraphic succession and argued that these reefs are of Bajocian age on the basis of ammonites and on the basis of a complete re-interpretation of the stratigraphic superposition. MORYCOWA & OLXZEWSKA (2013) recently suggested that foraminifera point to a Late Jurassic age. Here, we integrate our own field data and focus on multiple taxa to shed more light on the age controversy and to assess depositional conditions and the palaeoecology of the coral-reef communities.

Both Bajocian and Oxfordian coral reefs were widespread in epicontinental seas rimming the northern and southern margins of the Tethys (LEINFELDER et al. 2002). However, the development of coral reefs on the Czorsztyn Ridge either during the Bajocian or during the Oxfordian is rather surprising. First, Bajocian coral reefs were not reported from pelagic carbonate platforms in the Tethys, and any new occurrences will thus be informative about coral-reefecology in such environments. Second, Oxfordian deposits in the Pieniny Klippen Belt,

Central Western Carpathians, and Eastern Alps record the maximum relative sea-level rise. Radiolarites were deposited in troughs, and sedimentation was condensed on the shallow elevations: all Oxfordian facies indicate aphotic conditions.

The Vrsatec Formation is formed by white and pinkish biohermal coral framestones, bindstones, and rudstones, locally with bivalves, gastropods, nautiloids, brachiopods, decapods, holothurians, crinoid, ophiuroid, and echinoid ossicles, and calcareous sponges. In addition to reef constructors, the benthic communities are clearly dominated by species-rich bivalve assemblages. Brachiopods are rather rare and of low diversity (mainly represented by the genus *Parvirhynchia*). Coral reefs were horizontally replaced by (1) breccias that accumulate at footwall margins of faulted blocks (with clasts formed by biohermal limestones) and by (2) crinoidal limestones. Peri-biohermal breccias do not represent fore reef wave-exposed rubble but are comparable to scarp breccia (AUBRECHT & SZULC 2006). The deposition of biohermal limestones was replaced by crinoidal-spiculitic limestones on shallow pelagic carbonate platforms. The thickness of the Vrsatec Formation varies from few metres to more than 70 m.

The Bajocian age of the biohermal limestones is supported by ammonites, brachiopods, and benthic foraminifers that occur within and

above the Vrsatec Formation. Dykes and breccia interspaces within the biohermal limestones are locally filled with *Bositra buchi* concentrations and contain common specimens of the ammonite *Nannolytoceras tripartitum*, with a stratigraphic range from the Late Bajocian (*G. garantiana* and *P. parkinsoni* zones) to the Early Bathonian and early Middle Bathonian. Stratigraphic termination of coral-reef limestones is marked by abundant borings and ferruginous coatings that imply condensation and by abrupt replacement with cross-bedded crinoidal-spiculitic limestones. These crinoidal-spiculitic limestones contain unequivocal Middle Jurassic brachiopods (*Apringia*, *Stolmorhynchia*). The upper boundary of crinoidal limestones never extends beyond the Late Bajocian (*G. garantiana* Zone) in the Pieniny Klippen Belt. The Vrsatec Limestone thus clearly pre-dates the *G. garantiana* Zone.

The lower boundary of the Vrsatec Formation is poorly constrained but it should post-date the termination of siliciclastic-rich sedimentation on the Czorsztyn Ridge during the *H. discites* Zone. It can be either coeval with a significant hiatus at the basis of the crinoidal limestones (lowermost Bajocian – *W. laeviuscula* and *S. propinquans* zones) or with the lowermost part of the crinoidal limestones (*S. propinquans* Zone).

Assemblages of benthic foraminifera found in the Vrsatec Formation are diverse and contain species of genera with hyaline wall (*Spirillina*, *Tethysiella*, *Paalzowella*, *Hungarillina*, *Radiospirillina*, *Lenticulina*, and *Nodosariidae*), dark microgranular wall (*Troglotella*, *Earlandia*, *Glomospira*, *Planiinvoluta*), porcelanous wall (*Nubecularia*, *Labalina*, *Ophthalmidium*, *Cornuspira*), agglutinated wall (*Trochammina*, *Verneuilinoides*, *Textularia*, *Valvulina*, *Ammobaculites*) and aragonitic wall (*Epistomina* and *Trocholina*). Such taxonomic composition and diversity is comparable to assemblages from the Bajocian of the Jura Mountains and Burgundy only. *Ophthalmidium obscurum*, *O. terquemi*, *Labalina rawiensis*, and *Hungarillina media* appear for the first time in the Bajocian, and the first three species are restricted to the Bajocian-Bathonian.

The coral assemblages were described by MORYCOWA & MIŠÍK (2005). We re-assess the composition of coral assemblages on the basis of new and extensive sampling. The most abundant

genera are *Isastrea*, *Periseris*, *Thecosmilia*, *Cladophyllia*, *Dendraraea*, and *Thamnasteria*. Such a coral assemblage is quite typical of the Lower Bajocian reefs of France, Luxembourg, and Switzerland (LATHUILIÈRE 2000a, b). Five of these genera are also common in the Oxfordian, especially from higher-latitude reefs, but they are represented by morphologically similar but different species in the Bajocian and Oxfordian. *Periseris* does not occur in the Upper Jurassic. MORYCOWA & MIŠÍK (2005) also describe the genus *Atelophyllia* on the basis of two fragments. We confirm the identification of this genus that was known from the Lower Bajocian of France only. *Dendraraea dendroidea* also implies a Bajocian age (LATHUILIÈRE & GILL 1998). The Bajocian age also explains the absence of some coral taxa that are generally very abundant in Oxfordian reefs.

This research was supported by grants APVV 0644-10, APVV 0248-07 and VEGA 2/0068/11.

References

- AUBRECHT, R. & SZULC, J. 2006. Deciphering of the complex depositional and diagenetic history of a scarp limestone breccia (Middle Jurassic Krasin Breccia, Pieniny Klippen Belt, Western Carpathians). – *Sedimentary Geology* 186: 265–281.
- KOCHANOVÁ, M. 1979. Die Bivalven des Jura der Vršatec-Klippe. *Západné Karpaty, Paleontológia* 4: 7–34.
- LATHUILIÈRE, B. 2000a. Coraux constructeurs du Bajocien inférieur de France, 1ère partie. – *Geobios* 33: 51–72.
- LATHUILIÈRE, B. 2000b. Coraux constructeurs du Bajocien inférieur de France, 2ème partie. – *Geobios* 33: 153–181.
- LATHUILIÈRE, B. & GILL, G.A. 1998. *Dendraraea* corail scléactiniaire branchu jurassique: structure, systématique, écologie. – *Palaeontographica A* 248: 145–162.
- LEINFELDER, R.R., SCHMID, D.U., NOSE, M. & WERNER, W. 2002. Jurassic reef patterns. The expression of a changing globe. – *Society of Economic Paleontologists and Mineralogists, Special Publication* 72: 465–520.
- MIŠÍK, M. 1979. Sedimentological and mikrofacial study in the Jurassic of the Vrsatec (castle) klippe (neptunic dykes, Oxfordian bioherm limestones). *Západné Karpaty, Geológia* 5: 7–56. [in Slovak with English summary]
- MORYCOWA, E. & MIŠÍK, M. 2005. Upper Jurassic shallow-water scleractinian corals from the Pieniny Klippen Belt (Western Carpathians, Slovakia). – *Geologica Carpathica* 56: 415–432.
- MORYCOWA, E. & OLSZEWSKA, B. 2013. Foraminiferal assemblage in the coral-bearing limestones of the Vrsatec area (Pieniny Klippen Belt, Western Carpathians, Slovakia). – *Geologica Carpathica* 64: 63–69.
- SIBLÍK, M. 1979. Brachiopods of the Vršatec Castle Klippen (Bajocian – ?Berriasian) near Ilava (Slovakia). *Západné Karpaty, Paleontológia* 4: 35–64.

Distribution of the Jurassic Pectinoida and Ostreoida from the Tanggula Mountains, China: Biogeographic relations and importance of trans-Pacific migration and the Hispanic Corridor

JINGENG SHA¹ * & PAUL L. SMITH²

¹*Nanjing Institute of Geology and Palaeontology, Academia Sinica, 39 East Beijing Road, Nanjing 210008, China; E-mail: jgsha@nigpas.ac.cn*

²*Department of Earth, Ocean and Atmospheric Sciences, the University of British Columbia, 2207 Main Mall, Vancouver, B.C. V6T 1Z4, Canada; E-mail: psmith@eos.ubc.ca*

*Corresponding author

During the Jurassic, the wedge-shaped Tethys Ocean opened eastward to the west Pacific, connecting to the northwest and southwest Pacific faunal provinces. At various times beginning in the Early Jurassic it also connected westwards to the east Pacific through the Hispanic Corridor, an equatorial seaway along the junction of North and South America (SMITH & TIPPER 1986; DAMBORENEA 2000; ABERHAN 2001; SHA 2001/2002). To the northwest, the Tethys also was linked to the epicontinental seas of northwestern Europe which in turn connected to the Arctic sea via the Viking Corridor, again beginning in the Early Jurassic (HALLAM 1977, 1994). Towards the southeast, beginning in the Tithonian, it communicated with the south Pacific through the Southern Andes-East Africa seaway (HALLAM 1983, 1994). The Tanggula Mountains were situated at the northern margin of the eastern Tethys near the junction of the northern Tethys and northwestern Pacific. This is a key position, critical to our understanding of dispersal between the major oceans of the Jurassic globe.

In the main ridge of the Tanggula Mountains of west China, there are abundant Bajocian-Tithonian Pectinoida (SHA et al. 1998) and Ostreoida (SHA et al. 2002) consisting of 12 genera and 21 species. The temporal and spatial distribution of these freely migrating bivalves demonstrates that (1) the Mid-Late Jurassic pectinid and ostreid fauna in northeastern Tethys is most similar to that of northwestern Europe and similar to that of the Indian Plate. Some species originated in the east Pacific during the Early Jurassic. The fauna is little

related to that of Tanggula's neighbour, the northwest Pacific; (2) some species crossed the Pacific from east to west and the Tethys ocean from north to south; (3) the Hispanic Corridor played an important role in connecting Pacific with Tethyan bivalve faunal provinces from the earliest Jurassic onwards.

References

- ABERHAN, M. 2001. Bivalve palaeobiogeography and the Hispanic Corridor: time of opening and effectiveness of a proto-Atlantic seaway. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 165: 375–394.
- DAMBORENEA, S.E. 2000. Hispanic Corridor: Its evolution and biogeography of bivalve molluscs. – *GeoResearch Forum* 6: 369–380.
- HALLAM, A. 1977. Biogeographic evidence bearing on the creation of Atlantic seaways in the Jurassic. – *Milwaukee Public Museum Special Publication, Biology and Geology* 2: 23–34.
- HALLAM, A. 1983. Early and Mid-Jurassic molluscan biogeography and the establishment of the central Atlantic seaway. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 43: 181–193.
- HALLAM, A. 1994. *An outline of Phanerozoic biogeography*. 246 p., Oxford University Press, Oxford.
- SHA, JINGENG 2001/2002. Hispanic Corridor formed as early as Hettangian: On the basis of bivalve fossils. – *Science Bulletin* 46: 1821–1824 (2001, in Chinese); 47: 414–417 (2002, in English).
- SHA, JINGENG, FÜRSICH, F.T., SMITH, P.L. & WANG, LIJUN 1998. Jurassic Palaeotaxodonta, Pteriomorpha and Isofilibranchia (Bivalvia) of the main ridge of the Tanggula Mountains. – *Beringeria* 21: 3–55.
- SHA, JINGENG, SMITH, P.L. & FÜRSICH, F.T. 2002. New Jurassic Ostreoida (Bivalvia) from China (Tanggula Mountains, Qinghai–Xizang Plateau) and their paleobiogeographic context. – *Journal of Paleontology* 76: 431–446.
- SMITH, P.L. & TIPPER, H.W. 1986. Plate tectonics and paleobiogeography: Early Jurassic (Pliensbachian) endemism and diversity. – *Palaios* 1: 1–14

Palaeobiogeography and evolution of Kutch Virgatospinctinae

SABYASACHI SHOME¹ * & SUBHENDU BARDHAN²

¹Palaeontology Division - I, Geological Survey of India, Central Headquarters, Kolkata 700016, India; E-mail: sabyasachi60@gmail.com

²Department of Geological Sciences, Jadavpur University, Kolkata 700032, India; E-mail: sbardhan12@gmail.com

*Corresponding author

Due to regional uplift since the Late Oxfordian-Early Kimmeridgian the Kutch Basin became progressively shallow and the palaeo-shoreline showed rapid fluctuation and steadily receded towards west. During Oxfordian time the mainland represented the deeper part of the basin while the palaeo-shoreline went up to the Kantkote region of eastern Kutch. Diosa oolite was the dominant motif of the off-shore mainland, while nearshore the Kantkote sandstone dominated the shallow waters of eastern Kutch.

Ammonite distribution was more or less homogeneous. Within the perisphinctiins, *Discosphinctes* was dominant in both region, but *Ataxioceras* appeared first in the Kantkote sandstone of eastern Kutch. Next ammonite-bearing horizons were encountered at Bharodia – west of Kantkote of Upper Oxfordian age (FÜRSICH & PANDEY 2003). *Torquatisphinctes* made its first appearance along with older *Ataxioceras* and *Discosphinctes* in Upper Oxfordian to Upper Kimmeridgian Bharodia beds (SPATH 1931; FÜRSICH & PANDEY 2003) but the typical Kimmeridgian fauna of mainland, i.e. the *Katroliceras-Pachysphinctes* group is totally absent. The typical Lower to Middle Oxfordian mayatiins, present in the Kantkote sandstone and throughout the mainland of Kutch also did not continue here. Thus the age of the Bharodia ammonite bed may be locally assigned only to the Late to latest Oxfordian. It appears that the origin of *Torquatisphinctes* is very cryptic and that the genus evolved in a restricted area (nearshore eastern Kutch). In Bharodia, the only specimen recorded is fragmentary and incomplete. It is very difficult to identify the evolved *Torquatisphinctes* in septate specimens. The evolutionary novelties i.e., virgatome trifurcation, longer secondaries, etc. only appear on the later part of the chamber.

During Kimmeridgian time, the eastern sea of Kutch became shallower (BISWAS 1977; DESHPANDE & MERH 1980; RUDRA et al. 2007). This posed a problem for the survival of the stenohaline ammonites. The only Bharodia genus which successfully invaded the mainland of Kutch is *Torquatisphinctes*. The first occurrence of *Torquatisphinctes* in the mainland comes from the Lower Katrol horizons at Jurun (Jawahar Nagar) area which were assigned as Lower Kimmeridgian on the basis of belemnites (SPATH 1931). Two *Torquatisphinctes* species i.e., *T. jurunensis* and *T. alterniplicatus*, have been reported from here.

During the Middle Kimmeridgian the shoreline further shifted towards west. *Torquatisphinctes* community not only migrated but also quickly speciated to produce different genera such as *Katroliceras* and *Pachysphinctes* in a restricted locality on Kutch mainland, i.e. in Ler and adjoining areas. Although *Torquatisphinctes* lived side by side with these forms for a considerable stratigraphic span, the Middle Kimmeridgian is actually dominated by both *Katroliceras* and *Pachysphinctes*. Thereafter *Torquatisphinctes* was excluded from Kutch or rather Indo-Madagascar areas.

Katroliceras and *Pachysphinctes*, although morphologically quite distinct, overlapped both temporally and spatially in Kutch. So, it is very difficult to establish the correct evolutionary plexus. The ontogenetic study of adult *Pachysphinctes* reveals that *Katroliceras* is nothing but a form which retained the intermediate stage of it in its genetic spectrum. It appears, therefore, that *Torquatisphinctes* first gave rise to *Katroliceras* which soon produced *Pachysphinctes*. Evolution took place within the Early Kimmeridgian *Alterneplicatus* Zone of KRISHNA & PATHAK (1993), which according to them is equivalent to the Divisum Zone of Europe.

The evolution is very much compatible with the punctuation model involving macroevolution.

The *Katrolicer*-*Pachysphinctes* association lasted throughout the Middle and Late Kimmeridgian in Kutch. Both are represented by single species (SHOME 2009) which faced steep inter-specific competition. The great intra-specific variability of each species might be due to ecological displacement. One of the most dominant trends of character displacement is the contrast in body size. *Pachysphinctes* is the hypermorphic giant, while *Katrolicer* shows a declining body size up-section. *Pachysphinctes*, however, went extinct perhaps at the end of the Kimmeridgian while the ancestral *Katrolicer* species gave rise to the still smaller descendant *K. pottingeri*. KRISHNA & PATHAK (1993) indicated that it continued up to the Early Tithonian. The subsequent history of *Katrolicer* is obscured in the eastern part of the mainland since the younger sediments are sparsely fossiliferous.

The Tithonian succession is well exposed at the western fringe of the mainland of Kutch. Lower Cretaceous sediments with occasional fossiliferous (mostly bivalve) bands overlying the Tithonian strata are restricted to this region. It is evident that the sea further receded and the shoreline existed only in this part of Kutch before final withdrawal from the Kutch Basin during Aptian time (BISWAS 1991; RUDRA & BARDHAN 2006).

The most dominant Tithonian ammonite assemblage is characterized by *Virgatosphinctes denseplicatus*. It occurs in two distinct associations found at different localities. The Sahera-Moondan area, which is stratigraphically older than the Lakhapar section, contains only *Virgatosphinctes denseplicatus*. *Virgatosphinctes denseplicatus* in the Lakhapar section has the same population structure as in typical Late Tithonian assemblages (SHOME et al. 2004; SHOME & ROY 2006; SHOME & BARDHAN 2009). *Virgatosphinctes* has an almost circumglobal distribution and is found in many places spanning the entire Tithonian (VERMA & WESTERMANN 1972). Many workers described *Virgatosphinctes denseplicatus* even from Lower Tithonian horizons of different region. Therefore, it appears that the monotypic assemblage of the Sahera-Moondan section belongs to the Lower Tithonian. However, the evolution of *Virgatosphinctes* and its

place of origin are not very clear. Within the *Virgatosphinctinae*, *Virgatosphinctes* is not only the end member of the spectrum, it is the largest and most complex in terms of ornamentation. Virgatotome, fasciculate ribbing pattern, which appeared in the late phragmocone stage of *Pachysphinctes*, has been recapitulated in the early ontogeny of *Virgatosphinctes*. Nowhere these two taxa stratigraphically and geographically intergrade, but in many places *Virgatosphinctes* appears in horizons overlying *Pachysphinctes*-bearing beds. Once originated *Virgatosphinctes* immediately spread to many places. In most of the areas the genus is represented by *Virgatosphinctes denseplicatus* which shows less intraspecific variation than the Kutch population. In Kutch and some adjoining areas it continued up to the Late Tithonian. At the Jurassic-Cretaceous boundary the *Virgatosphinctes* lineage was terminated similar to many other ammonites that went extinct arguably during a mass extinction at the Jurassic-Cretaceous boundary. Appearance of virgatotome ribbing, which CALLOMON (1981) described as evolutionary innovation per excellence, lost its genetic uniqueness and never appeared in the Cretaceous ammonites.

References

- BISWAS, S.K. 1977. Mesozoic rock-stratigraphy of Kutch. - Quarterly Journal of the Geological Mining and Metallurgical Society of India 49 (3 & 4): 1-52.
- BISWAS, S.K. 1991. Stratigraphy and sedimentary evolution of the Mesozoic basin of Kutch, Western India, pp. In: TANDON, S.K., PANT, C.C. & CASSHYAP, S.M. (eds.), Sedimentary Basins of India: Tectonic Context: 74-103, Gyanodaya Prakashan.
- CALLOMON, J.H. 1981. Superfamily Perisphinctaceae. In: DONOVAN, D.T., CALLOMON, J.H. & HOWARTH, M.K. Classification of Jurassic ammonoidea. In: HOUSE, M.R. & SENIOR, J.R. (eds.), The Ammonoidea. - Systematics Association, Special Volume 18: 101-155.
- DESH PANDE, S.V., & MERH, S.S. 1980. Mesozoic sedimentary model of Wagad hills, Kutch, Western India. - Journal of the Geological Society of India 21: 75-83.
- FÜRSICH, F.T. & PANDEY, D.K. 2003. Sequence stratigraphic significance of sedimentary cycles and shell concentrations in the Upper Jurassic-Lower Cretaceous of Kutch, western India. - Palaeogeography Palaeoclimatology, Palaeoecology 193: 285-309.
- KRISHNA, J. & PATHAK, B. 1993. Late Lower Kimmeridgian - Lower Tithonian virgatosphinctins of India: evolutionary succession and biogeographic implications. - Geobios, Mémoire spécial 15: 227-136.
- RUDRA, P. & BARDHAN, S. 2006. Status of "*Trigonia ventricosa*" (Bivalvia) from the Upper Jurassic -

- Lower Cretaceous of Kutch, western India: Kitchin's unfinished synthesis. - *Cretaceous Research* 27: 611-628.
- RUDRA, P., BARDHAN, S. & SHOME, S. 2007. Phylogeny of the Late Jurassic-Early Cretaceous subgenus *Eselevitrigonia* (Bivalvia) of Kutch, India, and paleobiogeographic constraints. - *Journal of Paleontology* 81: 1066-1079.
- SHOME, S. 2009. Systematics, palaeobiogeography and evolution of the Upper Jurassic (Kimmeridgian-Tithonian) ammonites of Kutch, Western India. Unpublished PhD thesis, Jadavpur University, 168 p., Kolkata.
- SHOME, S., DE, S., RAY, P. & DAS, S.S. 2004. Ammonites as biological stopwatch and biogeographical black box - a case study from the Jurassic-Cretaceous boundary of Kutch, Gujarat. - *Current Science* 86: 197-202.
- SHOME, S. & ROY, P. 2006. New record of *Pterolytoceras* SPATH, 1927 from the Upper Jurassic (Late Tithonian) of Kutch, western India and its palaeobiogeographic significance. - *Indian Minerals* 59: 57-64.
- SHOME, S. & BARDHAN, S. 2009. A new Late Tithonian ammonite assemblage from Kutch, western India. - *Journal of Palaeontological Society of India* 54: 1-18.
- SPATH, L.F. 1931. Revision of the Jurassic cephalopod fauna of Kachh (Cutch). - *Palaeontologia Indica, Geological Survey of India, New Series* 9(2): 1-945.
- VERMA, H.M. & WESTERMANN, G.E.G. 1972. The Tithonian (Jurassic) ammonite fauna and stratigraphy of Sierra Cartoche, Sar Luis Potosi, Mexico. - *Bulletin of American Paleontology* 63 (277): 107-320.

Jurassic Boreal zonal standard: Possibilities of Boreal-Tethyan correlation based on an integrated bio-, magneto- and chemostratigraphic approach

BORIS N. SHURYGIN* & OXANA S. DZYUBA

Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of RAS, Acad. Koptyug av., 3, Novosibirsk 630090, Russia; E-mail: shuryginbn@ipgg.sbras.ru, dzyubaos@ipgg.sbras.ru

**Corresponding author*

In early studies, the Boreal Jurassic stratigraphy was based on data on ammonite occurrences in the numerous sections of the northern territories of Russia, Northern America, and East Greenland. The biostratigraphic studies were based on the assumption that biostratigraphic scales were applicable only within palaeobiogeographic provinces (SAKS et al. 1980). Regional zonal scales comprised provincial zones with different index species for synchronous biostratons. In these scales, ammonite zones with a wide geographic range correspond to time intervals when the taxonomic composition of faunal assemblages was geographically levelled (they are usually associated with significant transgressive events). As was stated (SAKS et al. 1980), such zones form a system of biostratigraphic markers with rather isochronous boundaries. Ten widely recognised markers were mentioned for the Jurassic sediments, namely, the *P. planorbis* Zone (Hettangian), *A. stokesi* Zone (Pliensbachian), *D. athleticum* Zone, *Z. monestieri* Zone (Toarcian), *O. jugatus* Zone (Bathonian), *C. elatmae* Zone (Callovian), *C. cordatum* Zone (Oxfordian), *A. eudoxus* Zone (Kimmeridgian), *P. pectinatus* Zone, and the *D. maximus* Zone (Volgian).

Long-distance correlations based solely on ammonite biostratigraphy have some restrictions. As a rule, ammonite zonal boundaries are postulated as based on evolutionary events. However, the phenotype well distinguished from its ancestor is not formed immediately close to the point of divergence. Therefore, the uncertainty interval of position of a phylo- or phenozone boundary will always exist near the point of divergence, even if one does not take into account the time for the geographic distribution of a new phenotype. Internationally accepted practice of definition of Global

Boundary Stratotype Section and Point (GSSP) aggravates the problem in the case when the GSSP is defined at the first appearance datum of a taxon. Extremely different points of view of ammonite experts on taxonomic affiliation of the same specimens (in part caused by a lack of monographic research) and the intention to produce a super-detailed zonation (up to biohorizons) complicate strongly the solution of long-distance correlation problems.

In addition to Jurassic ammonite biostratigraphy, great importance has recently been placed on using integrated parallel zonal scales from different Boreal groups of fossils (ammonites, belemnites, bivalves, microfauna, microflora) to provide more detailed and reliable correlations (ZAKHAROV et al. 1997; SHURYGIN et al. 2011; NIKITENKO et al. 2013). If one considers the Boreal standard as a combination of these scales, it can be regarded as a combination, in which the reference intervals are characterised by a unique succession of the results of bioevents of different (independent) nature (phylogenetic, chorologic, ecological). A fixed succession of independent events, apparently, has the highest probability of isochroneity when identified in different regions. The boundaries of biostratigraphic units distinguished for different fossil groups often do not coincide with each other. When sections are correlated with the help of the entire set of parallel zonal scales, the discrepancy of boundaries permits identifying and tracing very narrow intrazonal intervals (co-intervals, i.e., zone overlapping intervals between parallel scales).

The Boreal standard should reflect as much as possible the specificity of the Boreal (Arctic) domain. The stratotype region for this standard must have a typical Boreal (Arctic rather than mixed) fauna. Correspondingly, a possible

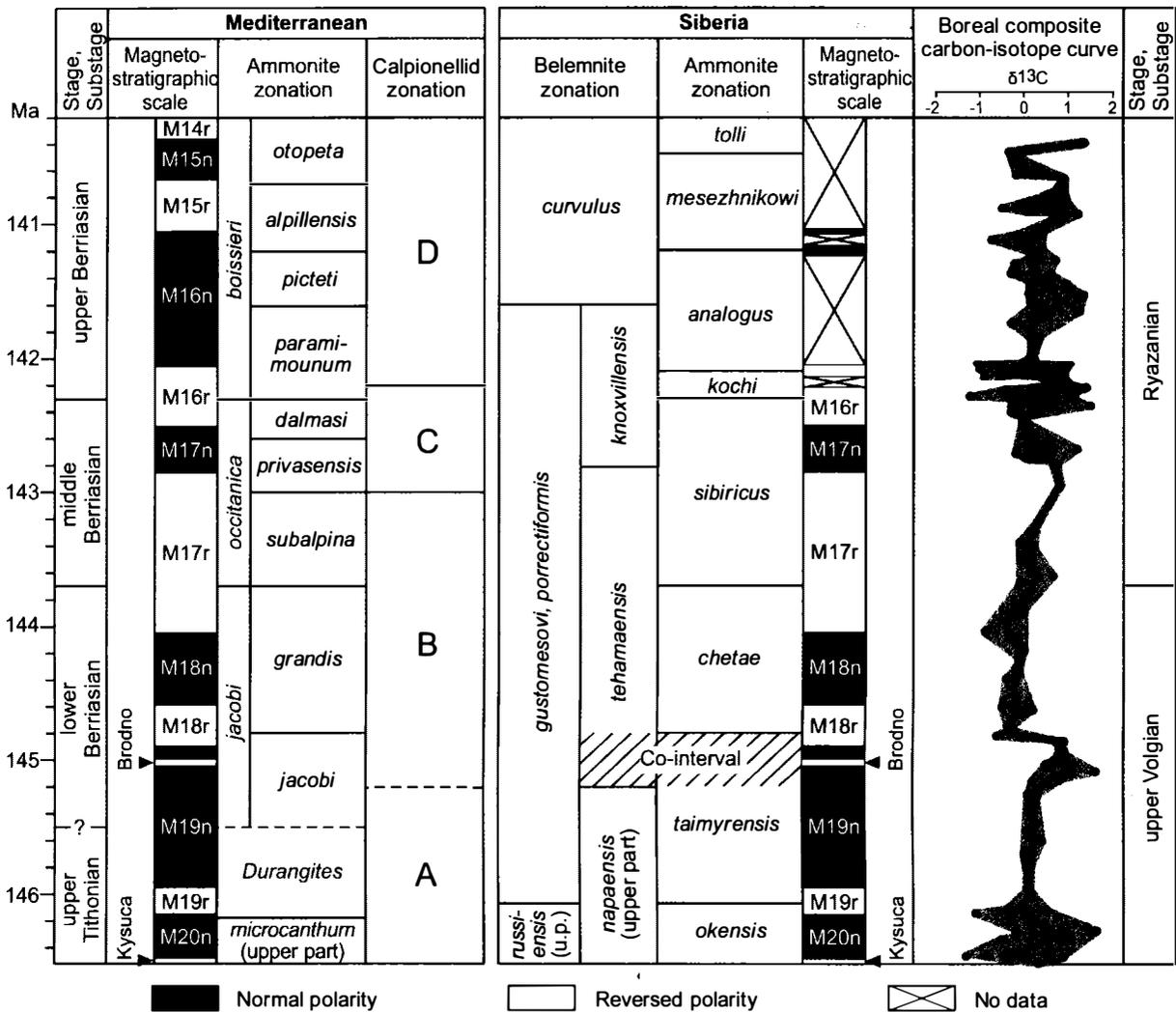


Fig. 1. Boreal (Siberian) ammonite-, belemnite-, magneto- and C-isotope stratigraphy across the J-K boundary calibrated against Tethyan (Mediterranean) standard after BRAGIN et al. (2013) and DZYUBA et al. (2013).

candidate is Siberia (and the Arctic biochorema), which is located in the centre of the Panboreal Superrealm, where the set of interrelated scales for various fossil groups is most complete (SHURYGIN et al. 2011; NIKITENKO et al. 2013). Note that the regional scales for the marginal biochoremas of the Panboreal Superrealm (like a zonal scheme for the Jurassic of Russian Platform), which reflect features of mixed faunas, remain crucial in correlating between Boreal and Tethyan successions.

In many instances, the integrated bio-, magneto- and chemostratigraphic approach is necessary to solve problems of Boreal–Tethyan correlation, and this approach is especially important for defining GSSPs. In our opinion, it is acceptable to use any event (palaeontological, geomagnetic reversal, isotopic excursion) as the marker for defining the GSSP. The problem is to

trace the GSSP boundary globally. Obviously, precise position of Tethyan biostratigraphic boundaries will be never defined in Boreal sections. There will always be a small or large uncertainty interval, even if GSSP is based on geomagnetic or isotopic event. Here we show that the uncertainty interval can be sufficiently narrowed by using an integrated approach, on an example of the Jurassic–Cretaceous (J–K) boundary interval, which is one of the most problematic intervals of the Phanerozoic (Fig. 1).

Two most widely used ‘Tethyan’ J–K boundary markers (the base of the B. jacobi ammonite Zone and the base of the calpionellid Zone B) in Boreal regions correspond to different levels within the Upper Volgian C. taimyrensis ammonite Zone (HOŠA et al. 2007; BRAGIN et al. 2013). The uncertainty interval

of their position in the Boreal standard is the whole *C. taimyrensis* Zone. If the base of the magnetozone M18r (GRADSTEIN et al. 2012) or the base of the *P. grandis* Subzone will be used as the J–K boundary marker the uncertainty interval can be narrowed to the co-interval of the *C. taimyrensis* ammonite Zone and the *C. tehamaensis* belemnite Zone. This co-interval also includes a narrow zone of reversed polarity interpreted as the Brodno Subzone (M19n.1r) and a distinct positive carbon isotope excursion (BRAGIN et al. 2013; DZYUBA et al. 2013).

This is a contribution to the RAS Programs 23 and 28 and the RFBR project 12-05-00453.

References

- BRAGIN, V.YU., DZYUBA, O.S., KAZANSKY, A.YU. & SHURYGIN, B.N. 2013. New data on the magnetostratigraphy of the Jurassic–Cretaceous boundary interval, Nordvik Peninsula (northern East Siberia). – *Russian Geology and Geophysics* 54: 329–342.
- DZYUBA, O.S., IZOKH, O.P. & SHURYGIN, B.N. 2013. Carbon isotope excursions in Boreal Jurassic–Cretaceous boundary sections and their correlation potential. – *Palaeogeography, Palaeoclimatology, Palaeoecology* 381–382: 33–46.
- GRADSTEIN, F.M., OGG, J.G., SCHMITZ, M.D. & OGG, G.M. (eds.) 2012. *The geologic time scale 2012*. – 1144 p., Elsevier, Amsterdam.
- HOUŠA, V., PRUNER, P., ZAKHAROV, V.A., et al. 2007. Boreal–Tethyan correlation of the Jurassic–Cretaceous boundary interval by magneto- and biostratigraphy. – *Stratigraphy and Geological Correlation* 15: 297–309.
- NIKITENKO, B.L., SHURYGIN, B.N., KNYAZEV, V.G., et al. 2013. Jurassic and Cretaceous stratigraphy of Anabar region (Arctic Siberia, Laptev Sea coast) and Boreal zonal standard. – *Russian Geology and Geophysics* 54 (in press).
- SAKS, V.N., ZAKHAROV, V.A., MELEDINA, S.V., et al. 1980. Modern theories about the development of fauna and the zonal stratigraphy of the Jurassic and Neocomian of the Boreal Belt. – *Soviet Geology and Geophysics* 21: 6–18.
- SHURYGIN, B.N., NIKITENKO, B.L., MELEDINA, S.V., et al. 2011. Comprehensive zonal subdivisions of Siberian Jurassic and their significance for Circum-Arctic correlations. – *Russian Geology and Geophysics* 52: 825–844.
- ZAKHAROV, V.A., BOGOMOLOV, YU.I., IL'INA, V.I., et al. 1997. Boreal zonal standard and biostratigraphy of the Siberian Mesozoic. – *Russian Geology and Geophysics* 38: 965–993.

Ammonite biostratigraphy of the Pliensbachian-Toarcian transition at Westgate, Nevada, USA

PAUL L. SMITH* & ANDREW H. CARUTHERS

Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver V6T 1Z4, Canada; Email: psmith@eos.ubc.ca, caruthers.andrew@gmail.com

*Corresponding author

The Pliensbachian-Toarcian interval is currently of significant interest because it appears to record a multi-phased, global, second-order mass extinction that may be linked to the environmental stresses imposed by eruptions within the Karoo-Ferrar large igneous province (PÁLFY & SMITH 2000; CARUTHERS et al. 2013). This poster and its accompanying paper contribute to our understanding of the Pliensbachian-Toarcian time scale, an important tool for comparing geochemical data sets from across the globe and for developing hypotheses to explore and explain the extinction event. The work presented here accompanies and complements the poster by Caruthers et al.

dealing with the geochemistry of the succession at Westgate in the Clan Alpine Mountains of west-central Nevada.

The Jurassic succession exposed at Westgate was first mapped in detail by CORVALAN (1962). The lithostratigraphic units he recognized that subsequently yielded the Pliensbachian–Toarcian ammonites described here are now assigned to the Mina Peak Member of the Sunrise Formation (TAYLOR et al. 1983). The Sunrise Formation is part of a regressive sequence that in the Shoshone and Gabbs Valley ranges to the south of Westgate is capped by the terrestrial deposits of the Pliensbachian Dunlap Formation. At Westgate, however, marine deposition continues into the Toarcian and probably into the Middle Jurassic.

The Pliensbachian ammonite zonation for North America has been described by SMITH et al. (1988) and the Toarcian zonation by JAKOBS et al. (1994). There have been numerous supporting publications describing in detail the Pliensbachian and Toarcian ammonites of Canada (e.g., SMITH & TIPPER 1996 and JAKOBS 1997) but, apart for the work of IMLAY (1968), little attention has been focused on the ammonites of the conterminous United States. The Westgate succession is of particular significance in this context because, when the North American Pliensbachian zonation was established, part of the Mina Peak Member was designated as a reference section for the uppermost Pliensbachian Carlottense Zone (Fig. 1).

The Pliensbachian-Toarcian ammonite succession at Westgate consists of four assemblages. In ascending stratigraphic order they consist of:

(1) An association of species of *Fanninoceras* and *Arietoceras* assigned to the Carlottense Zone of the Late Pliensbachian (Fig. 1).

		Northwest Europe	Western North America	Radiometric Age Ma error (2σ)
Toarcian	Middle	Variabilis	Crassicosta	181.4 (+1.2/-1.2)
		Bifrons	Planulata	182.0 (+3.3/-4.9)
	Early	Serpentinum	Kanense	183.6 (+1.7/-1.1)
		Tenuicostatum		
Pliens. Upper	Spinatum	Carlottense	184.1 (+1.2/-1.6)	
	Margaritatus	Kunae	185.7 (+0.5/-0.6)	

Fig. 1. The Upper Pliensbachian to Middle Toarcian North American ammonite zones recognized at Westgate, west-central Nevada. Approximate correlations of the North American secondary standard zones with the primary standard zones of Europe are indicated (adapted from SMITH et al. 1988: fig. 9; JAKOBS et al. 1994: fig. 12). Pliens. = Pliensbachian.

(2) An association of species of *Lioceratoides*, *Protogrammoceras*, and *Tiltoniceras*. This association is also assigned to the Carlottense Zone because it occurs below the first dactyloceratids and, in Canada, it includes species of *Fanninoceras*, *Arietoceras*, and *Amaltheus*.

(3) An association of the hildoceratids seen in assemblage 2 with species of *Dactyloceras* and *Nodicoeloceras?*, assigned to the Early Toarcian Kanense Zone (Fig. 1).

(4) An association of depressed dactyloceratids representing *Peronoceras* and *Catacoeloceras*, assigned to the Planulata Zone of the Middle Toarcian (Fig. 1).

References

- CORVALAN, J. 1962. Early Mesozoic stratigraphy of the Westgate area, Churchill County Nevada. Ph.D. thesis, Stanford University, California, 224 p.
- CARUTHERS, A.H., SMITH, P.L. & GRÖCKE, D. 2013. The Pliensbachian-Toarcian (Early Jurassic) extinction, a global multi-phased event. - *Palaeogeography, Palaeoclimatology, Palaeoecology*, in press.
- IMLAY, R.W. 1968. Lower Jurassic (Pliensbachian and Toarcian) ammonites from eastern Oregon and California. - United States Geological Survey Professional Paper 593 C: 1-51.
- JAKOBS, G. 1997. Toarcian ammonoids from North America. - Geological Survey of Canada Bulletin 428: 1-137.
- JAKOBS, G., SMITH, P.L. & TIPPER, H.W. 1994. An ammonite zonation for the Toarcian (Lower Jurassic) of the North American Cordillera. - Canadian Journal of Earth Sciences 31: 919-942.
- PÁLFY, J. & SMITH, P.L. 2000. Synchrony between Early Jurassic extinction, oceanic anoxic event, and the Karoo-Ferrar flood basalt volcanism. - *Geology* 28: 747-750.
- SMITH, P.L. & TIPPER, H.W. 1996. Pliensbachian biostratigraphy and ammonite fauna of the Queen Charlotte Islands, British Columbia. - *Bulletins of American Paleontology* 108: 1-122.
- SMITH, P.L., TIPPER, H.W., TAYLOR, D.G. & GUEX, J. 1988. A Lower Jurassic ammonite zonation for Canada and the United States: the Pliensbachian. - Canadian Journal of Earth Sciences 25: 1503-1523.
- TAYLOR, D.G., SMITH, P.L., LAWS, R.A. & GUEX, J. 1983. The stratigraphy and biofacies trends of the Lower Mesozoic Gabbs and Sunrise formations, west-central Nevada. - Canadian Journal of Earth Sciences 20: 1598-1608.

Ichnology of the Callovian-Oxfordian of Katrol Hill Range, Southwest of Bhuj, Kachchh, western India

PARAS M. SOLANKI¹ *, NISHITH Y. BHATT¹, SATISH J. PATEL² & JAGDISH M. PATEL³

¹Department of Geology, M. G. Science Institute, Ahmedabad – 380 009, Gujarat, India; Email: parassolankimg@yahoo.com, nybhattmg@yahoo.com

²Department of Geology, M. S. University of Baroda, Vadodara – 390 002, Gujarat, India; Email: sjpgeology@gmail.com

³Department of Geology, Shri R. R. Lalan College, Bhuj, Gujarat, India; Email: jmpbhuj@gmail.com

*Corresponding author

Callovian to Oxfordian rocks are well exposed in the northern part of the Katrol Hill Range of Mainland Kachchh (BHALLA & ABBAS 1978). The rocks are lithostratigraphically classified as Jumara Formation and further divided into four informal members, from I to IV in ascending order (BISWAS 1977, 1993). The studied sections of the Jumara Formation lie southwest of Bhuj in the Katrol hill range, where except the lower part of the Member I all members are well developed. Member I consist of shales, with thin bands of greyish limestone containing small bivalves and becoming cherty in the upper part. The upper boundary of Member I is fixed at a ferruginous sandstone band. The lower part of Member II is characterised by highly bioturbated shale-siltstone intercalations, while the upper part consists of thick, hard, medium to coarse sandstone which marks the upper boundary of Member II. Member III mainly consists of shale with thin bands of limestones and siltstones. Member IV is dominated by shales in its lower part, while the top part consists of oolitic limestones (Dhosa Oolite) forming a distinct marker horizon which separates the Jumara Formation from the Jhuran Formation (BISWAS 1977).

The exposed succession has a thickness of about 234 m comprising various sedimentary rock units which can be divided into six lithofacies based on sediment and bedding plane characteristics, grain size, and sedimentary structures. They are the Intercalated Calcareous Shale Siltstone Facies (ICSSF), Limestone Facies (LF), Ferruginous Sandstone Facies (FSF), Massive Felspathic Sandstone Facies (MFSF), Grey Shale Facies (GSF), and Oolitic Limestone Facies (OLF).

All facies types are highly bioturbated except the grey shale facies, and the maximum abundance of trace fossils was observed in a succession of interbedded shale, siltstone, and sandstone. Apart from incomplete and collapse structures, trace fossils include *Acanthorhapse incerta*, *Arenicolites carbonarius*, *A. isp.*, *Beaconites coronus*, *Bergaueria perata*, *B. isp.*, *Biformites insolitus*, *B. isp.*, *Calycraterion samsonowiczi*, *Chondrites targionii*, *Circulichnus isp.*, *Dendrotichnium llarenai*, *Didymaulichnus isp.*, *Diplocraterion parallelum*, *Dolopichnus gulosus*, *Fustiglyphus annulatus*, *Glockeria glockeri*, *Gyrolithes isp.*, *Helminthopsis isp.*, *Imponoglyphus torquendus*, *Lockeia siliquaria*, *Megagraption irregulare*, *Micatuba verso*, *Monocraterion isp.*, *Nereites imbricata*, *Ophiomorpha nodosa*, *O. annulata*, *Palaeophycus alternatus*, *P. annulatus*, *P. heberti*, *P. striatus*, *P. sulcatus*, *P. tubularis*, *Paleomeandron isp. aff. P. robustum*, *Parahaentzschelniia ardelia*, *Phoebichnus trochoides*, *Phycodes circinnatum*, *P. curvipalmatum*, *P. palmatum*, *Phymatoderma isp.*, *Protovirgularia cf. dichotoma*, *Psammichnites plummeri*, *Rotamedusa roztocensis*, *Skolithos linearis*, *Steigerwaldichnium heimi*, *Stellascolites radiatus*, *Taenidium serpentinum*, *T. satanassi*, *Teichichnus rectus*, *Thalassinoides suevicus*, *T. horizontalis*, *Zoophycus brianteus*, *Z. circinnatus*, and *Z. ville*.

The rich and highly diversified trace fossils revealed a wide range of animal behaviours represented by dwelling, feeding, crawling, and resting structures. Horizontal feeding structures are found abundantly in all lithofacies indicating low wave and current energy for deposition of poorly sorted muddy to sandy sediments. However, a few coarse layers containing

Arenicolites, *Ophiomorpha*, and *Skolithos* indicate exploitation of the sediment by opportunistic animals under intermittently moderate wave and current energy or storm-wave conditions in the shoreface zone. Unlined backfill structures such as *Taenidium* in ICSSF and MFSF of Member I and II indicate more distal regions and record oxygenated quiet waters and stable, continuous, slow deposition and bioturbation yielding complex bioturbate textures (FREY et al. 1990). *Thalassinoides* burrows are dominating in intercalated sandstones and shales as well as in thick sandstone lithofacies (ICSSF, MFSF and FSF) of Member II and III. These large, semi-permanent, mainly horizontal tunnel systems suggest deposit-feeders as producers and probably represent the lowest energy levels (FÜRSICH & HEINBERG 1983) in the shoreface.

Zoophycus is characteristically found in OLF of Member IV and together with various ichnospecies of *Chondrites*, *Rhizocorallium*, *Thalassinoides*, *Ophiomorpha* etc. *Zoophycus* is an opportunistic ichnospecies which appears together with *Chondrites* in opportunistic situations of low-resource, inhospitable oxygen-depleted environments (BROMLEY 1990). Sediments thoroughly bioturbated by the producer of *Zoophycus* indicates fairly low sediment input below the storm wave-base in offshore areas (PATEL et al. 2009).

The high diversity and abundance of deposit-feeding structures suggest availability of organic-rich and oxygenated substrates for colonization of endobenthic communities. The sedimentological characteristics of the lithofacies and presence of trace fossils indicate fluctuations of the sea level from the middle shoreface to offshore zone during deposition of the Callovian to Oxfordian sediments of the Jumara Formation.

References

- BHALLA, S.N. & ABBAS, S.M. 1978. Jurassic foraminifera from Kutch, India. – *Micropaleontology* 24: 160–209.
- BISWAS, S.K. 1977. Mesozoic Rock-Stratigraphy of Kutch, Gujarat. – *Quarterly Journal of the Geological, Mining and Metallurgical Society of India*. 49 (3 & 4): 1–52.
- BISWAS, S.K. 1993. Geology of Kutch: 52-98, K D. Malaviya Institute of Petroleum Exploration, Dehradun.
- BROMLEY, R.G. 1990. Trace fossils. Biology and taphonomy: – 280 pp., Unwin Hyman,
- FREY, R.W., PEMBERTON, S.G. & SAUNDER, T.D.A. 1990. Ichnofacies and bathymetry: a passive relationship. – *Journal of Palaeontology* 64: 155–158.
- FÜRSICH, F.T. & HEINBERG, C. 1983. Sedimentology, biostratigraphy and palaeoecology of an Upper Jurassic offshore sand bar complex. – *Bulletin of the Geological Society of Denmark* 31: 67–95.
- PATEL, S.J., DESAI, B.G. & SHUKLA, R. 2009. Paleocological significance of the trace fossils of Dhosa Oolite Member (Jumara Formation), Jhura Dome, Mainland Kachchh, Western India. – *Journal of the Geological Society of India*. 74: 601–614.

Response of Jurassic strata of Kachchh to Quaternary tectonics in an active intra-plate basin of Kachchh, western India

M. G. THAKKAR

Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj-Kachchh-370001, India; E-mail: mgthakkar@rediffmail.com

Kachchh is a peri-cratonic rift basin generated in Late Triassic Period during the break-up of Gondwanaland. The tectonic regime was normal, hence the early basinal faults formed half-graben basin. Post-Cretaceous Indo-Eurasia collision along with plutonism and sub-aerial volcanism started reverse tectonics of the Kachchh Basin, resulting into the uplift of all the Jurassic and Cretaceous strata exposing them on to the surface. Tertiary period, once again, witnessed large scale transgressive and regressive deposits at the open end of the basin, while fast uplift of Jurassic strata to the margin of the craton on the landward side. Quaternary period shaped the present day landscape of Kachchh exposing various features in Jurassic strata and revealed its complete stratigraphy. Depending on the nature of rocks, they form peculiar geomorphic features. Jhuran (Katrol) Formation in Katrol Hill range formed straight mountain fronts and ideal triangular facets along the Katrol Hill Fault. In the dome dominated northern hill range of Kachchh Mainland, the scarps have been developed where Jhuran and

Bhuj formations cap the earlier rocks resisting them for erosion, while Jumara and Jhuran shale formations are exposed as bumpy grounds against the scarps. Kaladungar and Khadir formations also preserve the neotectonic features in Pachchham, Khadir, Bela and Rapar uplifts. The response to Quaternary tectonics is reflected as bedrock gorges, gullies, scarps and triangular facets in the Jurassic strata. The author has explored them critically and classified with respect to their cohesiveness. The active fronts of KMF – Kachchh Mainland Fault, KHF – Katrol Hill Fault and IBF – Island Belt Fault exhibit precipitous scarps where hard limestone and sandstone caps, while the core region of the domes along the master faults makes hummocky grounds where shale facies dominate. Southern slopes of all the uplifts are characterized by the bedrock gorges in sandstones. The scarp recession is more where cohesive and compact rocks are less and more triangular facets, while the compact rocks show straight mountain fronts.

Untangling real from apparent seawater temperature variability during the Late Jurassic

ADAM TOMAŠOVÝCH¹ *, DORRIT JACOB^{2, 3}, MICHAEL JOACHIMSKI⁴, MATTHIAS LÓPEZ CORREA⁵, JÁN SCHLÖGL⁶

¹*Geological Institute, Slovak Academy of Sciences, Dubravská cesta 9, 84005 Bratislava, Slovakia; Email: geoltoma@savba.sk*

²*Institut für Geowissenschaften, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany*

³*Department of Earth and Planetary Sciences, Macquarie University, Level 5, E7A Building, NSW 2109 Australia; Email: dorrit.jacob@mq.edu.au*

⁴*GeoZentrum Nordbayern, Universität Erlangen-Nürnberg, Schlossgarten 5, 91054 Erlangen, Germany; Email: michael.joachimski@fau.de*

⁵*GeoZentrum Nordbayern, Universität Erlangen-Nürnberg, Loewenichstrasse 28, 91054 Erlangen, Germany; Email: matthias.lopez@gzn.uni-erlangen.de*

⁶*Department of Geology and Paleontology, Comenius University, Mlynska dolina G, 84215 Bratislava, Slovakia; Email: schlogl@fns.uniba.sk*

*Corresponding author

Latitudinal and bathymetric variation in temperature in present-day oceans is one of the major factors determining distribution patterns and diversity of marine organisms, and estimating the temperature variability in past oceans is thus crucial in studies that seek to explain major evolutionary, palaeobiogeographic, and palaeoecological patterns. However, palaeotemperature estimates based on oxygen isotopes strongly suffer from uncertainties related to weak constraints on spatial variation in seawater $\delta^{18}\text{O}$ composition. Other geochemical proxies are thus needed that can better constrain past seawater temperatures.

One of such proxies that remain weakly used in analyses of Jurassic seawater temperatures is represented by the Mg/Ca ratio of brachiopod shells. Our preliminary analyses of Recent brachiopods imply that although temperature sensitivity of Mg/Ca is rather low and Mg/Ca values can differ among brachiopod taxa sampled in the same habitat, brachiopod shells do capture seasonal temperature variations and can detect large-scale temperature differences among different locations.

Here, we focus on temperature estimates derived from $\delta^{18}\text{O}$ and Mg/Ca of Late Oxfordian and Early Kimmeridgian brachiopod shells from the northern Tethys shelf analysed using high-resolution sampling of the shells with LA-ICP-

MS and micromill. We constrain the analyses to two multicostate rhynchonellid genera that have similar life habits and morphology. First, we compare the $\delta^{18}\text{O}$ composition and Mg/Ca in brachiopods from shallow- and deep-shelf environments that lived during one ammonite zone (Epipeltoceras bimammatum Zone), thus effectively quantifying the bathymetric gradient in temperature. Second, we assess the temporal change in $\delta^{18}\text{O}$ and Mg/Ca of brachiopods that inhabited deep-shelf environments over ~4 Myr during the Late Oxfordian to Early Kimmeridgian.

During the Late Oxfordian Epipeltoceras bimammatum Zone, brachiopods from the shallow shelf (coral reefs of the Swiss and French Jura Mts.) have a consistently higher Mg/Ca ratio (by 3-4 $\mu\text{mol/mol}$) and lower $\delta^{18}\text{O}$ values (by -0.5 to -1‰) than brachiopods from deep-shelf habitats (sponge mounds of the Swabian and Franconian Alb). These shallow and deep water habitats were located at similar latitudes (25°-30°N) on the northern Tethys shelf (with individual localities separated by no more than ~500 km in longitudinal direction). The oxygen isotope analyses imply a ~4°-5°C temperature difference between coral-reef habitats located above storm wave base and sponge habitats located below storm wave base. Interestingly, brachiopod communities show a marked shift in species and genus composition at this depth

level, indicating that temperature stratification could be a major driver of regional-scale brachiopod distribution.

Over the course of the Late Oxfordian to Early Kimmeridgian, brachiopods that occupied deep-shelf environments with sponge mounds show remarkably stable Mg/Ca ratios (2-4 $\mu\text{mol/mol}$). However, we observe also a trend towards more negative $\delta^{18}\text{O}$ values with Kimmeridgian shells showing similarly low $\delta^{18}\text{O}$ values as Late Oxfordian shells from coral-reefs ($\delta^{18}\text{O} = -1.5$ to -1 ‰). We hypothesize that the discrepancy in the Mg/Ca and $\delta^{18}\text{O}$ trends largely imply temporal changes in seawater $\delta^{18}\text{O}$ composition (e.g., change in evaporation/

precipitation ratio leading to salinity changes) rather than changes in temperature *per se*. Importantly, brachiopod communities that occupied deep-shelf environments during this time interval were stable in terms of their taxonomic composition and abundance patterns, and never grade into brachiopod communities that inhabited coral reefs in the same region, supporting the hypothesis that trends based on $\delta^{18}\text{O}$ composition of brachiopod shells are decoupled from temporal changes in temperature.

This research was supported by the Slovak Research and Development Agency (APVV 0644-10) and by the Scientific Grant Agency (VEGA 0068/11).

Ichnological record of food content change in Middle–Upper Jurassic pelagic sediments of the Fatricum domain in the Tatra Mountains, southern Poland

ALFRED UCHMAN* & RENATA JACH

Institute of Geological Sciences, Jagiellonian University, Oleandry 2a, 30-063 Kraków, Poland; Email: alfred.uchman@uj.edu.pl; renata.jach@uj.edu.pl

**Corresponding author*

The general offshore decrease in food content in sediments is one of the basic ecological factors influencing benthic life. It is expected that this paradigm influences burrowing organisms and hence it is reflected in the ichnological record. This hypothesis is verified in the Jurassic sediments of the Fatricum domain (Křížna Nappe) in the Tatra Mountains (West Carpathians, southern Poland) which show a gradual deepening from nearshore to deep sea environments below CCD. The deepening was conditioned by opening of the Western Tethys, further rifting, and the general Jurassic transgression.

During the latest Early Jurassic extensional block tilting formed a horst and graben topography in the Western Carpathians, which persisted until the end of the Middle Jurassic. Subsiding basins were constantly filled with grey spotted limestones and marls, followed by grey nodular limestones with *Bositra*, while horsts acted as submarine palaeo-highs with condensed carbonates with glauconite and *Bositra*-crinoidal limestones. Upper Jurassic rocks record a post-rift thermal subsidence and continuous deepening with sedimentation of monotonous bio-siliceous-carbonate facies. The Upper Jurassic succession consists of pelagic sediments, mainly radiolarites, red nodular limestones, and platy micritic limestones. These sediments are almost totally bioturbated. Primary lamination is rare and limited to a few thin horizons.

Ten recognized ichnogenera include fodinichnia (*Zoophycus*, *Teichichnus*, *Phycodes*), chemichnia (*Chondrites*, *Trichichnus*), pascichnia (*Planolites*, *Phycosiphon*), and domichnia-fodinichnia (*Thalassinoides*). They represent the *Zoophycus* ichnofacies, which occurs in different marine settings from the deeper

shelf trough slope to basin plain in pelagic and hemipelagic sediments between phases of incidental sedimentation, mostly turbidites.

Abundance and diversity of trace fossils generally decrease stratigraphically up the studied succession. In the lower part, most beds of grey limestones and marls and the lowermost part of radiolarites display typical spotty structures, i.e. sections of beds are characterized by relatively dense and diverse cross-sections of trace fossils visible as variable spots. *Chondrites*, *Planolites*, *Thalassinoides*, and *Zoophycus* are common. Other trace fossils are rare or very rare in this and other parts of the studied interval.

Up-section, in the upper part of radiolarites and red nodular limestones, the spotty character of sediments is less distinct and may nearly completely disappear, i.e. the spots decrease in density, contrast, and diversity. In several beds any trace fossil can be seen; they display bioturbational structures or are massive. The commonest trace fossils are *Chondrites* and *Planolites*. *Thalassinoides* and *Zoophycus* are rarer and trace fossils are generally less compressed than in the lower part of the studied interval. The changes are not ideally linear, but fluctuations in these features do not discard the general trend.

The changes are not related to grain size or lithology of the sediment. Silicification can mask primary structures in some beds. More regular diagenetic disturbance occurs in red nodular limestones, in which trace fossils are preserved only within the nodules. However, this process does not influence the general trend in the distribution of trace fossils.

Primary lamination occurs only in a few thin horizons in the studied deposits and is not associated with sediments darker than in

other horizons. It can be referred to incidental rapid sedimentation, as is indicated by a subtle increase in grain size. This excludes changes in oxygenation of pore water as the significant factor controlling the ichnofauna. Instead, the changes of ichnological features in the studied interval are caused rather by a decrease in food content in the sediments. With deepening of the basin and decreasing sedimentation rate associated with generally advancing flooding of epicontinental areas, less and less food was supplied to the basin from shallower areas. Less and less organic matter was buried with decreasing sedimentation rate and increasing in distance from the shelf. In more eutrophic conditions (lower part of the interval),

organisms penetrated deeply in the sediment, where distinct trace fossils were produced. The thicker layer of nutritional sediments provided an ecospace for a higher diversity of burrowing organisms.

In more oligotrophic conditions (higher part of the succession), the organic matter was concentrated in the soupy sediment near the sediment-water interface, where preservation of distinct trace fossils was impossible. Only in some beds, organisms penetrated deeper and produced trace fossils. Thus, diversity and abundance of trace fossils can be used as a proxy of the trophic level in pelagic sediments.

This research has been financed by the grant N N307 016537.

First contribution to precise biostratigraphy of Upper Tithonian rocks from the Veracruz Basin (SE México)

ANA BERTHA VILLASEÑOR¹ & FEDERICO OLÓRIZ²

¹*Departamento de Paleontología, Universidad Nacional Autónoma de México, 04510, México, D.F. Mexico; Email: anab@unam.mx*

²*Departamento de Estratigrafía y Paleontología, Universidad de Granada, 18071 Granada, Spain; Email: foloriz@ugr.es*

Tithonian rocks are among those of greater potential for hydrocarbons sources in Mexico. The Pimienta Fm consists of more or less calcareous silt- and claystone with clayey to shaley intercalations and local development of concretions. These deposits are late Tithonian in age and accumulated in low-oxygenated sea bottoms across eastern Mexico (outcrop and subsurface successions with reported thicknesses of 3.5 to 100 m and 20 m, respectively) and the western Gulf Rim (subsurface and offshore sites approximately 20 m in thickness.). Deposits of equivalent age in central and northern Mexico belong to the La Caja and La Casita formations (reported thicknesses between 10-15 and 200 m), which represent a distal to proximal sedimentary succession under slightly more oxygenated sea bottom conditions, respectively. More calcareous sediments correspond to the La Caja Fm. while sandy and silty limestones and siltstones correspond to the La Casita Fm. Except for outcrops in north-central Mexico, macro- and microfossil assemblages of late Tithonian age have been largely collected from areas belonging to sedimentary basins with economic interest (hydrocarbon sources).

Since the earliest twentieth century, research on uppermost Jurassic deposits from Mexico focused on biostratigraphy characterizing ammonite assemblages, and less commonly calpionellid assemblages (Fig. 1). BURCKHARDT (1906, 1930), IMLAY (1939, 1980), BONET (1956), CANTÚ-CHAPA (1963, 1967, 1976), VERMA & WESTERMANN (1973), and TREJO (1980) are representative examples of the "Capas de" or "Ammonite Beds" biostratigraphic approach. A turning point towards precise ammonite-horizon-biostratigraphy was the Ph.D. thesis of one of the authors (VILLASEÑOR 1991), then followed by later papers with collaborators.

Other authors working on the same precise ammonite-horizon-biostratigraphy approach were Addate and collaborators (ADDATE et al. 1992 to 1996). Updated revisions based on this approach were provided by VILLASEÑOR et al. (2000a, 2012).

Since the earliest twentieth century up to date, variable combinations of ammonite genera such as *Haploceras*, *Acevedites*, *Proniceras*, *Corongoceras*, *Micracanthoceras*, *Suarites*, *Wichmanniceras*, *Mazatepites*, so-called *Kossmatia*, *Durangites*, *Substeueroceras*, *Paradontoceras*, and *Salinities* have been interpreted to represent the Upper Tithonian in Mexico (for extended revision see VILLASEÑOR et al. 2012). However, information about bed-by-bed sampling and the corresponding reference to detailed stratigraphic columns of Upper Tithonian rocks is found in less than 25% of the published papers, and no published information exists with precise Upper Tithonian biostratigraphy from the Veracruz Basin in ESE Mexico.

Following interpretations initially proposed by OLÓRIZ (1987, 1992), a large part of the problems, or uncertainty, with Upper Jurassic biostratigraphy and precise correlations in Mexico relates to habitat patchiness in neritic environments with irregular, unstable bottom physiography that accentuated the differential influence of relative sea level fluctuations on ecospace availability for ammonites. Resulting environmental heterogeneity, endemism, and dominant r-strategy in ammonites completed the picture determining the difficulty for reproducibility of precise homotaxial successions (e.g., VILLASEÑOR et al. 2012 for extended treatment). Potential, local hiatuses related to erosion or non-deposition are not conclusively known yet.

In such a context, the first precise, combined

information about Upper Tithonian deposits and fossil assemblages in SE Mexico (Veracruz State) is reported here on the basis of a bed-by-bed sampling during field surveys in 2012 and 2013. The analysed section crops out 10 km southeastwards of the village of Tlapacoyan, within the so-called Veracruz Basin. The ca. 20-m-thick section is well-bedded and comprised of more or less calcareous siltstone and claystone with argillaceous to shaley intercalations (Pimienta Fm.) and a single horizon with scarce calcareous concretions. Macro-invertebrates other than ammonites are bivalves (up to ca. 15%) and an insignificant number of gastropods, and rare brachiopods occur in a condensed level at the top of the section. Discontinuous ammonite horizons show commonly crushed inner moulds (leaf preservation) and no preservation of suture

lines in pauci-specific ammonite assemblages. Precise data about biostratigraphic ranges of ammonites such as *Proniceras*, *Mazatepites*, *Durangites*, and *Salinites*, together with other inconclusively known ammonite taxa, have been collected. Additionally, microfacies analysis of mainly peloidal rocks with silt-sized to fine- and medium-grained bioclasts and common recrystallization (microsparite) provides information about the biostratigraphic ranges of tinninoids such as *Chitinoidea*, *Crassicollaria*, and *Calpionella*.

The obtained information provides a first step for providing precise biostratigraphy of Upper Tithonian deposits outcropping in the Veracruz Basin, but more research is needed in other Mexican sections before its regional meaning and correlation potential within Mexico can be conclusively evaluated.



Fig. 1. Number of papers (PhD and undergraduate theses included) providing precise biostratigraphy based on bed-by-bed sampling and reference to precise horizons in stratigraphic sections within the regions highlighted. Red star for location of the studied section.

References

- ADATTE, T., STINNESBECK, W., HUBBERTEN, H. & REMANE, J. 1992. The Jurassic-Cretaceous boundary in Northeastern and Central Mexico - a multistratigraphical approach. - VIII Congreso Latinoamericano de Geología, Salamanca, Actas Tomo 4: 23-29.
- ADATTE, T., STINNESBECK, W., REMANE, J. & HUBBERTEN, H. 1996. Paleogeographic changes at the Jurassic-Cretaceous boundary in the Western Tethys, northeastern Mexico. - *Cretaceous Research* 17: 671-689.
- BONET, F. 1956. Zonificación microfauística de las calizas cretácicas del Este de México. - *Boletín de la Asociación Mexicana de Geólogos Petroleros* 8: 389-488.
- BURCKHARDT, C. 1906. La faune Jurassique de Mazapil avec un appendice sur les fossiles de Crétacique inférieur. - *Boletín del Instituto Geológico de México* 23: 1-217.
- Burckhardt, C. 1930. Etude systématique sur le Mesozoïque mexicain. - *Mémoires de la Société Paléontologique Suisse* 49-50 : 1-279.
- CANTÚ-CHAPA, A. 1963. Étude biostratigraphique des ammonites du centre et de l'Est du Mexique (Jurassique supérieur et Crétacé). - *Mémoires de la Société Géologique de France* 42 (4): 1-102.
- CANTÚ-CHAPA, A. 1967. El límite Jurásico-Cretácico en Mazatepec, Puebla (México). - Instituto Mexicano del Petróleo, Sección Geología, Monografía 1, Publicación No. 7 AI-11: 3-24.
- CANTÚ-CHAPA, A. 1976. El contacto Jurásico-Cretácico, la estratigrafía del Neocomiano, el hiato del Hauteriviano superior-Eoceno inferior y las amonitas del pozo Bejuco. - *Boletín de la Sociedad Geológica mexicana* 37: 68-83.
- IMLAY, R.W. 1939. Upper Jurassic ammonites from Mexico. - *Bulletin of the Geological Society of America* 50: 1-78.
- IMLAY, R.W. 1980. Jurassic paleobiogeography of the conterminous United States in its continental setting. - U.S. Geological Survey Professional Paper 1062: 1-134.
- OLÓRIZ, F. 1987. El significado biogeográfico de las plataformas mexicanas en el Jurásico superior. Consideraciones sobre un modelo eco-evolutivo. - *Revista de la Sociedad Mexicana de Paleontología* 1: 219-247.
- OLÓRIZ, F. 1992. North central and eastern Mexico. In: WESTERMANN, G.E.G. (ed.). *The Jurassic of the Circum Pacific*, part 4. - *Biochronology* 12: 100-107, Cambridge University Press, New York.
- TREJO, M. 1980. Distribución estratigráfica de los tintínidos Mesozoicos Mexicanos. - *Revista del Instituto Mexicano del Petróleo* 12(4): 4-13.
- VERMA, H.M. & WESTERMANN, G.E.G. 1973. The Tithonian (Jurassic) ammonite fauna and stratigraphy of Sierra de Catorce, San Luis Potosí, Mexico. - *Bulletin of the American Paleontology* 63(277): 107-320.
- VILLASEÑOR, A.B. 1991. Aportaciones a la bioestratigrafía, basada en fauna de ammonites, de la sucesión del Jurásico superior (Kimmeridgiano-Tithoniano) del área de Mazapil, Zacatecas, México. Unpublished PhD. Thesis, Facultad de Ciencias, Universidad Nacional Autónoma de México: 154 p.
- VILLASEÑOR, A.B., OLÓRIZ F. & GONZÁLEZ-ARREOLA, C. 2000. Recent advances in Upper Jurassic (Kimmeridgian-Tithonian) ammonite biostratigraphy from North-Central Mexico. Based in new collected ammonite assemblages. - *GeoResearchForum* 6: 249-262.
- VILLASEÑOR, A.B., OLÓRIZ, F., LÓPEZ PALOMINO, I. & LÓPEZ-CABALLERO, I. 2012. Updated ammonite biostratigraphy from Upper Jurassic deposits in Mexico. - *Revue de Paléobiologie*, Vol. spéc. 11: 249-267.

Foraminiferal zonation of the Jurassic of the Caucasus and Precaucasus

VALERY JA. VUKS

Federal State Unitary Enterprise "A.P. Karpinsky Russian Geological Research Institute" (FGUP "VSEGEI"), Sredny pr. 74, St.-Petersburg 199106, Russia; E-mail: Valery_Vuks@vsegei.ru

The first foraminiferal zonal schemes for the Jurassic of the Caucasus were offered in the 50s of the last century. They partially are reflected in the regional stratigraphic schemes on the Jurassic of the Caucasus which were published in 1984 (ROSTOVTSEV & KRYMHOLTZ 1984). Recent geological research, including the production of a new generation of geological maps, allowed collecting of a large number of new data which not always fit well within mentioned schemes. Therefore improvement of the stratigraphical schemes of the Jurassic of the Caucasus becomes an important task. Within this task it is necessary to be precise and work in detail on the biozonal schemes which are known and published.

During the Early and Middle Jurassic time the North Caucasian basins are usually considered as palaeo-basins with more or less similar living conditions. Therefore, correlation of these deposits as a whole does not create essential problems (AZBEL & GRIGELIS 1991; ROSTOVTSEV 1992). Thus, though there are three foraminiferal zonal schemes for the Russian part of the Caucasus, it is possible to use as a basis a foraminifer-based zonal scheme for the Western Caucasus and Pre-Caucasus (Fig. 1).

The Middle (Callovian) and Late Jurassic Caucasian basins are characterized by a high variety of facies and biotic assemblages that are reflected in the large number of foraminifer-based zonal schemes which cannot be united in a single scale (Fig. 2). Four foraminiferal zonal schemes are known in the mentioned stratigraphic interval of the Western Caucasus and Pre-Caucasus (Laba, Lagonaki, Abino-Gunajskaya, and Novorossijsko-Lazarevskaya zones) and one such scheme exists for the Central and Eastern Caucasus (GRIGELIS 1982; AZBEL & GRIGELIS 1991; VUKS 2004, 2007). The *Haplophragmium coprolithiforme* Local Zone and the *Labalina costata* – *Lenticulina tumida* Local Zone are established in the Laba Zone, but judging by composition of coeval foraminiferal

assemblages, these local zones can be traced in the above mentioned zones of the Western Caucasus and Pre-Caucasus also that found their reflection in the presented scheme.

Thus, all published foraminifer-based zonal schemes can be compared with ammonite zonations and the International Stratigraphic scale (Figs 1, 2). It should be noted that zonal divisions are not established for all structural-facies zones of the Caucasus and Pre-Caucasus. Besides, in a number of structural-facies zones, for which foraminifer-based scales exist, foraminifer divisions do not cover the whole Jurassic interval either because of absence of foraminifers in these deposits, or because of lack of foraminifer research. Reliability of zonal boundaries has not yet quite proved because of the rare occurrence of ammonites and existence of data with different degree of detail on the distribution of foraminifers in some deposits.

Attempts have been made to compare divisions of the International Stratigraphic scale and the zonal ammonite standard with regional ammonite and foraminifer scales of the Caucasus (Figs 1, 2). These schemes can be considered as a basis for discussion and improving of the regional stratigraphic schemes of the Jurassic of the Russian Caucasus.

References

- AZBEL, A.Y. & GRIGELIS, A.A. (eds.) 1991. *Prakticheskoe rukovodstvo po microfaune SSSR. T. 5. Foraminifery mezozoya* [Practical manual on microfauna of the USSR. V.5. Mesozoic foraminifers]. 375 p., Nedra, Leningrad (In Russian).
- GRIGELIS, A.A. (ed.) 1982. *Biostratigrafiya verkhneyurskikh otlozhenii SSSR po foraminiferam* [Upper Jurassic biostratigraphy of the USSR according to foraminifera]. 173 p., Mokslas, Vilnius (In Russian).
- ROSTOVTSEV, K.O. (ed.) 1992. *Yura Kavkaza* [Jurassic of Caucasus]. 192 p., Nauka, St.Petersburg (In Russian).
- ROSTOVTSEV, K.O. & KRYMHOLTZ G.Y. (eds.) 1984. *Reshenie 2 Mezhdedomstvennogo regional'nogo stratigraficheskogo soveshchaniya po mezozoyu Kavkaza (Yura) 1977 g.* [Decision of the Second Interdepartmental Regional Stratigraphic Conference on Mesozoic of the Caucasus (Jurassic) 1977]. 47 p.,

International and General Straigraphic scale (2006, 2012)				Biozonal ammonite standart Biostratigraphie du Jurassique Ouest - Europeen et Meditteraneen, 1997; The Jurassic of Denmark and Greenland, 2003	Regional biostratigraphic subdivisions				
System	Series	Stage	Substage		Ammonites	Foraminifers (local zones)			
						Western Caucasus and Precaucasus	Central and Eastern Caucasus	Calcareous Dagestan	
Jurassic	Middle	Bathonian	Upper	<i>Clydoniceras discus</i> <i>Oxycerites orbis</i>	?	?	?		
			Middle	<i>Procerites hodsoni</i> <i>Morrisiceras morrisi</i> <i>T. subcontractus</i> <i>Pr. progracilis</i>					
			Lower	<i>Asphinctites tenuiplicatus</i> <i>Zigzagiceras zigzag</i>	<i>Parkinsonia wurtembergica</i>	<i>Quinqueloculina micra</i> <i>Kaptorenkoella minima</i>	<i>O. balcaricum orientalis - R. epistominoides</i>	<i>E. peregrina - S. perlucida</i>	
			Bajocian	Upper	<i>P. parkinsoni</i> <i>Garantiana garantiana</i> <i>Str. niortense</i>	<i>Parkinsonia parkinsoni</i> <i>Garantiana garantiana</i>	<i>Sublamarkella terquemi</i> <i>Ophthalmidium caucasicum</i>	<i>O. balcaricum</i> <i>G. caucasica</i>	<i>Conoglobigerina dagestanica</i> <i>- Kaptorenkoella epistominoides</i>
				Lower	<i>Stephanoceras humphriesianum</i> <i>Otoites sauzei</i> <i>W. laeviuscula</i> <i>Sonninia ovalis</i> <i>H. discites</i>	<i>S. humphriesianum</i> <i>Otoites sauzei</i> <i>Witchellia laeviuscula</i> <i>Hyperlioceras discites</i>	<i>Verneuilinoides tchegemensis</i> <i>Ophthalmidium balcaricum</i>	<i>Verneuilinoides tchegemensis</i> <i>Ophthalmidium caucasicum</i>	<i>Hyperammina labaensis</i> <i>- Lenticulina mamillaris</i>
					Aalenian	<i>Graphoceras concavum</i> <i>Brasilia bradfordensis</i>	<i>Graphoceras concavum</i> <i>Brasilia bradfordensis</i>	?	<i>Ophthalmidium infraoolithicum</i>
		Lower	Aalenian	Lower	<i>Ludwigia murchisonae</i> <i>Leioceras opalinum</i>	<i>Ludwigia murchisonae</i> <i>Leioceras opalinum</i>	<i>Ophthalmidium mamontovae</i>	<i>Recurvoides baksanicus</i>	<i>Cornuspira orbicula</i> <i>- Lenticulina psekentchiensis</i>
				Toarcian	Upper	<i>Pleydellia aalensis</i> <i>D. pseudoradiosa</i> <i>Physeogrammoceras dispansum</i> <i>G. thouarsense</i> <i>Haugia variabilis</i> <i>Hildoceras bifrons</i> <i>H. serpentinum</i> <i>Dactylioceras tenuicostatum</i> <i>Pl. spinatum</i>	<i>Pleydellia aalensis</i> <i>Dumortiena pseudoradiosa</i> <i>G. thouarsense</i> <i>Haugia variabilis</i> <i>Hildoceras bifrons</i> <i>Harpoceras falciferum</i> <i>Dactylioceras semicelatum</i> ?	<i>Lenticulina toarcense</i> - <i>Lenticulina orbignyi elongata</i> <i>Haplophragmoides praekonvexus</i> - <i>A. asper</i> - <i>Trochammina squamataformis</i>	<i>Lenticulina toarcense</i> - <i>Lenticulina habarovae</i> <i>Haplophragmoides praekonvexus</i> - <i>Ammodiscus asper</i>
			Pliensbachian	Upper	<i>Amaltheus margaritatus</i> <i>P. davoei</i>	<i>Amaltheus margaritatus</i> ?	<i>Cornuloculina bakhensis</i> <i>Cornuloculina orbiculare</i>		?
				Lower	<i>Tr. ibex</i> <i>Uptonia jamesoni</i>	<i>Tragophylloceras ibex</i> <i>Uptonia jamesoni</i> <i>Tropidoceras flandrini</i>	?	?	
			Sinemurian	Upper	<i>E. raricostatum</i> <i>O. oxynotum</i> <i>A. obtusum</i>	<i>Echioceras declivus</i> , <i>Oxynotoceras oxynotum</i> , <i>Microderoceras birchi</i>	<i>Ophthalmidium concentricum</i> <i>Cornuloculina clausa</i>		
				Lower	<i>Caenisites tumeri</i> <i>A. semicostatum</i> <i>Arietites bucklandi</i>	?	?		
	Hettangian	Upper	<i>Schlotheimia angulata</i>						
		Lower	<i>Alsatites liasicus</i> <i>Psiloceras planorbis</i>						

Fig. 1. Biostratigraphic zonation of the Lower and Middle Jurassic of the Russian Caucasus.

International and General Straigraphic scale (2006, 2012)				Biozonal ammonite standart	Regional biostratigraphic subdivisions					
System	Series	Stage	Substage	Biostratigraphie du Jurassique Ouest - Europeen et Meditteraneen, 1997; The Jurassic of Denmark and Greenland, 2003	Ammonites	Foraminifers				
						Western Caucasus	Central and Eastern Caucasus			
Jurassic	Upper	Tithonian	Upper	<i>Durangites vulgaris</i>	?	Anchispirocyclus jurassica-Lenticulina ponderosa local zone	Spirulina cf. kuebleri local zone	<i>Quinqueloculina verbizhiensis</i> - <i>Trocholina elongata</i> zone		
				<i>Paraulacosphinctes transitorius</i>	<i>Paraulacosphinctes transitorius</i> local zone			?		
				<i>Simplisphinctes</i>	<i>Lithacoceras albulus</i> local zone			<i>Trocholina ex gr. solecensis</i> - <i>Textularia densa</i> local zone		
			<i>"Micracanthoceras" ponti</i>	<i>Lithacoceras ulmense</i> - <i>Glochiceras nimbatum</i> local zone	?					
			<i>Semiformiceras fallauxi</i>	<i>Lithacoceras ulmense</i> - <i>Glochiceras nimbatum</i> local zone	<i>Trocholina friburgensis</i> local zone					
			<i>S. semiforme</i>		?					
		Lower	<i>Virgatosimoceras albertinum</i>	<i>Lithacoceras ulmense</i> - <i>Glochiceras nimbatum</i> local zone	<i>Trocholina friburgensis</i> local zone					
			<i>Hybonotoceras hybonotum</i>		?					
		Kimmeridgian	Upper	<i>Aulacostephanus autissiodorensis</i>	?			Alveosepta ukrainica? local zone	Alveosepta jaccardi local zone	<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone
				<i>A. eudoxus</i>	<i>Aspidoceras - Idoceras</i> local zone					
			<i>Aulacostephanus mutabilis</i>	<i>Sutneria platinota</i> local zone						
		Lower	<i>Rasenia cymodoce</i>	<i>Aspidoceras - Idoceras</i> local zone	<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone					
	<i>Pictionia baylei</i>	<i>Sutneria platinota</i> local zone	<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone							
	Oxfordian	Upper	<i>Ringsteadia pseudocordata</i>	?	Alveosepta ukrainica? local zone	Alveosepta jaccardi local zone	<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone			
			<i>Perisphinctes cautisnigrae</i>	<i>Perisphinctes cautisnigrae</i> local zone						
		Middle	<i>Perisphinctes pumilus</i>	?				<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone		
			<i>Perisphinctes plicatilis</i>	<i>Perisphinctes plicatilis</i> local zone						
		Lower	<i>Cardioceras cordatum</i>	<i>Cardioceras cordatum</i> - <i>C. vertebrale</i> local zone					<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone	
			<i>Quenstedtoceras mariae</i>	<i>Cardioceras cordatum</i> - <i>C. vertebrale</i> local zone						
	Middle	Upper	<i>Quenstedtoceras lamberti</i>	<i>Quenstedtoceras lamberti</i> zone	Labalina costata-Lenticulina tumida local zone	<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone	<i>Lenticulina tumida</i> zone			
			<i>Peltoceras athleta</i>	<i>Peltoceras athleta</i> zone						
		Middle	<i>Erymnoceras coronatum</i>	<i>Erymnoceras coronatum</i> zone			<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone	<i>Labalina costata</i> zone		
			<i>Kosmoceras jason</i>	<i>Kosmoceras jason</i> zone						
		Lower	<i>Sigaloceras calloviense</i>	<i>Sigaloceras calloviense</i> - <i>Macrocephalites macrocephalus</i> zone				<i>Alveosepta jaccardi</i> - <i>Mesoendothyra izjumiana</i> zone	?	
<i>Proplanulites koenigi</i>										
<i>Macrocephalites herveyi</i>	<i>Sigaloceras calloviense</i> - <i>Macrocephalites macrocephalus</i> zone	<i>Haplophragmium coprolithiforme</i> local zone	<i>Recurvoides ventosus</i> - <i>Pseudonodosaria terquemi</i> zone							

Fig. 2. Biostratigraphic zonation of the Middle and Upper Jurassic of the Russian Caucasus.

Leningrad (In Russian).

VUKS, V.JA. 2004. Foraminiferal zonation of the Upper Jurassic of the Caucasus: comparison of schemes and new results. Abstract volume of the 32nd International Geological Congress, Florence, Italy. August 20-28th, 2004. Part 1: 823.

VUKS, V.JA. 2007. Biozonal'naya schema verkhnei yury

Zapadnogo Kavkaza: foraminifery i ikh facial'nye osobennosti [Biozonal scheme of the Upper Jurassic of the Western Caucasus: foraminifers and their facial features]. Jurassic System of Russia: Problems of stratigraphy and paleogeography. – Proceeding volume of the II. Russian meeting: 39–40, Yaroslavl State Pedagogical University, Yaroslavl (In Russian).

Syn- and post-tectonic palaeomagnetism of Jurassic sediments from the Velebit Mts (Karst Dinarides, Croatia)

TOMASZ WERNER¹, IGOR VLAHOVIC², MAGDALENA SIDORCZUK³ & MAREK LEWANDOWSKI⁴ *

¹*Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland; E-mail: twerner@igf.edu.pl*

²*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia; E-mail: igor.vlahovic@gmail.com*

³*Polish Geological Institute – National Research Institute, Warsaw, Poland; E-mail: msid@pgi.gov.pl*

⁴*Institute of Geological Sciences, Polish Academy of Sciences, Warsaw, Poland; E-mail: lemar@twarda.pan.pl*

**Corresponding author*

The Early to Late Jurassic deposits along a transect in Mali Halan in the southern part of the Velebit Mt. (Croatia) were studied using palaeomagnetic and rock magnetic measurements. Magnetic susceptibility of diamagnetic carbonates is not affected by heating up to 400-500°C. SIRM(T) experiments revealed low temperature ($T_{ub} < 400^\circ\text{C}$) Ti-poor magnetite and some hematite phase in fresh samples. Magnetic carriers were also documented by electron microscope and SEM analyses. Heating in air results in excessive growth of a new magnetite phase above 600°C, rendering NRM components analyses impossible above this temperature level.

Thermal and AF treatment was performed and was more successful for Early Jurassic sites with stronger NRM. It resulted in separation of two ChRM components: "L" with T_{ub} up to 200-250°C and "M" with T_{ub} up to 400-475°C or two coercivity spectra (very soft and harder) in most successfully demagnetized samples. In some samples only the soft/LT component was recorded.

The "M" component for Early and Middle

Jurassic sites (345/30 in situ) correlates well with results of Marton (2008) for Early Jurassic grainstones in the same area. The tilt-corrected data for the "M" component fall close to the Middle Jurassic segment for APWP for Africa. However, site mean values for the "M" component are distributed along the small circle with subhorizontal WNW trending axis. This may be interpreted as pre- to syntectonic remanence recorded during regional folding.

The "L" component (of lower accuracy) for Early/Middle Jurassic sites (in situ) falls close to APWP for Africa and also indicates its post-tectonic secondary origin. For Late Jurassic sites with lower NRM intensity the "L" component seems to be post-tectonic but results for the "M" component need to be yet discussed. Generally, the origin of the characteristic NRM component may be regarded as syntectonic, acquired during progressive uplifting and tilting, and in line with the model proposed for remagnetized Permian clastic sediments in the Velebit Mts. (Crne Grede and Kosna localities, LEWANDOWSKI et al. 2012, AGU Fall Meeting, GP21A-1136).

Oxygen and carbon isotope records of uppermost Callovian–Lower Kimmeridgian belemnite rostra and bulk carbonates from the Polish Jura Chain (central Poland): environmental changes in the Submediterranean Province of Europe

HUBERT WIERZBOWSKI

Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, PL 00-818 Warszawa, Poland; E-mail: hwierzbo@twarda.pan.pl

Oxygen and carbon isotope values of mesohibolitid belemnite rostra from the Upper Callovian–Lower Kimmeridgian of the Submediterranean ammonite province (Polish Jura Chain in south-central Poland, Kujawy area in north-central Poland and Swabian Alb in southern Germany) were presented by WIERZBOWSKI (2002, 2004) and WIERZBOWSKI et al. (2009). The data show relatively constant temperatures of bottom waters, where studied belemnites lived, throughout the Late Callovian–Middle Oxfordian and a temperature rise of ca. 2°C at the Middle–Late Oxfordian transition (i.e. the transition of the *Transversarium* and *Bifurcatus* chrons). Belemnite $\delta^{13}\text{C}$ values point to the existence of the two positive carbon isotope excursions in the Upper Callovian (*Athleta* and *Lamberti* zones) and the Middle Oxfordian (*Plicatilis* and *Transversarium* zones) of the Submediterranean Province (cf. WIERZBOWSKI 2002, 2004; WIERZBOWSKI et al. 2009).

Belemnite rostra collected from the Middle–Upper Oxfordian of the Polish Jura Chain were previously screened for the state of preservation using the cathodoluminescence microscope (WIERZBOWSKI 2002). As this method is considered insufficient by some authors (cf. VEIZER 1974, 1983; MARSHALL 1992) the studied samples have been recently analysed for iron, manganese and strontium contents. Only well-preserved rostra characterized by low Fe (< 200 ppm) and Mn (< 50 ppm) concentrations as well as by high Sr (>800 ppm) contents were incorporated in revised stable isotope trends (Fig. 1). The revised belemnite data confirm the timing of temperature variations and the carbon isotope excursions in the Polish Jura Chain. These variations are consistent with the palaeoenvironmental records of other areas

of the Submediterranean Province (Fig. 1). Newly analysed data also show a short-lived increase in the $\delta^{18}\text{O}$ values and a decrease in bottom water temperatures at the Callovian–Oxfordian transition (in the uppermost part of the *Lamberti* Subchron of the *Lamberti* Chron) in the Polish Jura Chain basin.

Carbon isotope trends derived from micritic bulk carbonates and belemnite rostra from the Polish Jura Chain are partly dissimilar (Fig. 1). This is likely caused by secular changes in the origin and the isotope composition of carbonate micrite sedimented in the Polish Jura Chain basin. Vast variations of the sedimentation rate are observed in this area in the Oxfordian – a gradual rise in the calcium carbonate sedimentation rate is observed starting from the *Plicatilis* Zone of the Middle Oxfordian. The rise is followed by an abrupt increase in the deposition rate in the *Planula* Zone of the Upper Oxfordian (in Submediterranean zonation) due to the flux of material from the prograded carbonate platform (MATYJA & WIERZBOWSKI 1994).

The study was partly supported by the Polish National Science Centre (grant no. 2012/05/B/ST10/02121).

References

- MATYJA, B.A., WIERZBOWSKI, A. 1994. Monografia górnej jury Pasma Krakowsko-Wieluńskiego. Projekt Badawczy KBN nr 600799101 (unpublished report): 1–39, Warszawa.
- MARSHALL, J.D. 1992. Climatic and oceanographic isotopic signals from the carbonate rock record and their preservation. – *Geological Magazine* 129: 143–160.
- VEIZER, J. 1974. Chemical diagenesis of belemnite shells and possible consequences for paleotemperature determinations. – *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 147: 91–111.
- VEIZER, J. 1983. Chemical diagenesis of carbonates: theory and trace element technique. In: ARTHUR, M.A., ANDERSON, T.F., KAPLAN, I.R., VEIZER, J. & LAND,

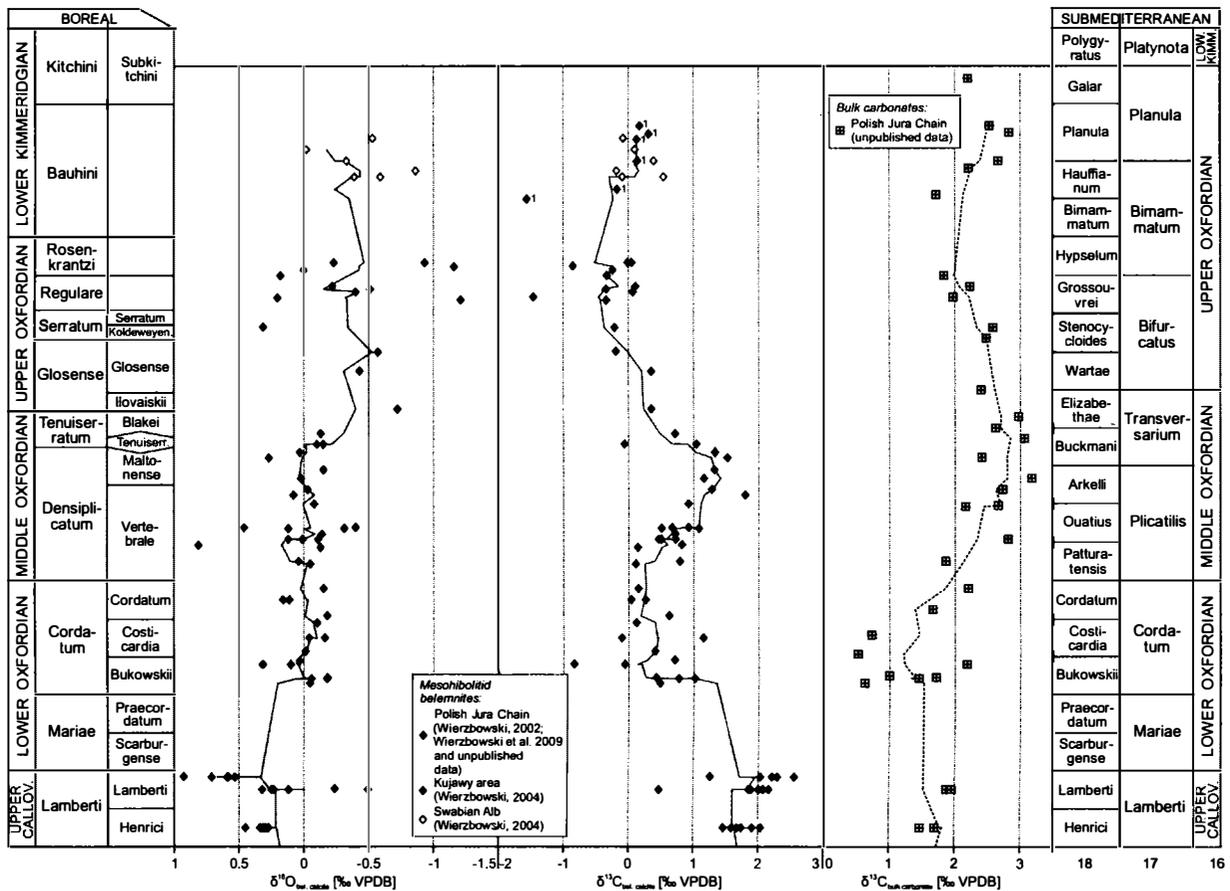


Fig. 1. Uppermost Callovian–Oxfordian stratigraphy, $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values of well-preserved belemnite rostra and bulk carbonates from the Polish Jura Chain, Kujawy, and the Swabian Alb. $\delta^{13}\text{C}$ values of dull luminescent Upper Oxfordian belemnite samples from the Polish Jura Chain (marked with “1”) are shown for comparison. Curves represent 5-point running averages for the isotope data.

L.S. (eds.), Stable isotopes in sedimentary geology. – SEPM Short Course No. 10: 3-1-3-100.

WIERZBOWSKI, H. 2002. Detailed oxygen and carbon isotope stratigraphy of the Oxfordian in Central Poland. – *International Journal of Earth Sciences (Geologische Rundschau)* 91: 304–314.

WIERZBOWSKI, H. 2004. Carbon and oxygen isotope composition of Oxfordian–Early Kimmeridgian belemnite rostra: palaeoenvironmental implications

for Late Jurassic seas. – *Palaeogeography Palaeoclimatology Palaeoecology* 203: 153–168.

WIERZBOWSKI H., DEMBICZ, K. & PRASZKIER, T. 2009. Oxygen and carbon isotope composition of Callovian–Lower Oxfordian (Middle–Upper Jurassic) belemnite rostra from central Poland: A record of a Late Callovian global sea-level rise? – *Palaeogeography, Palaeoclimatology, Palaeoecology* 283: 182–194.

Revised seawater strontium isotope curve for the Late Bajocian–Oxfordian (Middle–Late Jurassic)

HUBERT WIERZBOWSKI¹ *, ROBERT ANCKIEWICZ², JAKUB BAZARNIK³ & JACEK PAWLAK⁴

¹*Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, PL 00-818 Warszawa, Poland; E-mail: hwierzbo@twarda.pan.pl*

²*Institute of Geological Sciences, Polish Academy of Sciences, ul. Senacka 1, PL 31-002 Kraków, Poland; E-mail: ndanczki@cyf-kr.edu.pl*

³*Institute of Geological Sciences, Polish Academy of Sciences, ul. Senacka 1, PL 31-002 Kraków, Poland; E-mail: ndbazarn@cyf-kr.edu.pl*

⁴*Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, PL 00-818 Warszawa, Poland; E-mail: dzeq@twarda.pan.pl*

**Corresponding author*

The seawater strontium-isotope curve is characterised by a broad and a deep trough at the Middle–Late Jurassic transition (with the lowest ⁸⁷Sr/⁸⁶Sr ratio in the Phanerozoic). Due to the significant scatter or scarcity of strontium isotope data in some stratigraphic intervals a well-defined fit of the strontium isotope curve could not be produced for the Middle to Late Jurassic (cf. JONES et al. 1994; JENKYNs et al. 2002). New data derived from well-preserved belemnite rostra have recently allowed the presentation of the high-resolution strontium isotope curve for the Late Bajocian–Callovian period (WIERZBOWSKI et al. 2012).

Well-dated stratigraphically and well-preserved belemnite rostra (non-luminescent, C_{Fe} < 150 ppm, C_{Mn} < 50 ppm, C_{Sr} > 950 ppm) from the Oxfordian of the Polish Jura Chain in central Poland and the Swabian Alb in southern Germany have been newly analysed for their strontium isotope composition. The samples were dissolved in 2.5M HCl. The leachates were evaporated to dryness. Strontium separation was performed in two steps with Bio-Rad 50W-X8 and Eichrom Sr-spec resins. A blank of chemical procedures was less than 20 pg strontium. Isotope analyses of strontium were conducted using a MC ICP-MS Neptune at the Institute of Geological Sciences, Polish Academy of Sciences in Cracow, Poland. All isotope ratios were corrected for fractionation effect using the ⁸⁷Sr/⁸⁶Sr value of 0.1194. Reproducibility of measured SRM 987 ratio over the course of the analyses was 0.710262 ± 6*10⁻⁶ (2σ, n=11). Measured sample ⁸⁷Sr/⁸⁶Sr ratios were

normalized to the recommended SRM 987 ⁸⁷Sr/⁸⁶Sr ratio of 0.710248 (cf. McARTHUR et al. 2001). The strontium isotope curve was estimated using a LOWESS statistical model (cf. HERCMAN & PAWLAK 2012). The 95% confidence interval was calculated with the Monte Carlo method taking account of measurement uncertainties.

The new strontium isotope data supplemented with published data by JONES et al. (1994), CALLOMON & DIETL (2000), and WIERZBOWSKI et al. (2012) allowed producing a high resolution seawater strontium isotope curve for the Late Bajocian–Oxfordian (Fig. 1). The data show that the seawater ⁸⁷Sr/⁸⁶Sr ratio decreased gradually from the Late Bajocian to the Middle–Late Bathonian transition (from ca. 0.707070 to ca. 0.707000). An abrupt decrease of the ⁸⁷Sr/⁸⁶Sr ratio to ca. 0.706875 occurred in the Late Bathonian–Early Callovian. The ratio fell slightly during the Middle Callovian and reached a quasi-constant value of ca. 0.706850 in the Late Callovian. A further decrease of the ⁸⁷Sr/⁸⁶Sr ratio occurred in the Early Oxfordian, and the Early–Middle Oxfordian transition is characterized by the lowest ratio of ca. 0.706830. An stepwise increase of the ⁸⁷Sr/⁸⁶Sr ratio took place starting from the latest Middle Oxfordian. The seawater ⁸⁷Sr/⁸⁶Sr ratio reached a value of ca. 0.706880 at the Oxfordian–Kimmeridgian transition (according to the Submediterranean ammonite zonation).

The Middle–Late Jurassic trough of the seawater ⁸⁷Sr/⁸⁶Sr ratio is linked to a pulse of hydrothermal activity of the seafloor, which

resulted in the influx of isotopically light, non-radiogenic strontium to the oceans (cf. JONES et al. 1994; JONES & JENKYN 2001). There is much evidence for the acceleration of the oceanic crust spreading and the opening of new oceanic basins at the Middle–Late Jurassic transition (cf. WIERZBOWSKI et al. 2012).

The new data show that the seawater had the lowest Phanerozoic $^{87}\text{Sr}/^{86}\text{Sr}$ ratio at the Early–Middle Oxfordian transition – a bit later than it was previously assumed (cf. JENKYN et al. 2002; WIERZBOWSKI 2012; see Fig. 1). The presented data along with other published strontium isotope data may be used to obtain a best fit of the strontium isotope curve in the Middle–Late Jurassic.

References

CALLOMON, J.H. & DIETL, G. 2000. On the proposed basal boundary stratotype (GSSP) of the Middle Jurassic Callovian Stage. – *GeoResearch Forum* 6: 41–54.
HERCMAN, H. & PAWLAK, J. 2012. An age-depth model

construction algorithm. – *Quaternary Geochronology* 12: 1–10.

JENKYN H.C., JONES, C.E., GRÖCKE, D.R., HESSELBO, S.P. & PARKINSON, D.N. 2002. Chemostratigraphy of the Jurassic System: applications, limitations and implications for palaeoceanography. – *Journal of the Geological Society, London* 159: 351–378.

JONES, C.E. & JENKYN, H.C. 2001. Seawater strontium isotopes, oceanic anoxic events, and seafloor hydrothermal activity in the Jurassic and Cretaceous. – *American Journal of Science* 301: 112–149.

JONES, C.E., JENKYN, H.C., COE, A.L. & HESSELBO, S.P. 1994. Strontium isotopic variations in Jurassic and Cretaceous seawater. – *Geochimica et Cosmochimica Acta* 58: 3061–3074.

MARTHUR, J.M., HOWARTH, R.J. & BAILEY T.R. 2001. Strontium isotope stratigraphy: LOWESS version 3: best fit to the marine Sr-isotope curve for 0–509 Ma and accompanying look-up table for deriving numerical age. – *Journal of Geology* 109: 155–170.

WIERZBOWSKI, H., ANCKIEWICZ, R., BAZARNIK, J. & PAWLAK, J. 2012. Strontium isotope variations in Middle Jurassic (Late Bajocian–Callovian) seawater: Implications for Earth's tectonic activity and marine environments. – *Chemical Geology* 334: 171–181.

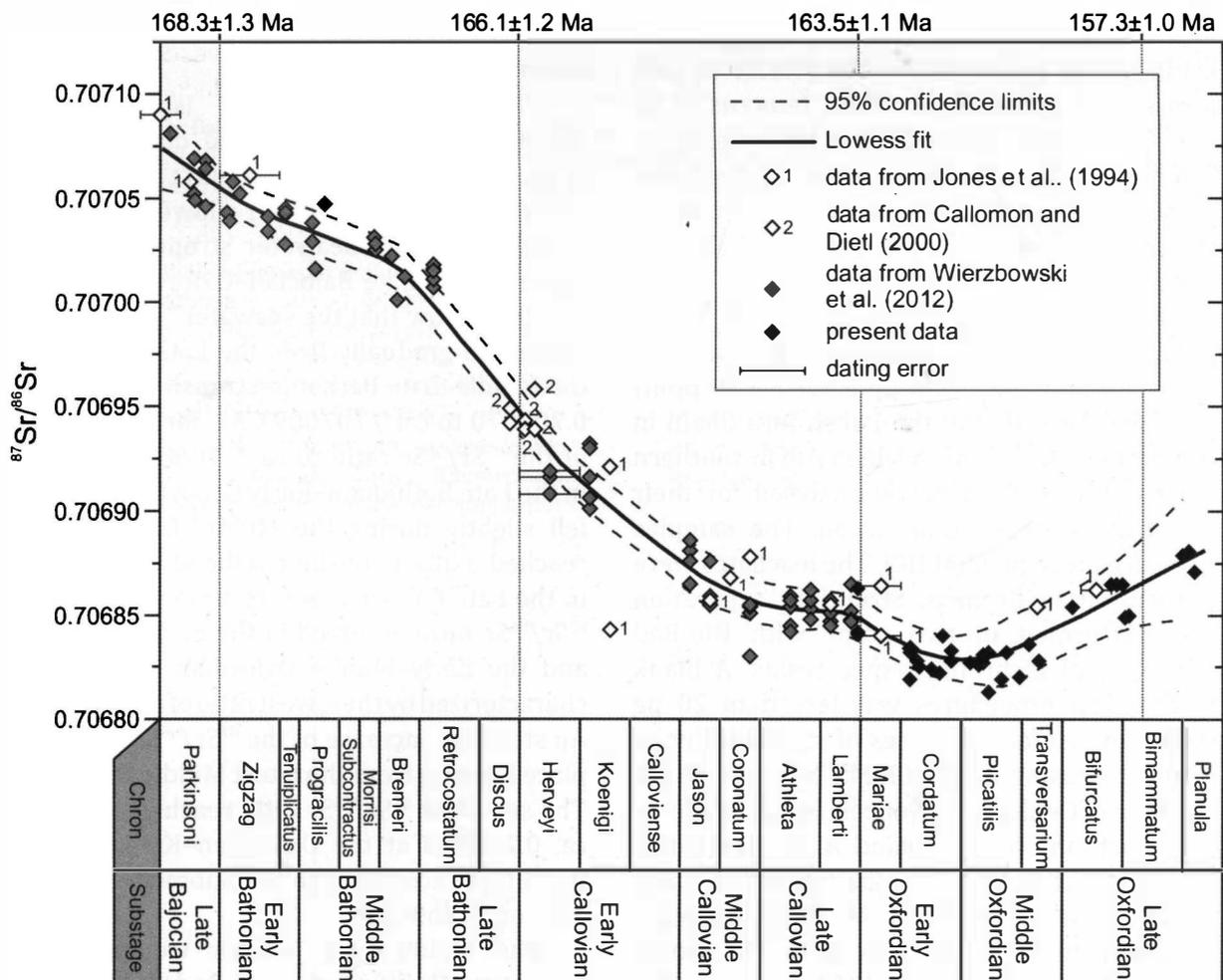


Fig. 1. Strontium isotope variations in Late Bajocian–Oxfordian seawater. The time scale of the diagram is based on the assumed equal duration of ammonite subchrons. Dating errors higher than one subchron are marked.

Orbital cyclicity and its environmental response – a case study from the Upper Bathonian of Central Poland

PIOTR ZIÓŁKOWSKI¹ *, TOMASZ WERNER², ZOFIA DUBICKA³ & LINDA A. HINNOV⁴

¹Faculty of Geology, University of Warsaw, PL-02-089 Warsaw, Poland; E-mail: pziolkow@uw.edu.pl

²Institute of Geophysics, Polish Academy of Sciences, PL-01-452 Warsaw, Poland; E-mail: twerner@igf.edu.pl

³Faculty of Geology, University of Warsaw, PL-02-089 Warsaw, Poland; E-mail: z.dubicka@uw.edu.pl

⁴Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, USA; E-mail: hinnov@jhu.edu

*Corresponding author

Upper Bajocian to Upper Bathonian black clays and siltstones with ironstone concretions are known as the Ore Bearing Czeszochowa Clay Formation which is famous due to the wealth of extraordinarily preserved ammonites. They have been known since the nineteenth century and are the basis for a very detailed chronostratigraphic interpretation (MATYJA et al. 2006). The Ore Bearing Czeszochowa Clay Formation is currently well exposed in the Czeszochowa Region in several clay pits.

The macroscopically monotonous rocks were the focus of very detailed magnetic susceptibility (MS) investigations. The output MS signal was subjected to spectral analysis (ZIÓŁKOWSKI & HINNOV 2009) that showed a strong bundling pattern which corresponds to the ratio of orbital Milankovitch cyclicity. Samples for further investigations were collected from the MS extrema to answer the question, whether there is any more evidence for environmental response to a changing insolation.

Analysis of magnetic hysteresis parameters using the MicroMag™ magnetometer and a method described by BORRADAILE & WERNER (1994) allowed us to estimate the relative content of diamagnetic, paramagnetic, and ferromagnetic minerals in selected samples. We found that only several percent of the MS depends on the presence of ferromagnetic grains and their content varies only slightly within particular samples. MS variations are caused by the changing proportions of paramagnetic and diamagnetic minerals in the studied succession.

X-ray diffraction analyses on sedimented,

glycolated and heated samples have allowed to identify illite, kaolinite, chlorite, quartz, and calcite as the rock forming minerals. XRD semi-quantitative analysis has shown that specimens with the highest MS values contain relatively more illite (paramagnetic) and less kaolinite (diamagnetic) than the specimens with the lowest MS values which contain relatively less illite and more kaolinite.

In the last step of our investigations we studied foraminifera from selected samples. The analyses were carried out in the $\geq 75 \mu\text{m}$ size fraction and an average number of 300 specimens of foraminifera per sample was identified and counted. In general, the Bathonian clays yield rich and well-preserved foraminiferal assemblages dominated by benthic foraminifera; planktonic foraminifera occur only sporadically (cf. SMOLEŃ 2012). More than 30 species of the genera *Ammobaculites*, *Astacolus*, *Epistomina*, *Flabellinella*, *Fronicularia*, *Garantella*, *Geinitzinita*, *Conoglobigerina*, *Ichthyolaria*, *Lagena*, *Lenticulina*, *Nodosaria*, *Ophthalmidium*, *Palaeomiliolina*, *Paalzowella*, *Planularia*, *Pseudoglandulina*, *Reophax*, *Reinholdella*, *Spirillina*, and *Saracenaria* were recorded (Fig. 1). This study reflects strong cyclic fluctuations of the foraminiferal assemblages. Some samples are almost monospecific assemblages in which 90% of the individuals belong to *Epistomina nuda* TERQUEM. Other samples show very high taxonomic diversity with a high content of *Epistomina*, *Ophthalmidium*, *Lenticulina*, *Palaeomiliolina*, and *Spirillina*.

The cyclic record of the foraminifers is well correlated with the magnetic susceptibility record and the illite/kaolinite content. Periods of

cooler climatic conditions are characterized by the opportunistic foraminifer *Epistomina nuda* TERQUEM and the prevalence of illite – a product of weathering in a cool and dry climate. On the contrary, during relatively warm conditions the foraminiferal assemblages were characterized by high diversity and the sediment by a higher content of kaolinite, formed in a humid and warm climate.

References

- BORRADAILE, G.J. & WERNER, T. 1994. Magnetic anisotropy of some phyllosilicates. – *Tectonophysics* 235: 223–248.
- MATYJA, B., WIERZBOWSKI, A., GEDL, P., BOCZAROWSKI, A., KAIM, A., KEDZIERSKI, M., LEONOWICZ, P., SMOLEN, J., SZCZEPANIK, P. & WITKOWSKA, M. Field trip B1 - Biostratigraphical framework from Bajocian to Oxfordian. In: WIERZBOWSKI, A. et al. (eds.), *Jurassic of Poland and adjacent Slovakian Carpathians. Field trip guidebook of 7th International Congress on the Jurassic System*; Poland, Kraków, September 6-18, 2006: 149–152, Polish Geological Institute, Warsaw.
- SMOLEŃ, J. 2012. Faunal dynamics of foraminiferal assemblages in the Bathonian (Middle Jurassic) ore-bearing clays at Gnaszyn, Kraków-Silesia Homocline, Poland. – *Acta Geologica Polonica* 62: 403–419.
- ZIÓŁKOWSKI, P. & HINNOV, L.A. 2009. Cyclostratigraphy of Bathonian using magnetic susceptibility – preliminary report. In: KROBICKI, M. (ed.), *Jurassica VIII, Vrsatec 09-11.10.2009*, *Geologia*, 35 3/1: 115 (in Polish).

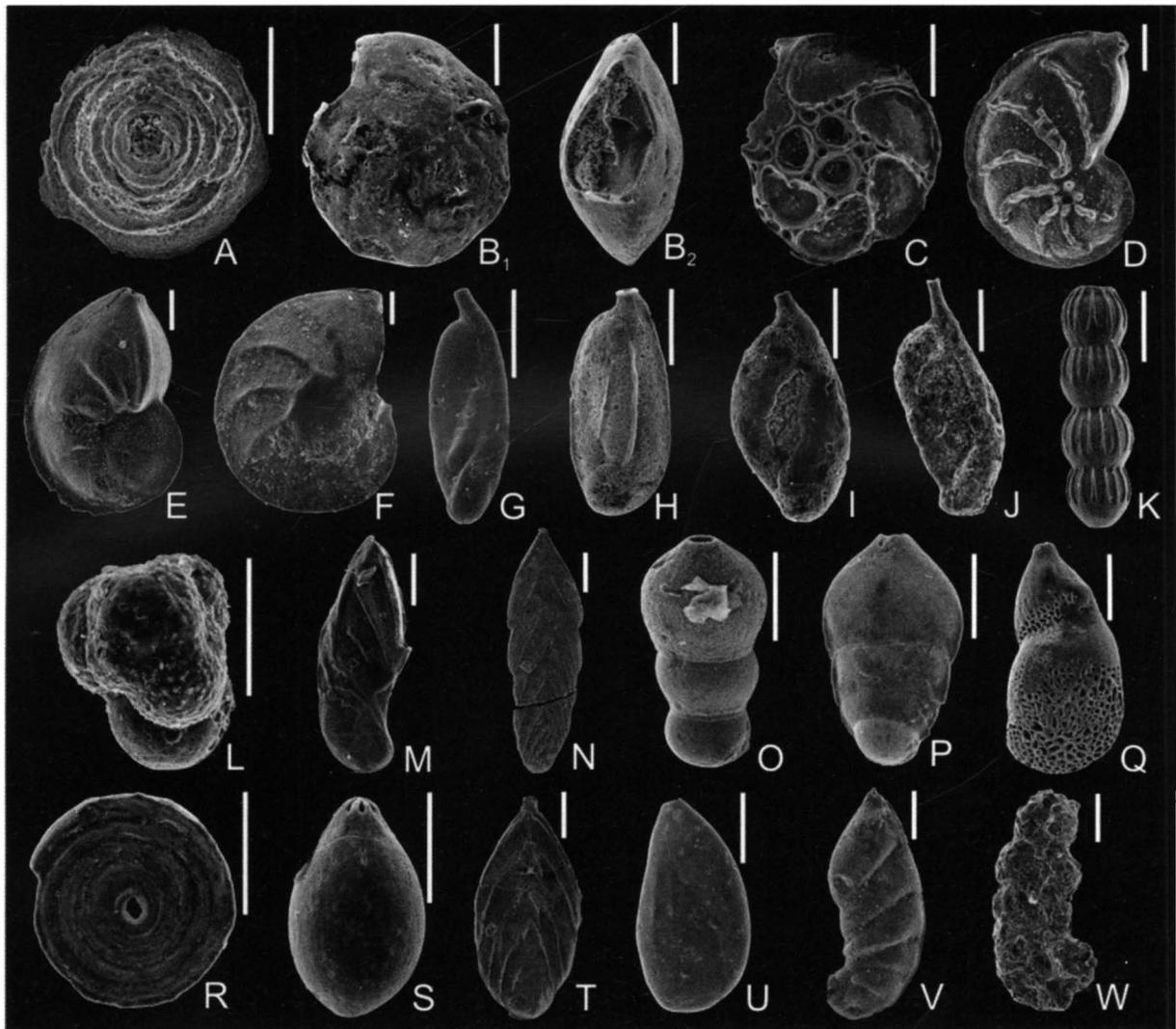


Fig. 1. Foraminifers from the Upper Bathonian ore-bearing Czestochowa Clay Formation. A. *Paalzowella pazdroe* BIELECKA; B. *Epistomina nuda* TERQUEM; C. *Epistomina regularis* TERQUEM; D. *Lenticulina (Astaculus) argonauta* (KOPIK); E. *Lenticulina muensteri* (ROEMER); F. *Lenticulina helios* (TERQUEM); G. *Ophthalamidium* sp.; H. *Palaeomiliolina czestochowiensis* PAZDROWA; I, J. *Ophthalamidium carinatum agglutinans* PAZDROWA; K. *Nodosaria pulchra* (FRANKE); L. *Conoglobigerina bathoniana* (PAZDROWA); M. *Planularia prava* (FRANKE); N. *Flabellinella* sp.; O. *Pseudoglandulina tenuis* (BORN); P. *Frondicularia cf. lingulaeformis* SCHWAGER; Q. *Lenticulina (Astaculus) dictyotes dictyotes* (DEECKE); R. *Spirillina radiata* TERQUEM; S. *Lagena globosa* (MONTAGU); T. *Frondicularia* sp.; U. *Planularia cordiformis* (TERQUEM); V. *Planularia filosa* (TERQUEM); W. *Ammobaculites coprolithiformis* (SCHWAGER); scale bar: 100 μ m.

Index of Contributors

Agarwal, A.	11	Echevarría, J.	43
Alberti, M.	13	Fan, R.	45
Al-Saad, H.	16	Farboodi, M.	96
Alsen, P.	32, 118	Feldman-Olszewska, A.	101
Al-Suwaidi, A. H.	17	Felsch, T.	67
Anczkiewicz, R.	207	Fernandez-Lopez, S. R.	54, 134
Angelozzi, G. N.	17	Fortwengler, D.	139
Arabas, A.	19	Frid, C. L. J.	57
Arai, M.	50	Fürsich, F. T.	13, 59, 67, 124
Bardhan, S.	182	Galbrun, B.	139
Barski, M.	21	Gardin, S.	139
Bartolini, A.	139	Garg, R.	151
Baudin, F.	17	Garg, S.	151, 153, 155
Bayon, G.	48	Gill, B. C.	34
Bazarnik, J.	207	Glinskikh, L.	120
Bhatt, N. Y.	23, 88, 190	Głowniak, E.	60
Bhaumik, S.	126	Golej, M.	179
Biswas, S. K.	26	Gosling, W. D.	94
Blau, J.	28	Grădinaru, M.	103, 105
Błażejowski, B.	29	Gregory, F. J.	92
Boulila, S.	139	Gröcke, D. R.	34, 147
Braham, B.	92	Guillou, H.	137
Brahim, El Hadj Y.	31	Gulyaev, D.	62
Brański, P.	145	Gupta, M.	151, 153, 155
Budiel, C. C.	54	Gurav, S. S.	65
Caillaux, V. C.	54	Guzhov, A.	48
Callomon, J. H.	32	Haggart, J.	48
Caruthers, A. H.	34, 73, 147, 188	Hammer, Ø.	75
Caswell, B. A.	36, 57	Hesselbo, S. P.	17, 66
Chadi, M.	31	Hethke, M.	13, 67
Charbonnier, G.	48	Hillebrandt, A. von	70
Chaudhari, A.	38	Hinnov, L. A.	209
Chauhan, G.	39	Hnylko, O.	101
Chinnappa, C.	158	Hodbod, M.	21, 143
Coe, A. L.	36, 40, 94	Hou, P.	34, 73, 147
Coimbra, R.	41	Hryniewicz, K.	75
Collin, P.-Y.	139	Huault, V.	139
Condon, D.	17	Huret, E.	139
Cuny, G.	48	Ippolitov, A.	62, 77, 79
Damborenea, S. E.	17, 43	Ishida, N.	81
Delsate, D.	48	Ivanov, A.	120
Deng, S.	45	Ivanova, D.	179
Dera, G.	48	Iwańczuk, J.	83, 101
Dommergues, J.-L.	115	Izumi, K.	93
Duarte, S.	50	Jach, R.	195
Dubicka, Z.	209		
Dzyuba, O. S.	52, 120, 185		

Jacob, D.	193	Mitta, V.	118, 120
Jadhav, P. B.	11	Monna, F.	137
Jain, R. L.	85	Mukherjee, D.	122
Jain, S.	153	Munsch, H.	59
Jaitly, A. K.	86		
Jenkyns, H. C.	17	Nakrem, H. A.	75
Jha, N.	50, 87	Niedźwiedzki, G.	145
Joachimski, M.	193	Nieto, L. M.	167
Jodhawat, R. L.	85	Nomade, S.	137
Joseph, J. K.	88		
Joshi, H.	87	Olev, V.	75
		Olóriz, F.	41, 197
Kachhara, R. P.	85		
Kaim, A.	75	Pan, Y.	124
Kale, A. S.	11	Pandey, B.	133
Kelly, S. R. A.	92	Pandey, D. K.	13, 126, 127, 128, 151, 153
Kemp, D.	93		
Kennedy, A. E.	94	Patel, J. M.	190
Khaksar, A.	96	Patel, N. J.	129
Khaksar, K.	96	Patel, S. J.	23, 88, 129, 155, 190
Khosla, A.	98	Pathak, D. B.	133
Khosla, S. C.	100	Pavia, G.	134
Kimoto, K.	81	Pawlak, J.	207
Kiselev, D.	62	Pellenard, P.	137, 139
Kishimoto, N.	81	Pestchevitskaya, E. B.	141
Korte, C.	66	Pieńkowski, G.	143, 145
Kostyleva, V.	120	Pooniya, D.	127
Krobicki, M.	101, 105	Popa, M. E.	105
Kulkarni, K. G.	65	Popov, E.	48
Kupriyanova, E.	77	Porter, S. J.	34, 73, 147
Kurihara, T.	81	Prakash, N.	87, 148
		Prunier, J.	48
		Pucéat, E.	48
Lal, M. M.	108		
Lathuilière, B.	179	Rai, J.	150, 151, 153, 155
Lazăr, I.	103, 105	Rajanikanth, A.	158
Lewandowski, M.	204	Ranawat, T. S.	161
Li, X.	45	Randrianaly, H. N.	162
Little, C. T. S.	75	Rasoamiaramanana, A.	162
López Correa, M.	193	Reolid, M.	163, 165, 167
Lu, Y.	45	Riccardi, A.	17
		Riding, J. B.	94
Majidifard, M. R.	107	Rodríguez-Tovar, F. J.	167
Manceñido, M.	17	Rogov, M. A.	48, 169, 171, 174
Manisha, K.	108	Roy, P.	176
Marchand, D.	139		
Marok, A.	165	Sadki, D.	177
Martire, L.	137	Sadooni, F.	16
Matsuoka, A.	81, 110	Saldivar, E. G.	54
Mattioli, E.	167	Sandy, M. R.	75
Matyja, B. A.	21, 29, 111, 113	Schlögl, J.	19, 79, 179, 193
Meister, C.	28, 115	Sebane, A.	165
Misra, A.	116		

Selby, D.	147
Seltzer, V.	120
Sha, J.	181
Shchepetova, E. V.	174
Shome, S.	182
Shukla, H.	155
Shurygin, B. N.	120, 185
Sidorczuk, M.	204
Singh, A.	151, 153, 155
Smith, P. L.	34, 48, 73, 147, 181, 188
Sobień, K.	83
Solanki, P. M.	190
Srivastava, N.	161
Strogen, D. P.	92
Surlyk, F.	32
Swami, N.	128
Thakkar, M. G.	39, 192
Thakur, B.	155
Thierry, J.	139
Thies, D.	48
Tomašových, A.	179, 193
Uchman, A.	195
Ullmann, C. V.	66
Vidhya, S.	108
Villaseñor, A. B.	197
Villier, L.	179
Vlahovic, I.	204
Vuks, V. J.	200
Werner, T.	204, 209
Whitham, A. G.	92
Wierzbowski, A.	19, 21, 29, 111, 113, 174
Wierzbowski, H.	29, 174, 205, 207
Wilmsen, M.	59
Yoshino, T.	81
Ziółkowski, P.	209



Middle Oxfordian Passendorferiinae (Perisphinctidae, Ammonoidea) from Estepa (Seville, Betic Cordillera, S Spain): Evolution, biostratigraphy and biogeographic meaning.

Meléndez Guillermo^{a*}, Yáñez-Jerónimo, Juan de Dios^b, Sequeiros, Leandro^c,
Affiliation and address including e-mail – Font size 12, italics

a Departamento de Geología, universidad de Zaragoza, c./ Pedro Cerbuna 12, E-50009 Zaragoza, (Spain, Email-gmelende@unizar.es

*b c./ La Roda de Andalucía, 19, E-41560 Estepa, Sevilla Spain, E-mail- juyaje@hotmail.com
c c./ Pintor El Greco 8, 5°. E-14004 Córdoba (Spain) Email- lsequeiros@probesi.org*

** Corresponding author*

References to the Jurassic of the surroundings of Estepa (Sevilla) in the so-called “Subbetic Zone” of the Betic Cordillera (S Spain) are scarce and scattered. First detail studies and ammonite biostratigraphic data come from Sequeiros (1974) who studied the Callovian-Oxfordian ammonite successions in the surroundings of Estepa, (the so-called: “*Sierra de Estepa*”) including such sections as Arroyo seco, Acebuchosa and Puente Genil, as well as some quarries around the town. Above the Callovian-Oxfordian boundary, within a 4-5 m thick nodular limestone interval (*Rosso ammonitico* facies) ammonite successions recognized in these localities have allowed characterising the middle and upper part of the Transversarium Biozone (referred to by this author as the *Riazi Biozone*) the upper part of the Bifurcatus Biozone and the lower part of the upper Oxfordian, including the Hypselum and lower Bimammatum biozones. More recent samplings carried out by J.D. Yáñez have allowed gathering an interesting collection of well preserved specimens adding new information to the existing data and confirming the good possibilities of the sections and of the studied interval (Meléndez *et al.*, 2013). Among the taxa recognized, it is worth mentioning the good collected specimens of oppeliids, (*Taramelliceras*) together with abundant representatives of *Gregoryceras*, *Mirosphinctes*, *Euaspidoceras* and most particularly, representatives (M and m) of Passendorferiinae. Among them, it is especially noteworthy the record of numerous specimens of *Pass. (M & m) erycensis* Meléndez (= *Per. regalmicensis* Gemmellaro, 1877; non 1874; Fig 1a) and *Sequeirosia cf. brochwiczi* (Sequeiros, 1974). This association, together with common specimens of *Gregoryceras* of the group *riazi* (Grossouvre), *Mirosphinctes* and *Glochiceras* of the group *subclausum* (Oppel)-*crenatum*, allows characterizing the Luciaeformis-Schilli subbiozones of the Transversarium Biozone (= *Riazi Biozone*, Sequeiros). A recorded specimen of *Passendorferia*, close to *Pass.*

erycensis, (Fig. 1b) holds a particular interest as it shows an early ontogenetic stage closely comparable to the inner whorls of the original type of *Per. regalmicensis* Gemmellaro (1874, Pl XIV, fig 3a,b) a rather little known form, very rarely quoted besides the type specimen, which is a poorly preserved wholly septate inner whorl of a macroconch. This would suggest a close phylogenetic relationship between both forms and explain the possible origin of *Pass. regalmicensis* from its presumable ancestor *Pass. erycensis*, by means of a proterogenetic process. At the same time, this faunal similarity should reflect the biogeographic connection



Fig 1a



Fig 1b

Figure 1. (a) *Passendorferia erycensis* Meléndez: adult microconch. (b) Specimen (septate adult macroconch) showing a ribbing similar to the type specimen of *Pass. regalmicensis* Gemmellaro 1874, in inner whorls.

between both epiocenic areas (Betics and the Trapanese domain; Nw Sicily) during middle Oxfordian. The general aspect of the type of *Pass. regalmicensis* Gemm, characterized by the evolute slow coiling and the thick ribbing sets it closer to the representatives of *Bifurcatus* Biozone than to those of middle-late *Transversarium* Biozone. It seems that the stratigraphic interval formed by the subbiozones *Rotoides*, *Stenocycloides* and *Grossouvrei*, or the corresponding ammonite recorded associations, is well represented in the studied area, which might not always be the case in other regions of the Subbetic Zone or in Sicily (D'Arpa *et al.* 2004).

All studied specimens (macro and microconch) from all subfamilies, are adult individuals, no specimens showing juvenile stage features having been recorded. Among the microconch representatives of subfamilies *Glochiceratinae*, *Taramelliceratinae* and *Peltoceratinae*, specimens preserving the adult body chamber or even the peristome are not uncommon. Among the macroconchs instead, complete specimens are virtually absent, all studied specimens being incomplete phragmocones. They are generally fragmented or show a disarticulation surface along a septum, displaying a clear lithological, textural and structural

discontinuity between the infilling (micritic limestone) and the surrounding matrix, more typically bioclastic or even including micritic fossil fragments. They, hence, constitute reelaborated elements, categorized as fragmented or disarticulated internal moulds. Specimens showing truncation facets are less common to absent. The more or less complete microconch specimens, although being preserved as peristomed shells, are also reelaborated elements, showing similar discontinuity between the micritic infilling and the surrounding bioclastic matrix. From the biochronological point of view the analysed recorded associations represent the late *Transversarium* (Schilli-Rotoides) and *Bifurcatus* (mainly *Grossouvrei*) taxorrecords. From the biostratigraphical point of view the reelaborated ammonite recorded associations are diachronic with (older than) the beds containing them. However, the homogeneity of the assemblages and the recognized general absence of diachronic specimens in the same associations are criteria against a high diachrony between the recorded associations and the beds containing them. From the biogeographic point of view, the studied ammonite associations constitute taphonic populations of *type 3*, i.e. representing allochthonous and ademic elements. However, the taxonomic and biogeographic homogeneity of the associations, typically Tethyan (*Passendorferiinae*) with very scarce representatives of *Perispinctinae*, suggests local (regional) drift of adult shells from near, deeper platform areas.

Acknowledgements:

Research project CLG 2011-21947/BTE (MICIIN). Research team (consolidated Groups) E-17 from the Government of Aragón (DGA) Spain.

References

- D'Arpa, C. & Meléndez, G. 2004. Middle to early upper Oxfordian ammonite associations from West Sicily. *Rivista Italiana di Paleontologia*, 110 (1), 255-267.
- Gemmellaro, G.G. (1874) – Sui fossili della Zona con *Peltoceras transversarium* Quenst. sp. della Provincia di Palermo e di Trapani. *Atti Accad. di Sci., Lett., ed Arti di Palermo*. 4: 11 p., Palermo.
- Gemmellaro, G.G. (1877) – Sopra alcuni fossili della zona con *Peltoceras transversarium*, Quenstedt del Monte Erice or San Giuliano. *Giorn. Sci. Nat. Econ.* XII: 82-98, Palermo.
- Meléndez, G., Yáñez, J.D., Sequeiros, L. 2013. Las sucesiones de ammonites del Oxfordiense de Estepa (Sevilla, cordilleras Béticas): interés paleontológico y bioestratigráfico. In: *Trending Topics in Paleontology*. (Navas-Parejo, P., Martínez-Pérez C., Pla-Pueyo, S. eds), 69-70. Atarfe, Granada.
- Sequeiros, L. 1974. *Paleobiogeografía del Calloviense y Oxfordiense en el sector central de la Zona Subbética*. I: *Bioestratigrafía*, II: *Paleontología*. Tesis Doctorales Univ. Granada, 65, (I): 275 p. (II): 360 p.

The 9th International Congress on the Jurassic System

January 6 - 9, 2014

Jaipur, Rajasthan, India.



Souvenir & Technical sessions

Organized by:

Department of Geology
University of Rajasthan



&

Department of Science & Technology
Government of Rajasthan
Jaipur, India

Venue: Birla Auditorium, Jaipur, India

The Jurassic Origin, Cretaceous Evolution and Diversification of Planktic Foraminifera and the need for search of its origin in India: Overview

Raju Venkatachalapathy

Department of Geology, Periyar University, Salem-636011, India

Email-rvenkatachalapathy@gmail.com

The planktic foraminifera appeared during the Jurassic period (Caron & Homewood, 1983) indicating that the planktic foraminifera evolved from pre-existing benthic ancestors, as is the case in a number of other groups of organisms (Tappan & Loeblich, 1973). During the Jurassic the extent of the oceans was far more widespread than they had been in the Triassic. The Jurassic sea level rose and flooded large portions of the continents across the world. The Jurassic and Cretaceous succession in India has yielded rich varieties of fauna and flora. The planktic foraminifera are one of the most abundant and best studied stratigraphic records among the fossil group. Planktic foraminiferal diversity and ranges make them suitable for evolutionary studies. The phylogenetic evolution of planktonic foraminifera is considered closely associated with global and regional changes in climate and oceanography.

It is generally agreed that the planktic foraminifera group probably evolved from a benthic ancestor via a meroplanktic (partially planktic) stage into a holoplanktic (totally planktic) mode of life in the Mid-Jurassic (Bajocian) sea-level highstand (Haq et al., 1987) enforced the evolution and distribution of the early planktic foraminifera. Fuchs (1967) described a group of 'Trias-Globigerinen' and suggested that this was the first group with a planktic mode of life. According to Fuchs' (1975) scheme, the Triassic genus *Oberhauserella* was the ancestor of the Jurassic planktic genera *Conoglobigerina* and *Praegubkinella* and gave rise to the evolution and diversification of the planktic foraminifera. Hart et al. (2003) confirm that the ancestral stock of planktic foraminifera is identified as *Oberhauserella quadrilobata* s.s..

According to Hemleben *et al.* (1989) the sea surface temperature is one of the controlling factors for evolutionary trends. During cold periods, the diversity of species decreases and the morphology of the tests become simple, whereas in the species radiate and spread to various ecological niches with newly evolving species. Throughout the Mesozoic the evolution and diversification of planktic foraminifera appears to coincide with the repeated development of anoxic water masses in the world oceans and a subsequent sea-level rise (Leckie, 1985, 1987, 1989, Hart *et al.* 2003; Leckie *et al.*, 2002).

The appearance of foraminifera with a planktic mode of life in the Mesozoic was arguably the most important event in the entire evolutionary history of foraminifera, as subsequently their development had a significant impact on the whole marine biosphere (Boudagher-Fadel, 2013). She indicated that the planktic foraminifera made their first appearance in the Late Triassic (Fig. 1). The planktic mode of life evolved again independently in the Jurassic, with the appearance of the Conoglobigerinidae in the Late Bajocian. Simmons *et al.* (1997) recorded the oldest known planktic species viz. *Conoglobigerina avariformis* Kasimova, *C. balakhmatovae* (Morozova), *C. dagestanica* Morozova and (?) *C. avarica* Morozova from the Bajocian of eastern Europe. Initially the benthic forms evolved as partially planktic (meroplanktic) and finally evolved as fully planktic mode (holoplanktic) and widespread taxon. The Conoglobigerinids seem to persist across the Jurassic-Cretaceous boundary, but their occurrence in the Upper Jurassic is rare and across the Jurassic-Cretaceous boundary the record is very incomplete.

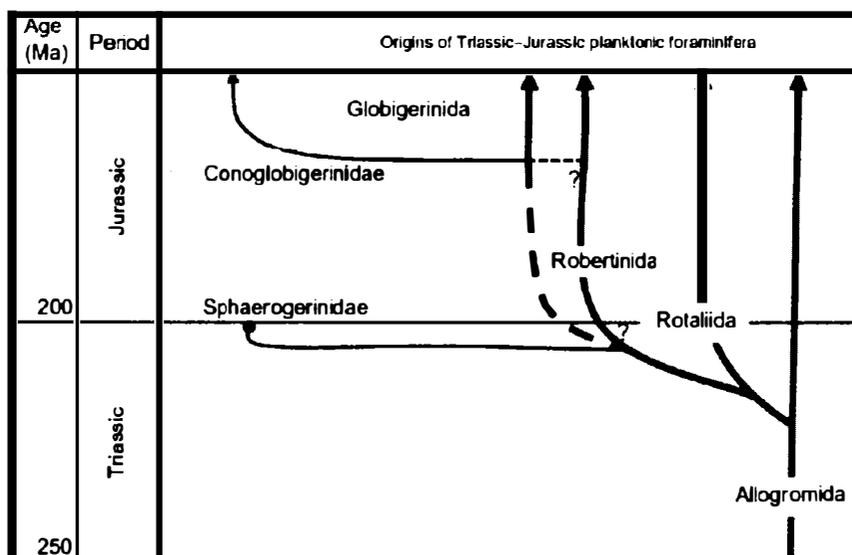


Fig. 1. The evolution of early planktonic foraminifera (Boudagher-Fadel, 2013).

After examining Fuchs collections in Vienna, Hart (2010) opined that, "it is unlikely that any of these Triassic taxa exhibited a planktic mode of life". He suggested that the earliest Conoglobigerina are probably derived from Oberhauserella-Praegubkinella lineage in the mid-Toarcian, in association with the post-extinction event recovery. In the Bajocian of Carpathians in Poland and the Bakony Mountains in Hungary there is evidence of the first foraminiferal ooze in red limestone facies. In these successions there is a 99:1 % planktic:benthic (P/B) ratio and the rocks can be described as foraminiferal packstones. It was in the region of the Jurassic-Cretaceous boundary that the planktic foraminifera changed their tests from aragonite to calcite: a transition yet to be documented. After remaining a low diversity assemblage, with quite restricted distribution, in the earliest Cretaceous, the planktic foraminifers evolved and diversified in the middle and late Cretaceous until a final warming pulse in the latest Maastrichtian was followed by evidence of cooling immediately before the K/Pg boundary (Hudson et al. 2009, Hart et al. 2012). Hart et al., (2003) are of the opinion that the Early Toarcian Oceanic Anoxic Event in combination with a sea-level highstand as the triggering mechanism for a change from a benthic to a planktic mode of life (Fig. 2).

In spite its importance, their origin in Jurassic rocks of India and their evolution and diversification in Cretaceous of India are less understood. While there are still many questions to resolve, new data from Jurassic and Cretaceous sediments from India may provide some answers or support to the evolution of the planktic foraminifera. The taxonomy and stratigraphic distribution of Cretaceous planktic foraminifera are also revised. Understanding the evolution of foraminifera will be usefulness in correlation of marine strata and paleobiogeography.

References

- Bolli, H.M., Saunders, J.B., Perch Nielson, K. 1985. Plankton stratigraphy. Cambridge University Press, Cambridge, 1032 pp.
- Boudagher-Fadel M.K. 2013. Biostratigraphic and Geological Significance of Planktonic Foraminifera. (2nd ed.). Office of the Vice Provost (Research), UCL: London, UK. 287 pp.

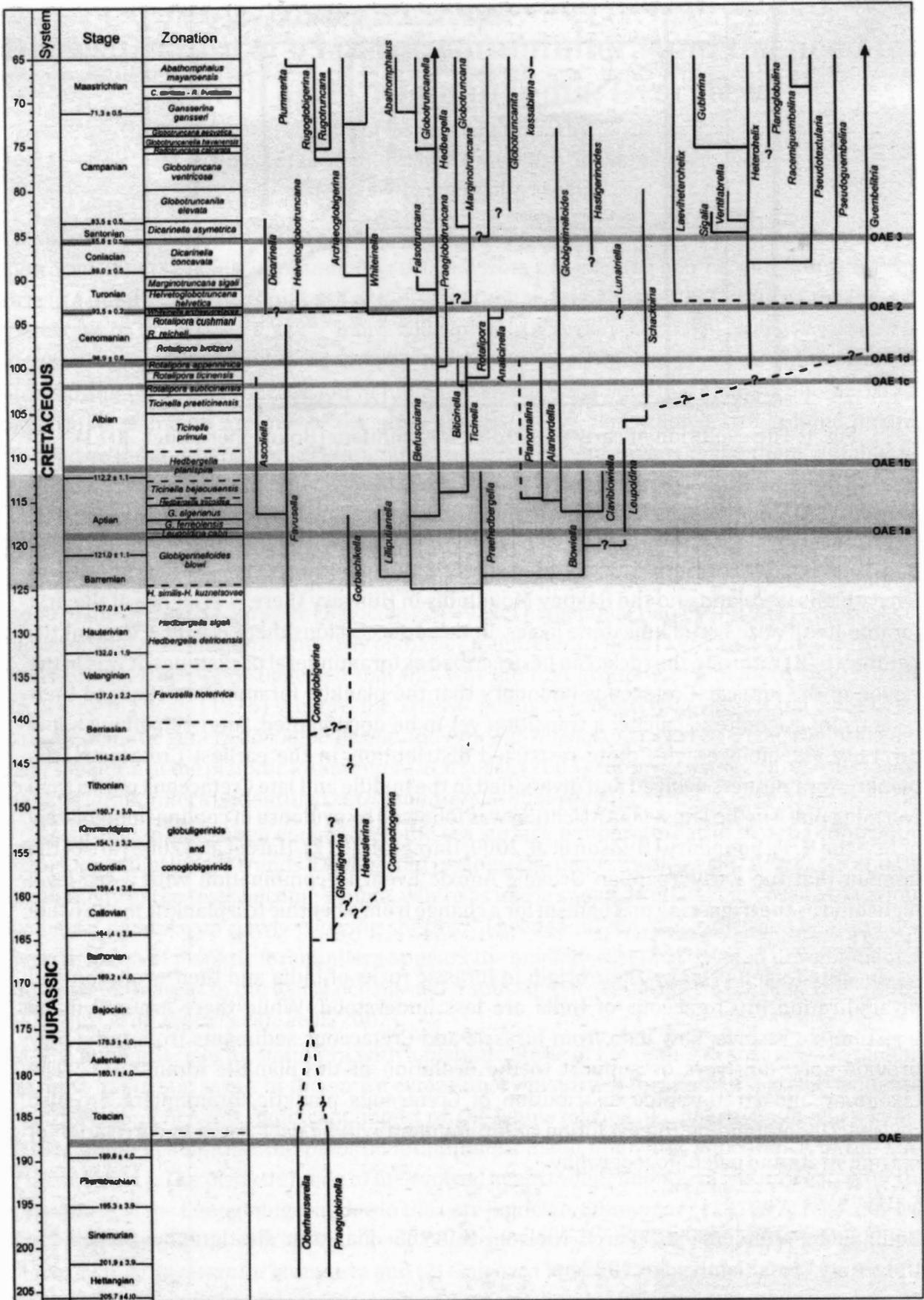


Fig. 2: Jurassic origin and Cretaceous evolution of planktic foraminifera (Hart et al., 2003), with biostratigraphical zonation of Sliter (1989) and Premoli Silva and Sliter (1999).

Caron, M. & Homewood, P. 1983. Evolution of early planktic foraminifera. *Marine Micropaleontology*, 7: 453-462.

Fuchs, W. 1967. Über Ursprung und Phylogenie der Trias-'Globigerinen' und die Beurteilung dieses Formenkreises für das echte Plankton. *Verh. Geol. Bundesanst. Wien* 1-2: 135-161.

Fuch, W. 1975. Detailuntersuchungen an Trias-"Globigerinen" mit Hilfe eines Rasterelektronenmikroskopes. *Verh. Geol. B.-A.*, 4: 235-246, Wien.

Hart, M.B., Hudson, W., Smart, C.W. & Tyszka, J. 2012. A reassessment of '*Globigerina bathoniana*' Pazdrowa, 1969 and the palaeoceanographic significance of Jurassic planktonic foraminifera from southern Poland. *Journal of Micropaleontology*, 31: 97-109.

Hart, M.B., Hylton, M.D., Oxford, M.J., Price, G.D., Hudson, W., & Smart, C.W. 2003. The search of the origin of the planktic Foraminifera. *Journal of the Geological Society, London*, 160: 341-343.

Haq, B.U., Hardenbol, J., & Vail, P.R. 1987. Chronology of fluctuating sea levels since the Triassic. *Science*, 235: 1156-1167.

Hemleben, Ch., M. Spindler, & O. R. Anderson. 1989. *Modern Planktonic Foraminifera*, Springer Verlag, Berlin, 363 pp.

Hudson, W., Hart, M.B., & Smart, C.H. 2009. Palaeobiogeography of early planktonic foraminifera. *Bulletin Society Géology. France*, 180: 2738.

Leckie, R.M. 1985. Foraminifera of the Cenomanian-Turonian boundary interval, Greenhorn Formation, Rock Canyon Anticline, Pueblo, Colorado. In: Pratt, L.M. Kauffman, E.G., Zelt, F.B. (Eds.), *Fine-Grained Deposits and Biofacies of the Cretaceous Western Interior Seaway: Evidence of Cyclic Sedimentary Processes*. SEPM Field Trip Guidebook 4, Tulsa, pp. 139-149.

Leckie, R.M. 1987. Paleoecology of mid-Cretaceous planktonic foraminifera: A comparison of open ocean and epicontinental sea assemblages. *Micropaleontology*, 33: 164-176.

Leckie, R.M. 1989. A paleoceanographic model for the early evolutionary history of planktonic Foraminifera. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 73: 107-138.

Leckie, R.M., Bralower, T.J. & Cashman, R. 2002. Oceanic anoxic events and plankton evolution: Biotic response to tectonic forcing during the mid-Cretaceous. *Palaeoceanography* 17(3): 10.2029/2001PA000623.

Lipps, J.H., 1970. Plankton evolution. *Evolution*, 24: 1-22.

Premoli Silva, I. & Sliter W.V. 1999. Cretaceous paleoceanography: Evidence from planktonic foraminiferal evolution. *Geological Society of America. Special Paper*, 332: 301-328.

Simmons, M.D., BouDagher-Fadel, M.K., Banner, F.T. & Whittaker, J.E. 1997. The Jurassic Favosellacea, the earliest Globigerinina. In: BouDagher-Fadel, M.K., Banner, F.T., Whittaker, J.E. (Eds.). *The Early Evolutionary History of Planktonic Foraminifera*. Chapman & Hall, London: 17-51.

Sliter, W.V. 1989. Biostratigraphic zonation for Cretaceous planktonic foraminifers examined in thin sections. *Journal of Foraminiferal Research*, 19: 1-19.

Tappan, H., & Loeblich, A.R., 1973. Evolution of the oceanic plankton. *Earth Science Reviews*, 9: 207-240.

List of the participants attending the 9th International Congress on the Jurassic System

Mr. El Hadj	Youcef Brahim	Algeria	<i>wahidyb@yahoo.fr</i>
Prof. Alberto	C. Riccardi	Argentina	<i>riccardi@fcnym.unlp.edu.ar</i>
Prof. Miguel	Oscar Mancenido	Argentina	<i>mmanceni@ciudad.com.ar</i>
Dr. Susana	Ester Damborenea	Argentina	<i>sdambore@fcnym.unlp.edu.ar</i>
Dr. Sarah	Duarte	Brazil	<i>sarahpalino@yahoo.com.br</i>
Dr. Andrew	Harry Caruthers	Canada	<i>caruthers.andrew@gmail.com</i>
Dr. Jnelle	Young	Canada	<i>caruthers.andrew@gmail.com</i>
Mr. Pengfei	Hou	Canada	<i>phou@eos.ubc.ca</i>
Dr. Sarah	J Porter	Canada	<i>sporter@eos.ubc.ca</i>
Prof. Dong	Ren	China	<i>rendong@mail.cnu.edu.cn</i> <i>rendong@cnu.edu.cn</i>
Prof. Huang	Diyong	China	
Prof. Jingeng	Sha	China	<i>jgsha@nigpas.ac.cn</i>
Dr. Liao	Huanyu	China	<i>342142598@qq.com</i>
Prof. Shenghui	Deng	China	<i>dsh63@petrochina.com.cn</i>
Dr. Yanhong	Pan	China	<i>yhpan@nigpas.ac.cn</i>
Dr. Yaqiong	Wang	China	<i>yqwang@nigpas.ac.cn</i>
Prof. Yongdong	Wang	China	<i>ydwang@nigpas.ac.cn</i>
Dr. Peter	Alsen	Denmark	<i>pal@geus.dk</i>
Prof. Bernard	Lathuilière	France	<i>bernard.lathuiliere@univlorraine.fr</i>
Dr. Guillaume	Dera	France	<i>guillaume.dera@get.obsmp.fr</i>
Dr. Pierre	Pellenard	France	<i>Pierre.Pellenard@u-</i> <i>bourgogne.fr</i>
Prof. Axel	von Hillebrandt	Germany	<i>axel.vonhillebrandt@</i> <i>campus.tu-berlin.de</i>
Dr. Eckhard	Mönnig	Germany	<i>e.moennig@naturkunde-</i> <i>museum-coburg</i>
Prof. Franz	Theodor Fürsich	Germany	<i>franz.fuersich@gzn.uni-</i> <i>erlangen.de</i>
Mrs. Valsamma	Fürsich	Germany	
Dr. Joachim	Blau	Germany	<i>joachim.blau@geolo.unigiessen.de</i>
Ms. Manja	Hethke	Germany	<i>manja.hethke@gzn.unierlangen.de</i>
Mr. Tobias	Felsch	Germany	
Dr. Matthias	Alberti	Germany	<i>alberti@gpi.uni-kiel.de</i>
Miss Simone	Zippel	Germany	
Prof. Rudolph	Scherreiks	Germany	<i>r.scherreiks@hotmail.com</i>

Ms. Luise	Scherreiks	Germany	
Dr. Abha	Singh	India	<i>abha.maurya@gmail.com</i>
Mr. Alok	Chaudhari	India	<i>alok.hhh@gmail.com</i>
Dr. Amita	Gill	India	<i>director-dst@rajasthan.gov.in</i>
Prof. Anand K.	Jaitly	India	<i>anandjaitly@yahoo.co.in</i>
Mr. Anant	Misra	India	
Prof. Anil	Maheshwari	India	<i>dranilmaheshwari@gmail.com</i>
Mr. Ankur	Bairwa	India	
Dr. Annamraju	Rajanikanth	India	<i>rajanikanth.annamraju@gmail.com</i>
Ms. Anshika	Agarwal	India	<i>aanshikageo@gmail.com</i>
Dr. Arpan	Misra	India	<i>arpanmisra@yahoo.com</i>
Prof. Asha	Pande	India	
Dr. Ashu	Khosla	India	<i>khosla100@yahoo.co.in</i>
Mr. B. K.	Meena	India	
Mr. Bhupendra	Kumar Dadheech	India	
Dr. Bindhyachal	Pandey	India	<i>drbpandey@yahoo.co.in</i>
Dr. Chinnappa	Chopparapu	India	<i>chinnabsip@gmail.com</i>
Dr. Debahuti	Mukherjee	India	<i>debahuti.mukherjeegsi@gmail.com</i>
Dr. Dev	Swarup	India	<i>vc@uniraj.ernet.in</i>
Dr. Deo Brat	Pathak	India	<i>dbpathak@yahoo.com</i>
Mr. Dharamveer	Pooniya	India	<i>dharma.geo@gmail.com</i>
Mr. Dheeraj	Kumar	India	
Prof. Dharendra K.	Pandey	India	<i>dhirendrap@hotmail.com</i>
Mr. Dinesh	Saini	India	
Mr. Gaurav	Chauhan	India	<i>gdc_dew@yahoo.com</i>
Mr. Hanuman	Sahay	India	
Mr. Harinam	Joshi	India	<i>harinamjoshi@yahoo.com</i>
Prof. Harsh	Bhu	India	
Dr. Hemant	Pareek	India	
Mrs. Ila Jaitly		India	
Dr. Jagdish M.	Patel	India	<i>jmpbhuj@gmail.com</i>
Ms. Jaquelin K.	Joseph	India	<i>sjpatel@gmail.com</i>
Mr. Jitendra	Sharma	India	
Dr. Jyotsana	Rai	India	<i>jyotsana@yahoo.com</i>
Mr. Kailsh	Chand Sharma	India	
Dr. Kantimati	Girish Kulkarni	India	<i>kantimatik@gmail.com</i>
Mr. Karan	Singh Rajawat	India	
Dr. M.G.	Thakkar	India	<i>mgthakkar@rediffmail.com</i>
Prof. M.K.	Pandit	India	<i>panditmanoj@hotmail.com</i>
Dr. Mamilla	Venkateshwarlu	India	<i>mamila_v@rediffmail.com</i>

Mr. Maneesh	Lal	India	<i>ohmstar987@gmail.com</i>
Dr. Manish	Gupta	India	<i>manish8170@gmail.com</i>
Dr. Manisha	Kumari	India	<i>drmkumari@gmail.com</i>
Mr. Mukesh	Kumar Bairwa	India	
Prof. N.K.	Chauhan	India	
Dr. N.S. Mahla		India	<i>nsmgeo@gmail.com</i>
Mr. Narendra	Swami	India	<i>narendraswami92@rediffmail.com</i>
Mr. Naveen	Kumar Bokoliya	India	
Dr. Neeraj	Srivastava	India	<i>neeraj.shrivastava@golcha.com</i>
Dr. Neerja	Jha	India	<i>neerjajha@yahoo.co.uk</i>
Dr. Neeru	Prakash	India	<i>neerup_in@yahoo.com</i>
Dr. Nishith Y.	Bhatt	India	<i>nybhattmg@yahoo.com</i>
Dr. Paras M.	Solanki	India	<i>parassolankimg@yahoo.com</i>
Mr. Parma	Ram Choudhary	India	
Mr. Parveen	Sharma	India	
Ms. Pinaki	Roy	India	<i>pinakieroy@gmail.com</i>
Mr. Pranay	Prasun Pradhan	India	
Ms. Punyotoya	Paul	India	
Dr R. K.	Saxena	India	<i>saxenarajk1@gmail.com</i> <i>09410390469</i>
Prof. R.	Venkatachalapathy	India	<i>rvenkatachalapathy@gmail.com</i>
Dr. R.L. Jain		India	<i>rljaingsi@gmail.com</i>
Dr. R.L.	Somani		
Prof. R.P.	Kachhara	India	<i>kachharar@yahoo.com</i>
Prof. R. S.	Sharma	India	<i>sharma.r.sw@gmail.com</i>
Dr. Rajan	Parture	India	
Mr. Rajender	Kumar Yadav	India	
Mr. Rajesh	Singh Shekhawat	India	<i>88rajesh88@gmail.com</i>
Mr. Ram	Lal Choudhary	India	
Mr. Raman	Patel	India	
Mr. Rameshwar	Prasad Gurjar	India	
Dr. Ranjana	Singh	India	
Mr. Ravi	Kumar Meena	India	
Mr Roop	Narayan Kuldeep	India	
Prof. S.C.	Khosla	India	<i>sckhosla1@yahoo.com</i>
Prof. S. K.	Manju	India	
Dr. S.K. Biswas		India	<i>sanjibkbiswas2001@yahoo.co.in</i>
Dr. Sabyasachi	Shome	India	<i>sabyasachi60@hotmail.com</i>
Prof. Salil	Agrawal	India	<i>drsaliil@satyam.net.in</i>

Mr. Sanjay	Kumar Dayama	India	
Dr. Satish J.	Patel	India	<i>sjpgeology@gmail.com</i>
Mr. Shaitan	Singh Choudhary	India	
Mr. Sharwan	Lal Meena	India	
Prof. Shekhar	Verma	India	<i>mrfixit4u@gmail.com</i>
Dr. Shishir	Sharma	India	<i>shishirsharma5@gmail.com</i>
Ms. Shweta S.	Gurav	India	<i>shwtgrv@gmail.com</i>
Dr. Shyam N.	Mude	India	<i>shyammude25@yahoo.co.in</i>
Ms. Sneha	Bhaumik	India	<i>dbhaumik588@gmail.com</i>
Dr. Soumna	Datta	India	
Ms. Surabhi	Garg	India	<i>Jyotsana@yahoo.com</i>
Mr. Surendra	Singh Shekhawat	India	
Prof. Sushant	Kanjilal	India	
Prof. Sushma	Sood	India	
Dr. Tej	Bahadur	India	<i>tejbahadurrajawat@gmail.com</i>
Mr. Vineet	Kumar	India	<i>vineetgeology@gmail.com</i>
Prof. Vinod	Agrawal	India	<i>vinodudz@yahoo.com</i>
Mr. Vipin	Kumar	India	<i>vipinmalikjaipur@gmail.com</i>
Mr. Virendra	Kumar Poonia	India	
Mr. Vishavjit		India	
Mr. Yogesh	Kumar	India	
Dr. Mahmoud	Reza Majidifard	Iran	<i>m_majidifard@yahoo.com</i>
Prof. Giulio	Pavia	Italy	<i>giulio.pavia@unito.it</i>
Prof. Atsushi	Matsuoka	Japan	<i>matsuoka@geo.sc.niigata-u.ac.jp</i>
Dr. Naoto	Ishida	Japan	<i>nao.ishida21@mbn.nifty.com</i>
Dr. Munna	Ayesh Alsalameen	Kuwait	<i>munaalsalameen@yahoo.com</i>
Dr. Ana Bertha	Villaseñor Martínez	Mexico	<i>anab@unam.mx</i>
Prof. Driss	Sadki	Morocco	<i>driss.sadki@gmail.com</i>
Mrs. Agnieszka	Zuzanna Arabas	Poland	<i>a.arabas@twarda.pan.pl</i>
Prof. Alfred	Uchman	Poland	<i>alfred.uchman@uj.edu.pl</i>
Prof. Andrzej	Wierzbowski	Poland	<i>andrzej.wierzbowski@pgi.gov.pl</i>
Mrs. Ewa	Wierzbowska		
Dr. Anna	Feldman-Olszewska	Poland	<i>aols@pgi.gov.pl</i>
Dr. Błażej	Błażejowski	Poland	<i>bblazej@twarda.pan.pl</i>
Prof. Bronisław	Andrzej Matyja	Poland	<i>matyja@uw.edu.pl</i>
Dr. Ewa K. Glowniak		Poland	<i>eglownia@uw.edu.pl</i>
Mr. Peter	Pervesler	Poland	
Prof. Grzegorz	Pieńkowski	Poland	<i>grzegorz.pienkowski@pgi.gov.pl</i>
Dr. Hubert	Wierzbowski	Poland	<i>hubert.wierzbowski@pgi.gov.pl</i>

Ms. Jolanta	Iwanzuk	Poland	<i>jiwa@pgi.gov.pl</i>
Ms. Katarzyna	Sobień	Poland	<i>ksob@pgi.gov.pl</i>
Dr. Magdalena	Sidorczuk	Poland	<i>msid@pgi.gov.pl</i>
Prof. Marek	Lewandowski	Poland	<i>lemar@twarda.pan.pl</i>
Mrs Marta	Hodbod	Poland	<i>marta.hodbod@pgi.gov.pl</i>
Mr. Piotr	Szrek	Poland	
Dr. Michal	Krobicki	Poland	<i>krobicki@geol.agh.edu.pl,</i> <i>michal.krobicki@pgi.gov.pl</i>
Dr. Paweł	Brański.	Poland	<i>pawel.branski@pgi.gov.pl</i>
Dr. Piotr	Ziolkowski	Poland	<i>pit@uw.edu.pl</i>
Dr. Hamad	Al-Saad Al-Kuwari	Qatar	<i>hamadsaad@qu.edu.qa</i>
Dr. Iuliana	Lazar	Romania	<i>iuliana.lazar@g.unibuc.ro,</i> <i>iulianalazar_jurassic2014@yahoo.com</i>
Mr.Alexei	Ippolitov	Russia	<i>ippolitov.ap@gmail.com</i>
Dr. AnnaAnatolievna	Goryacheva	Russia	<i>GoryachevaAA@ipgg.sbras.ru</i>
Dr. Boris	Shurygin	Russia	<i>shuryginbn@ipgg.sbras.ru</i>
Dr. Olga	Sergeevna Urman	Russia	<i>UrmanOS@ipgg.sbras.ru</i>
Dr.Oxana	Dzyuba	Russia	<i>dzyubaos@ipgg.sbras.ru</i>
Dr. Valery	Ja. Vuks	Russia	<i>valery_vuks@vsegei.ru</i>
Dr. Vasily	V. Mitta	Russia	<i>vmitta@mail.ru</i>
Dr. Adam	Tomasovych	Slovakia	<i>Adam.Tomasovych@savba.sk</i>
Dr. Ján	Schlögl	Slovakia	<i>schlogl@nic.fns.uniba.sk</i>
Prof. Federico	Olóriz	Spain	<i>foloriz@u.gr.es</i>
Prof. Guillermo	Melénde	Spain	<i>gmelende@unizar.es</i>
Prof. Matias	Reolid	Spain	<i>mreolid@ujaen.es</i>
Prof. Sixto R.	Fernandez-Lopez	Spain	<i>sixto@geo.ucm.es</i>
Dr. Christian	Charles Albert Meister	Switzerland	<i>christian.meister@ville-ge.ch</i>
Dr. Aisha	Al-Suwaidi	UAE	<i>aalsuwaidi@pi.ac.ae</i>
Dr. Sandra	D. Chapman	UK	<i>s.chapman@nhm.ac.uk</i>
Mr. Vincent C.	Gillespie	UK	
Mr. Simon	Kettle	UK	<i>simon.kettle@hotmail.co.uk</i>
Ms. Alice	Kennedy	UK	<i>alice.kennedy@open.ac.uk</i>
Dr. Angela L.	Coe	UK	<i>A.L.Coe@open.ac.uk</i>
Dr. Bryony A.	Caswell	UK	<i>bac@liverpool.ac.uk</i>
Prof. Chris	Frid	UK	<i>C.L.J.Frid@liverpool.ac.uk</i>
Dr. David	Kemp	UK	<i>david.kemp@open.ac.uk</i>
Dr.Simon R.A.	Kelly	UK	<i>simon.kelly@casp.cam.ac.uk</i>
Prof. Stephen	Hesselbo	UK	<i>stephen.hesselbo@earth.ox.ac.uk</i>
Dr. Maureen	Steiner	USA	<i>magnetic@uwoy.edu</i>