

Late Cretaceous ammonites from the Bou Angueur syncline (Middle Atlas, Morocco) – stratigraphic and palaeobiogeographic implications

by

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With 2 plates, 8 text-figures and 1 table

Zusammenfassung

Erstmals wird eine umfassende oberkretazische Ammonitenfauna aus dem Mittleren Atlas (Marokko) vorgestellt, genauer aus der Amghourzif Formation der Bou Angueur Synklinale. Sie enthält Arten der Gattungen *Lewesiceras*, *Calycoceras* (*Newboldiceras*), *Nigericeras*, *Morrowites*, *Pseudaspidoceras*, *Metoicoceras*, *Spathites* (*Jeanrogericeras*), *Mammites*, *Vascoceras*, *Thomasites*, *Choffaticeras* und *Coilopoceras*, die frühes Spätcenoman bis älteres Turon (mittleres Turon?) anzeigen. Die Faunenzusammensetzung zeigt eine Dominanz von Vertretern der Unterordnung Ammonitina und ein Fehlen von solchen der Phylloceratina, Lytoceratina und Ancyloceratina (Heteromorphen). Keine der nachgewiesenen Taxa ist endemisch, aber die Vascoceraten und *Thomasites* weisen die Assoziation der West-/Zentraltethys bzw. der Vascoceraten-Provinz zu. Zahlenmäßig werden die Vascoceraten jedoch von Acanthoceraten übertroffen. Die meisten Ammoniten der Fauna sind Kosmopoliten, hier sind besonders *Calycoceras* (*N.*) *asiaticum asiaticum*, *Pseudaspidoceras footeanum*, *Mammites nodosoides* und *Metoicoceras geslinianum* zu nennen. Ausschließlich im gemäßigeren Faunenraum vorkommende Taxa fehlen im Mittleren Atlas, welcher in der bearbeiteten Zeitscheibe als Teil eines ausgedehnten neritischen, intrakontinentalen Meeresraumes am Südrand der Tethys betrachtet werden muß.

Die Amghourzif Formation hat eine isochrone Basis im unteren Obercenoman, obwohl regional vollständige Kondensation eine unterturonale Basis vortäuscht. Das Top der Formation lieferte keine Ammoniten, sie ist aufgrund einer Mikroflora des Turon/Coniac-Grenzbereiches, aus den Schichten direkt über dieser Formation, in das Oberturon einzustufen.

Aus der darüber folgenden Ait 'Sba-Formation können erstmals Ammoniten beschrieben werden. In Übereinstimmung mit der faziellen Entwicklung und der globalen Meeresspiegelchronologie zeigen *Libycoceras* cf. *afikpoense* und *L.* cf. *ismaelis* ein spätcampanes Alter an.

Schlüsselwörter: Biostratigraphie – Systematische Beschreibung – Ammoniten – Oberkreide – Cenoman – Turon – Campan – Mittlerer Atlas – Marokko

Summary

The first comprehensive Late Cretaceous ammonite fauna of the Middle Atlas (Morocco) has been obtained from the Amghourzif Formation of the Bou Angueur syncline. It contains species of the genera *Lewesiceras*, *Calycoceras* (*Newboldiceras*), *Nigericeras*, *Morrowites*, *Pseudaspidoceras*, *Metoicoceras*, *Spathites* (*Jeanrogericeras*), *Mammites*, *Vascoceras*, *Thomasites*, *Choffaticeras* and *Coilopoceras*, indicating an earliest late Cenomanian to early Turonian (? middle Turonian) age. The faunal composition is characterised by a dominance of taxa belonging to the suborder Ammonitina and an absence of those belonging to Phylloceratina, Lytoceratina and Ancyloceratina (heteromorphs). None of the recorded taxa is endemic, but the vascoceratids and *Thomasites* classify the assemblage as western/central Tethyan, respectively of the Vascoceratid Province. However, vascoceratids are conspicuously outnumbered by acanthoceratids. Most ammonites of the fauna are cosmopolitan, namely *Calycoceras* (*N.*) *asiaticum asiaticum*, *Pseudaspidoceras footeanum*,

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Mammites nodosoides and *Metoicoceras geslinianum*. Exclusively temperate taxa are missing in the Middle Atlas, which was part of an extended neritic, intracontinental seaway at the southern margin of the Tethys during the time interval studied.

The Amghourzif Formation is considered to have an isochronous base in the earliest late Cenomanian, although regionally complete condensation makes pretence of an earliest Turonian base. The top of the Formation was not dated by ammonites, but is considered to be within the late Turonian because of a microflora derived from superjacent beds that indicates the Turonian/Coniacian boundary interval.

A first record of ammonites is described from the overlying Ait 'Sba-Formation (*Libycoceras* cf. *afikpoense* and *L.* cf. *ismaelis*). These, in association with facies and global sea level history, indicate a Late Campanian age.

Key words: Biostratigraphy – Systematic palaeontology – Ammonites – Upper Cretaceous – Cenomanian – Turonian – Campanian – Middle Atlas – Morocco

1. Introduction

A total of 84 ammonites were collected during several mapping and facies studies in the Bou Angueur syncline, Middle Atlas, Morocco, during the autumn 1995 and spring 1996 by one of us (H.-G. HERBIG) and his students from the University of Cologne. The majority of specimens (82 ammonites) has been obtained from the Cenomanian/Turonian Amghourzif Formation, particularly from the boundary interval between the two stages. Two ammonites had been sampled from the overlying Ait 'Sba Formation.

The specimens represent the first comprehensive ammonite fauna collected in the Middle Atlas and enable description of 19 taxa. Our paper is also the first taxonomic description of Late Cretaceous ammonites from northwestern Africa outside the Tarfaya and Essaouria basins (SALVAN 1955; COLLIGNON 1967) and the central High Atlas (MEISTER & RHALMI 2002; ETTACHFINI et al. 2005). Based on these results, the biostratigraphy of the Amghourzif and Ait 'Sba formation can be reevaluated. A major goal is to elucidate the palaeobiogeographic relations of the fauna and to contribute to the regional Late Cretaceous palaeogeography which was briefly assessed by LEHMANN & HERBIG (2003). Moreover, the fauna provides the basis for a review of the scanty and dispersed occurrences of Cenomanian/Turonian ammonites from central, eastern and southeastern Morocco and to provide a more coherent picture of the regional facies and stratigraphy.

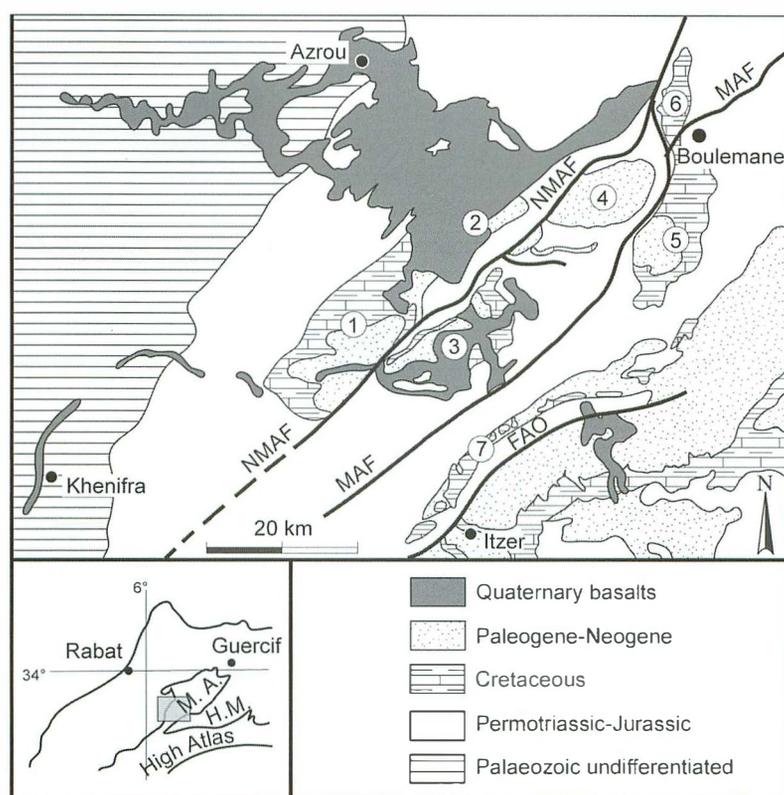
2. Geological and stratigraphical setting

The Middle Atlas is a northeast-trending mountain range, separating the Variscan realms of the Moroccan Meseta in the west from the Meseta of Oran (Moulouya, Hauts Plateaux) in the east, which is widely covered by a thin veneer of Mesozoic and continental Neogene sediments (MICHARD 1976). The mountain range is characterized by northeast-trending, deep-seated strike slip faults (Text-fig. 1). Along one of these faults, the Northern Middle Atlas Fault, the range is separated into the northwestern block-faulted Middle Atlas Plateau and the southwestern Folded Middle Atlas. The latter consists of tight anticlines, accompanied by major strike-slip faults along their northwestern limbs, and separated by wide, gently folded synclines (COLO 1961). The synsedimentary activity of these faults during the Mesozoic and Cenozoic has been fully demonstrated (DU DRESNAY 1969; FEDAN 1978, 1989; DUÉE et al. 1979; MARTIN 1981; FEDAN & THOMAS 1986; HERBIG 1988, 1991, 1993; CHARRIÈRE 1990; ENSSLIN 1992, 1993; SCHEELE 1994; RHRIB 1997).

Early to Middle Jurassic marine limestones and marls, grading upward into marginal marine and continental facies, cover most of the expanse of the Middle Atlas, but post-Jurassic strata are preserved in several synclines west of Boulemane (Text-fig. 1). From northwest to southeast, Cretaceous rocks are present in the synclines of Bekrit (= Koubbat syncline), Bou Angueur, Oudiksou, and Zad; the Tighboula syncline is the northeastern prolongation of the Oudiksou syncline, north of the Middle Atlas fault and the accompanying anticline.

South of the Middle Atlas, Cretaceous rocks are well exposed in the Haute Moulouya, which represents the southwesternmost tip of the Meseta of Oran.

Except for the extended reviews of CHOUBERT (1939, 1948), CHOUBERT & SALVAN (1949), BASSE & CHOUBERT (1959), SALVAN (1959), and CHOUBERT & FAURE-MURET (1962), which were mostly based on mapping, our knowledge of the Cretaceous of the Middle Atlas and adjacent regions remained meagre for long time. After COLO (1961), papers by MARTIN (1973, 1981), ANDREU (1986, 1989, 1992, 1993a, 1993b), FEDAN (1989), CHARROUD (1990), CHARRIÈRE (1990, 1992, 1996), ANDREU-BOUSSUT (1991), ENSSLIN (1992, 1993), CHARRIÈRE et al. (1998) and CISZAK et al. (1999) need to be mentioned.

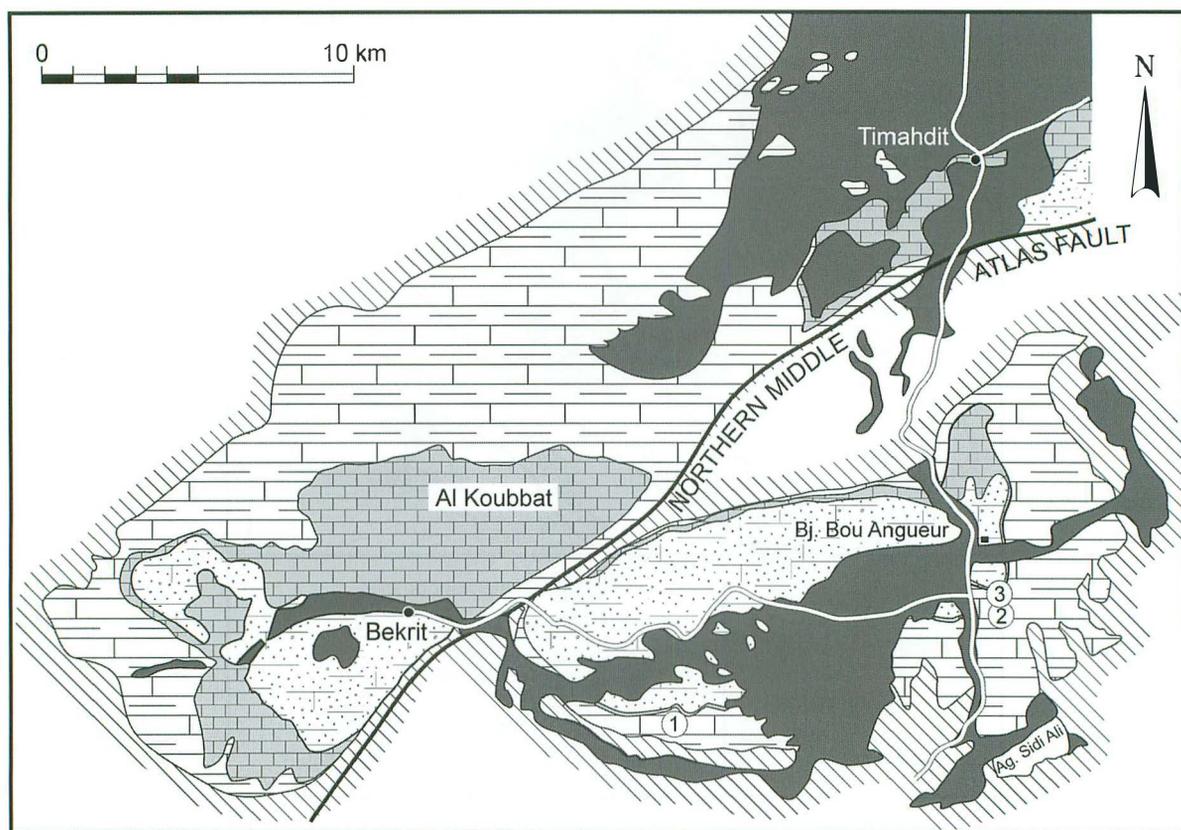


Text-fig. 1. Geology of the central part of the Middle Atlas, situated between the Palaeozoic of the Moroccan Meseta and the Meseta of Oran (Haute Moulouya – H.M in index map). The latter is widely covered by continental Neogene strata (southeast of the Fault of Ait Oufella). Cretaceous to Paleogene marine strata are preserved in several synclines separated by major strike-slip faults. 1 – Bekrit syncline, 2 – Timahdit syncline, 3 – Bou Angueur syncline, 4 – Feleddi syncline (Ain Nokra syncline), 5 – Oudiksou syncline, 6 – Tighboula syncline, 7 – Zad syncline. NMAF – Northern Middle Atlas Fault, delineating the Middle Plateau in the northwest from the Folded Middle Atlas in the southeast, MAF – Middle Atlas Fault, FAO, Fault of Ait Oufella. M. A. – Middle Atlas.

Contributions dealing with the stratigraphy of the Bekrit syncline are from RAHHALI (1970), ZEMMOURI (1976a, 1976b), and ANDREU & TRONCHETTI (1996). The Tighboula syncline and some sections in the adjacent Oudiksou syncline were studied by ANDREU (1995, 1996), ANDREU & CHARRIÈRE (1986), and ANDREU et al. (1988, 1995), mostly with special emphasis on the ostracode fauna and its biostratigraphic and palaeobiogeographic value. Knowledge of the succession of the Zad syncline still remains scarce and to our knowledge is restricted to sections measured by ENSSLIN (1993) and CHARRIÈRE et al. (1998).

Following first reconnaissance studies (TERMIER & DUBAR 1933 1940; TERMIER 1936; ZEMMOURI 1976a, b; MARTIN 1981; HERBIG 1988; ENSSLIN 1992), only ENSSLIN (1993), HERBIG & FECHNER (1994), CHARRIÈRE et al. (1998) and ENSSLIN & SCHLAGINTWEIT (1999) paid special attention to the Cretaceous of the Bou Angueur syncline. The few results of CHARROUD (1990) have to be used with prudence since he neither presented an adequate geological map nor a correct stratigraphic column of the syncline.

The Bou Angueur syncline (Text-fig. 2) is a strongly asymmetrical structure. Along the southern flank, the Cretaceous sedimentation (Sidi Larbi Formation) started in the interval between the Jurassic/Cretaceous transition and the Valanginian on top of a faint angular unconformity above Bajocian limestones and marls (HERBIG & FECHNER 1994). Along the northern flank, a succession of phosphatic-calcareous sandstones, bituminous marls, and light, partly sandy siltstones and marls (Foum Kheneg Formation, HERBIG 1991) overlaps Lower Jurassic (Upper Pliensbachian) limestones with angular unconformity (TERMIER 1936, see also HERBIG 1988). Teeth of the shark *Squalicorax pristodontus* (AGASSIZ 1843) occur at the base of the Foum Kheneg (CHOUBERT et al. 1952). Although the age range of the species is Campanian/Maastrichtian (CAPPETTA 1987), it is used as Maastrichtian guide in Morocco.



Text-fig. 2. Geology of the Bou Angueur syncline and the Bekrit-Timahdit syncline, which are separated by the Northern Middle Atlas Fault. Diagonally ruled = Triassic red beds–Jurassic limestones; horizontally ruled bricks = Cretaceous–Paleocene siltstones, marls and limestones; light grey bricks = late Paleocene–middle Eocene limestones (Bekrit-Timahdit Formation); stippled = post-middle Eocene continental rocks (Ain Nokra Group, HERBIG 1993); dark grey = Quaternary basalts. 1 – Ammonite-bearing localities including section C/CK at the Assaka-n-Aouam ridge, 2 – ammonite-bearing section C/MH2 at the A'ari-n Moulay Cadiq hill, 3 – location of ammonites from the Ait 'Sba Formation.

The Cretaceous succession of the southern flank of the syncline (HERBIG & FECHNER 1994) starts with 60 m of bedded dolostones, yellowish-brown and red siltstones and mudstones and buff to olive marls with intercalated beds of calcareous sandstones and dolostones (“série rosé” of the Sidi Larbi Formation, ANDREU & CHARRIÈRE 1986). 150 m of monotonous light-coloured yellowish to olive marls with few intercalated dolomite beds follow (“série jaune” of the Sidi Larbi Formation). On top, the up to 54 m thick upper Cenomanian/Turonian Amghourzif Formation of ENSSLIN (1993) yielded the ammonite fauna dealt with herein. It represents the classical guide level of the “barre calcaire du Cénomano/Turonien” of CHOUBERT (1948). According to ENSSLIN (1993), it represents the lateral, strongly calcareous facies equivalent of the marl-limestone succession of the Ait Ben Ali Formation from the Tighboula and northeastern Oudiksou synclines (ANDREU & CHARRIÈRE 1986).

The Amghourzif is overlain by the Ait 'Sba Formation (ANDREU & CHARRIÈRE 1986). The formation was emended by ENSSLIN (1993) to include all late Late Cretaceous strata of the Middle Atlas and the Haute Moulouya, which widely is a quite monotonous, mostly marginal marine series. Further subdivisions (“Ait 'Sba Formation” sensu ANDREU & CHARRIÈRE 1986, “Calcaires d'Ich ou Sklou”, “Marnes de Tighboula”) are only recognizable within the Tighboula syncline. In the Bou Angueur syncline, it is a sequence of buff marls and siltstones with few intercalated, thin dolostone beds, which strongly resembles the “série jaune” of the Sidi Larbi Formation. In the middle part of the formation yellowish brown, thin- to thick-bedded sparitic limestones and intercalated whitish or yellowish marls form a conspicuous rock ledge. The few ammonites described herein have been obtained from strata somewhat below the rock ledge.

Due to the syndimentary tectonic movements along the northern flank of the Bou Angueur syncline, the top of the formation is strongly diachronous and is overlain by different formations (HERBIG 1991, and unpublished mapping results). In the northeast, the Ait 'Sba Formation grades into the Campanian(?)/Maastrichtian Fom Kheneg Formation described above. It tapers out towards the west. In the southeast, it is conformably overlain by Late Thanetian/Lutetian (?Bartonian) shallow-marine limestones (Bekrit-Timahdit Formation). In the southwest, at the Assaka-n-Aouam ridge, the top of the formation becomes progressively older towards the west and is either overlain by yellow siltstones, sandstones and conglomerates attributed to the Maastrichtian/Thanetian Irbzer Formation (RAHHALI 1970, for discussion of the stratigraphic range see also SCHUDACK & HERBIG 1995), or by black bituminous and phosphatic marls of the older Campanian/Maastrichtian El Koubbat Formation (RAHHALI 1970, emended by ENSSLIN 1993 by inclusion of the Campanian "Calcaires de l'Oued Izem").

3. Taxonomic and biostratigraphic information

Most taxonomic and biostratigraphical data on Late Cretaceous ammonites from Morocco is obtained from the Atlantic-bound Tarfaya basin (COLLIGNON 1967). The biostratigraphy was revised and improved by WIEDMANN and co-authors (WIEDMANN et al. 1978a, 1978b, 1982), and supplemented by data from the Agadir-Essaouira basin in the same papers. In contrast, Late Cretaceous ammonite faunas of central, eastern and southeastern Morocco, especially from the extremely widespread "barre calcaire du Cénomano/Turonien" (CHOUBERT 1948) remain almost unknown. Available data are restricted to some listed, unfigured taxa, obviously randomly sampled during geological mapping (e.g. BASSE & CHOUBERT 1959), or mentioned in studies devoted to other aspects of regional geology and stratigraphy (e.g. COLO 1961). A notable exception is MEISTER & RHALMI (2002), who described *Neolobites vibrayeanus brancai* ECK, 1908, *Neolobites vibrayeanus* s.s. (D'ORBIGNY 1841), *Coilopoceras* gr. *requienianum* (D'ORBIGNY 1841), and *Coilopoceras* aff. *newelli* BENAVIDES-CÁCERES, 1956, as well as the nautilids *Angulites* sp. and *Eutrephoceras* sp. from measured sections at the southern rim of the High Atlas in the region between Goulmima and Boudenib (Errachidia-Boudenib-Erfoud bassin).

BASSE & CHOUBERT (1959, compare also faunal lists in CHOUBERT 1939, 1948) gave a comprehensive review of "upper Cenomanian to upper Turonian" ammonites known from central, eastern, and southeastern Morocco. Their list shows that faunas from the Rekkame/Hauts Plateaux are somewhat different from those of adjacent regions of the Moyenne Moulouya/Haute Moulouya, and the High Atlas of El Ksiba and Beni Mellal (Tab. 1). At that time only two badly preserved ammonites of supposed Cretaceous age were known from the Middle Atlas. They had been collected from the El Mers syncline, east of Boulemane and were named *Leoniceras* aff. *L. quaasi* DOUVILLÉ and *Fagesia* cf. *peroni* by BASSE & CHOUBERT (1959). Later, COLO (1961) named the same specimens *Leoniceras quaasi* DOUVILLÉ [*Choffaticeras* (C.) *quaasi* of modern nomenclature, e.g. CHANCELLOR et al. 1994] and *Thomasites* sp. (det. W.J. ARKELL). However, doubts remained that *Leoniceras* and two earlier sampled specimens of the Bathonian taxon *Clydoniceras discus* (see TERMIER et al. 1940) might have been confused. (DRESNAY 1963). Later, DRESNAY (1975) stressed the Bathonian age of the uppermost marine strata in that syncline. Revision of Bajocian/Bathonian Middle Atlas faunas by ENAY et al. (1987) and the discovery of a Middle Bathonian *Cadomites* cf. *bremeri*, the hitherto youngest ammonite from the El Mers syncline (FEDAN 1989), supported the conclusions of DRESNAY (1963, 1975), which were corroborated by later authors (e.g. ANDREU 1989; CHARRIÈRE 1992, 1996). This exemplifies the problem of many determinations in older literature of taxa that were never been figured.

Additional ammonite data have been obtained since the late nineteen eighties from the marl-limestone succession of the Turonian Ait Ben Ali Formation, which is known from the Tighboula and adjoining Oudiksou synclines (ANDREU & CHARRIÈRE 1986; ENSSLIN 1993), as well as from the more calcareous late Cenomanian/Turonian Amghourzif Formation in the Bekrit, Bou Angueur, and Zad synclines of the Middle Atlas, and from the Haute Moulouya (ENSSLIN 1993; compare Text-fig. 1).

The basal part of the Ait Ben Ali Formation consists of an approximately 1 m thick unit of white, commonly ammonite bearing limestones. Ammonites are especially concentrated in the condensed topmost bed, but only the lower Turonian index species *Mammites nodosoides* was mentioned (ANDREU & CHARRIÈRE 1986; ANDREU 1989). CHARRIÈRE (1990, p. 307) supplemented the faunal list with *Hoplitoides ingens*, *Vascoceras* sp.,

Table 1. Cenomanian-Turonian ammonites from eastern Morocco known to BASSE & CHOUBERT (1959); species names have been updated according to usage of nomenclature in recent papers (e.g. WRIGHT & KENNEDY 1981; ROBASZYNSKI et al. 1990; CHANCELLOR et al. 1994).

Rekkame/Hauts Plateaux	Moyenne Moulouya/Haute Moulouya, High Atlas of El Kisba/Beni Mellal
<p><i>Acanthoceras</i> sp. (interpreted as acanthoceratid non det. here) <i>Engonoceras thomasi</i> PERVINQUIÈRE <i>Fagesia thevesthensis</i> (PERON) <i>Leoniceras</i> sp. <i>Lewesiceras peramplum</i> (MANTELL) <i>Mammites</i> cf. <i>nodosoides</i> (SCHLÜTER) <i>Mammites</i> sp. <i>Metasigaloceras</i> sp. <i>Thomasites meslei</i> PERVINQUIÈRE (a synonym of <i>T. rollandi</i> following CHANCELLOR et al. 1994) <i>Thomasites rollandi</i> var. <i>globosa</i> PERVINQUIÈRE (<i>T. rollandi</i> following CHANCELLOR et al. 1994) <i>Thomasites</i> cf. <i>rollandi</i> PERVINQUIÈRE <i>Thomasites</i> sp.</p>	<p><i>Acanthoceras</i> sp. (interpreted as acanthoceratid non det. here) <i>Choffaticeras</i> sp. <i>Coilopoceras requienianum</i> (D'ORBIGNY) <i>Hoplitoides ingens costatus</i> SOLGER (<i>H. ingens</i> following CHANCELLOR et al. 1994) <i>Lewesiceras peramplum</i> (MANTELL) <i>Mammites</i> (<i>Pseudaspidoceras</i>) "<i>salinensis</i>" respectively <i>Pseudaspidoceras salmuriensis</i> COURTILLER (interpreted as <i>Pseudaspidoceras</i> sp. herein) <i>Neolobites vibrayeanus</i> D'ORBIGNY <i>Neoptychites cephalotus</i> COURTILLER <i>N. xetiformis</i> PERVINQUIÈRE (a synonym of <i>N. cephalotus</i> following CHANCELLOR et al. 1994) <i>Pseudaspidoceras</i> sp.</p>

Euomphaloceras africanum and *Pseudaspidoceras paganum*. This fauna was also cited by ANDREU-BOUSSUT (1991, pp. 142, 146), but considered to represent the topmost Sidi Larbi Formation, an assumption not followed in further papers (e.g. ENSSLIN 1993; ANDREU et al. 1995).

ANDREU (1989, fig. 8, p. 71) and ANDREU-BOUSSUT (1991, pp. 139, 146) mentioned three ammonite-bearing horizons from the Jebel Tifratine section, northeastern Bekrit syncline, (Text-fig. 1) that belong also to the lower Amghourzif Formation. The lower horizon yielded *Vascoceras* gr. *cauvini*, *Kamerunoceras*, *Choffaticeras* sp., *Pseudaspidoceras?* sp. and *Pseudaspidoceras* sp., indicating the uppermost Cenomanian/lower Turonian. The middle horizon yielded undetermined Vascoceratinae of the same age, but *Thomasites* sp. and *Choffaticeras* sp. occurring in the upper horizon unequivocally indicate an early Turonian age.

The observations from the Bekrit syncline were extended by CHARRIÈRE et al. (1998) to the western Bou Angueur syncline (Assaka-n-Aouam ridge, Text-figs. 1, 2). Here again, three ammonite horizons of latest Cenomanian (*Nigericeras?* sp., *Vascoceras* sp. ex gr. *cauvini*), earliest early Turonian (*Pseudaspidoceras flexuosum*, *Vascoceras* cf. *durandi*), and the latest early Turonian (*Mammites nodosoides*) age could be identified; from the eastern Bou Angueur syncline, *Pseudaspidoceras* cf. *pseudonodosoides* (late Cenomanian) and *Pseudaspidoceras* sp. (latest Cenomanian or earliest Turonian) were mentioned (see below).

Ammonites from the Haute Moulouya are extremely rare. ENSSLIN (1992, 1993) mentioned a single late Turonian *Coilopoceras requienianum* (D'ORBIGNY) from a section north of Itzer at the southern rim of the Middle Atlas, a taxon already mentioned from the same region by BASSE & CHOUBERT (1959; also cited in COLO 1961). From the Midelt region, CHARRIÈRE et al. (1998; also cited in CISZAK et al. 1999) recorded a late Cenomanian *Neolobites vibrayeanus* from massive calcareous mudstones close to the base of the Amghourzif Formation, and a juvenile vascoceratid, *Neoptychites?*, probably of early Turonian age, from platy limestones ("calcaires en plaquettes") in the middle part of the formation.

The data from the Middle Atlas and the Haute Moulouya are complemented by new ammonite data from the High Atlas of Beni Mellal (ETTACHFINI et al. 2005, fig. 7/1–4). In the Naour syncline (Ben Cherrou), chalky limestones yielded *Watinoceras* sp., *Vascoceras proprium*, *Fagesia catinus*, and *Mammites* sp. or *Kamerunoceras* sp., which in association with planktonic foraminifera taxa indicate an early Turonian age. In the Ouauizaght syncline massive chalky limestones yielded *Romaniceras ornatissimum*, indicating the middle Turonian.

4. Locality details of the ammonite fauna

4.1 Amghourzif Formation

The greater part of the fauna was collected loose during mapping by students of the University of Cologne in the southwestern Bou Angueur syncline in the years 1995 and 1996, at the southern slope of the Assaka-n-Aouam ridge (Lambert coordinates $x = 525.38$, $y = 273.03$; Text-fig. 2). Only single specimens of the early Turonian *Pseudaspidoceras* cf. *footeanum*, *Mammites nodosoides*, and *Pseudaspidoceras* sp. have been obtained from localized units within section C/CK near-by (Text-fig. 3; Lambert coordinates of base of section: $x = 526.20$, $y = 274.78$). Lithofacies of the measured section unequivocally proves derivation of the Assaka-n-Aouam fauna from the lowermost ten meters of the formation.

Calycoceras (*Newboldiceras*) *asiaticum asiaticum* (JIMBO 1894)

Calycoceras (*Newboldiceras*?) sp.

Calycoceras sp.

Choffaticeras sp.

Choffaticeras n. sp.

Fagesia?

Lewesiceras peramplum (MANTELL 1822)

Mammites nodosoides (SCHLÜTER 1871)

Mammites cf. *nodosoides* (SCHLÜTER 1871)

Metioceras geslinianum (D'ORBIGNY 1850)

Morrowites wingi (MORROW 1935)

Nigericeras sp.

Pseudaspidoceras pseudonodosoides (CHOFFAT 1898)

Pseudaspidoceras cf. *footeanum* (STOLICZKA 1864)

Pseudaspidoceras aff. *footeanum*

Pseudaspidoceras sp.

Spathites (*Jeanrogericeras*) *reveliereanus* (COURTILLER 1860)

Spathites (*Jeanrogericeras*) cf. *postsaenzi* (WIEDMANN 1960)

Thomasites cf. *gongilensis* (WOODS 1911)

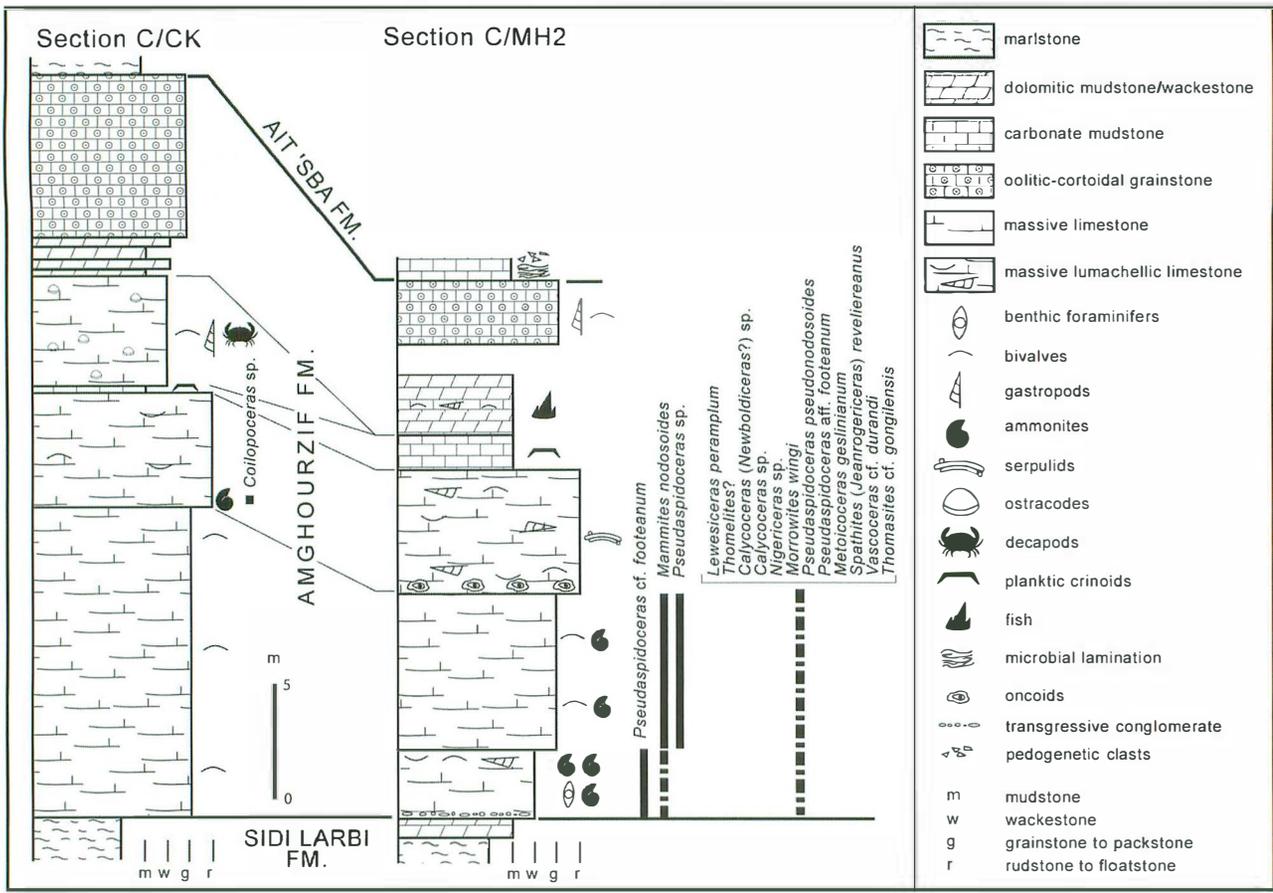
Thomelites?

Vascoceras cauvini CHUDEAU, 1909

Vascoceras durandi (THOMAS & PERON 1889)

Vascoceras cf. *durandi*

In section C/CK, the 24.2 m thick Amghourzif Formation starts with a thin transgressive conglomerate on top of a 0.8 m thick, dark yellow dedolomitized mudstone bed of the underlying Sidi Larbi Formation. The lowermost 3 m of the formation is a massive unit of light yellow to whitish-grey, microbioclastic, benthic foraminiferal wackestone bearing abundant bivalves (mostly pycnodont oysters) and few other bioclasts. Towards the top it grades into a lumachellic gastropod-bivalve wackestone to floatstone. Ammonites are common and especially concentrated in the top of the unit. Above, 7 m of very thick-bedded to massive, light yellowish to white, densely packed, clotted peloidal packstone follows. Ammonites and bivalves are present throughout the unit, but the abundance of ammonites decreases upwards, vice versa abundance of bivalves increases. At the top, a 5.3 m thick, light yellowish to white lumachellic gastropod-bivalve wackestone to floatstone occurs. Noteworthy is oncoid-bearing echinoderm-bivalve-gastropod grainstone to rudstone at the base of the unit and local serpulid boundstone, which had been already observed by HERBIG & FECHNER (1994) from the southeastern Bou Angueur syncline. The unit is overlain by 1.65 m of indistinctly laminated, fossiliferous mudstone occasionally bearing nektonic crinoids and few other biota, like bivalves. It grades into 2.55 m of fossiliferous dolomitic mudstone to sparsely packed bioclastic dolostone with a few vertebrate remains and bivalves; a few lumachellic gastropod-bivalve wackestones to floatstones are intercalated. A 1.4 m thick, unexposed, probably marly interval is followed by 3 m of yellow oolitic grainstone bearing some larger mollusc fragments. It is the topmost unit of



Text-fig. 3. Sections of the Amghourzif Formation (by C. Gross). Section C/CK, Assaka-n-Aouam ridge, western Bou Angueur syncline. Dashed = ammonite bearing interval at base of formation, continuous line = taxa collected from specified interval. Section C/MH2, A'ari-n Moulay Cadiq hill, southeastern Bou Angueur syncline.

the Amghourzif Formation. Above, unfossiliferous, microbially laminated carbonate mudstone and pedogenetic carbonate breccia form the base of the Ait 'Sba Formation.

Additional sections at the Assaka-n-Aouam ridge were published by ENSSLIN (1993, pp. 26, 44), but measured thicknesses (38–50 m) deviate from thicknesses recorded herein. A section from CHARRIÈRE et al. (1998) closely corroborates our results. They identified a rich fauna of benthonic foraminifera from a limestone bed 4 m below the base of the compact limestone succession of the Amghourzif Formation, i.e. an horizon considered by ENSSLIN (1993) and us to belong into the topmost Sidi Larbi Formation. The wackestone yielded taxa belonging to the alveolinitid subfamily Rhapydionininae. Especially the association of *Pseudorhipidionina casertana* and *Pseudorhapydionina laurinensis* proves the late, but not latest Cenomanian – comparable faunules are known from the Bekrit syncline and the Haute Moulouya (ENSSLIN 1993). At the base of the limestones of the Amghourzif Formation *Nigericeras?* sp. and *Vascoceras* sp. ex gr. *cauvini* date the latest Cenomanian. About 4 m up-section, *Pseudaspidoceras flexuosum* and *Vascoceras* cf. *durandi* indicate the basal early Turonian; again 4 m higher, a 4 m thick interval with *Mammites nodosoides* indicates the late early Turonian.

Twelve additional determinable ammonites were collected from different places in the southeastern Bou Angueur syncline, along the hills Taфраout-n-Tamlaline, A'ari-n Moulay Cadiq and east of the latter, i.e. west and east of national road P 21 Azrou-Midelt. They have been obtained from the same stratigraphic interval than above.

Fagesia?

Mammites nodosoides

Mammites cf. *nodosoides*

Nigericeras cf. *gadeni* (CHUDEAU 1909)

Pseudaspidoceras footeanum

Pseudaspidoceras pseudonodosoides

Pseudaspidoceras cf. *pseudonodosoides*

Pseudaspidoceras sp.

Spathites (*Jeanrogericeras*) sp.

Thomasites rollandi

Vascoceras cauwini

Vascoceras durandi

A single *Coilopoceras* sp. has been obtained from a horizon 16 m above the base of the 33.1 m thick Amghourzif Formation in section C/MH2 at the A'ari-n Moulay Cadiq hill, about 0.75 km east of national road P 21 (Text-figs. 2, 3; Lambert coordinates of base of section: x = 535.36, y = 278.93). The lower 13.75 m of the section is whitish, mostly massive, densely packed, clotted peloidal packstone bearing some molluscs (mostly pycnodontid oysters and other bivalves). On top, the ammonite-bearing unit is a 5.0 m thick unit consisting of whitish, mostly massive, densely packed bioclastic-peloidal bivalve rudstone; radiolitid rudist fragments, pycnodontid oysters, and gastropods occur besides sparse other biota. Notable is the overlaying 0.6 m thick horizon of white, thin-bedded, platy mudstone bearing occasionally nektonic crinoids and planktonic foraminifers, known also in the Assaka-n-Aouam section. At the top, 5.0 m of massive, moderately to densely packed ostracode wackestone yielded abundant bivalves (mostly pycnodontid oysters), gastropods, and decapods; a diverse further biota is recorded. A 1.8 m thick alternation of dolomitic mudstone and bioclastic dolomitic wackestone separates the uppermost 6.8 m of the formation, which consist of variegated, reddish, rose- and yellow-coloured, well-bedded bioclastic-cortoidal-oolitic grainstone bearing mostly gastropods, bivalves, and echinoids.

Lithofacies and carbonate microfacies are closely comparable with a section directly west of national road P 21 described by HERBIG & FECHNER (1994) and section P1 figured in ENSSLIN (1993, p. 44). CHARRIÈRE et al. (1998) figured a section somewhat further northeast, called "coupe versant oriental de la butte de Ta'arit Lakhçoum". According to our mapping that hill consists of the Bajocian R'cifa Formation ("calcaires à corniche"). This is confirmed by the find of a single *Stephanoceras* sp., a cosmopolitan Lower Bajocian ammonite genus already known from North Africa, at the northern slopes of the Ta'arit Lakhçoum (x = 538.78, y = 281.40). We assume that the section of CHARRIÈRE et al. (1998) is located about 1.5 km further west, WNW of the unnamed height 2114. The authors mentioned a basal wackestone unit, less than ½ m thick, bearing calcispheres and diverse benthonic foraminifers, including *Scandonea pumilia*, *Dicyclina* sp., and *Spirocyclina* sp. At the top, white, dolomitic, chalky limestones yielded at the base *Pseudaspidoceras* cf. *pseudonodosoides* (late Cenomanian) and *Pseudaspidoceras* sp. (latest Cenomanian or earliest Turonian).

Detailed carbonate facies interpretation of the Amghourzif and Ait Ben Ali formations is found in ENSSLIN (1993) and additional remarks concerning the Bou Angueur syncline in HERBIG & FECHNER (1994). According to the latter, the palaeoenvironment of the chalky, massive lower part of the Amghourzif Formation in the Bou Angueur syncline is difficult to interpret. ENSSLIN (1993) described predominating biopelmicrites bearing diverse minuted fossil debris and nektonic crinoids and considered them to be strongly reworked, restricted lagoonal deposits (his microfacies M-10). However, the discovery of abundant ammonites indicates an open platform environment, well compatible with the presence of nektonic crinoids and abundant microbioclasts. In the ammonite-bearing lower Amghourzif Formation of the Bekrit syncline, ENSSLIN (1993) described identical microfacies and associated calcisphere (pithonellid) biomicrites. In the ammonite-bearing basal Ait Ben Ali Formation again, he records calcisphere (pithonellid) biomicrites and fossiliferous micrites bearing additionally, other biota such as globigerinids and filaments (planktic larval shells). Finally, he mentioned chert-bearing platy limestones ("Plattenkalke") from the lower Turonian sediments of the Haute Moulouya.

Summing up; ammonites and carbonate facies indicate a rapid high-amplitude transgression starting in the early late Cenomanian of the Haute Moulouya-Middle Atlas realm. According to the ammonite fauna, relatively

high sea levels were maintained throughout the early Turonian, though minor sea level variations are recorded by facies shifts, e.g. lumachellic intercalations. High sea levels apparently continued into the middle Turonian above the *Coilopoceras* horizon (section C/MH2), where a key bed of thin-bedded platy carbonate mudstones with nektonic crinoids and globigerinids is developed throughout the Bou Angueur syncline. At the top of the succession, shallowing-upward deposition is well expressed in the upper Amghourzif Formation (HERBIG & FECHNER 1994).

It has to be stressed that THEIN (1988) observed an almost identical sea level history and corresponding facies in the Turonian of the western and central High Atlas realm.

4.2 Ait 'Sba Formation

We record ammonites for the first time from the Ait 'Sba Formation: *Libyoceras* cf. *afikpoense* and *Libyoceras* cf. *ismaelis*. They were collected from the eastern Bou Angueur syncline, 1 km east of national road P 21, east of the bifurcation to Bekrit ($x = 535.51$, $y = 279.66$) at the top of an about 50 m thick succession, which forms the lower Ait 'Sba (Text-fig. 2). In the Bou Angueur syncline, the lower Ait 'Sba consists in general of pale yellowish marls and intercalated thin, unfossiliferous dolostone beds, but in the eastern part of the syncline the marls are fossiliferous, yielding bivalves, gastropods, echinoids, and a few ammonites. The body chamber of a badly preserved, undetermined ammonite specimen is filled with a fossiliferous mudstone containing very fine-grained fossil debris, sponge spicules, thin-shelled ostracodes, miliolid and few tiny rotaliid foraminifers as well as tiny echinoid and shell fragments. The marl succession ends below a conspicuous rock ledge recognized throughout the Bou Angueur syncline. The ledge consists of light yellowish to brownish limestones and is supposed to represent a sea level rise in the Late Campanian that is known as the *mucronata* transgression in the boreal realm and can be traced into the Tethys (JARVIS et al. 2002). In Morocco this eustatic event has been earlier recorded in the Agadir-Essouira basin by WIEDMANN et al. (1982).

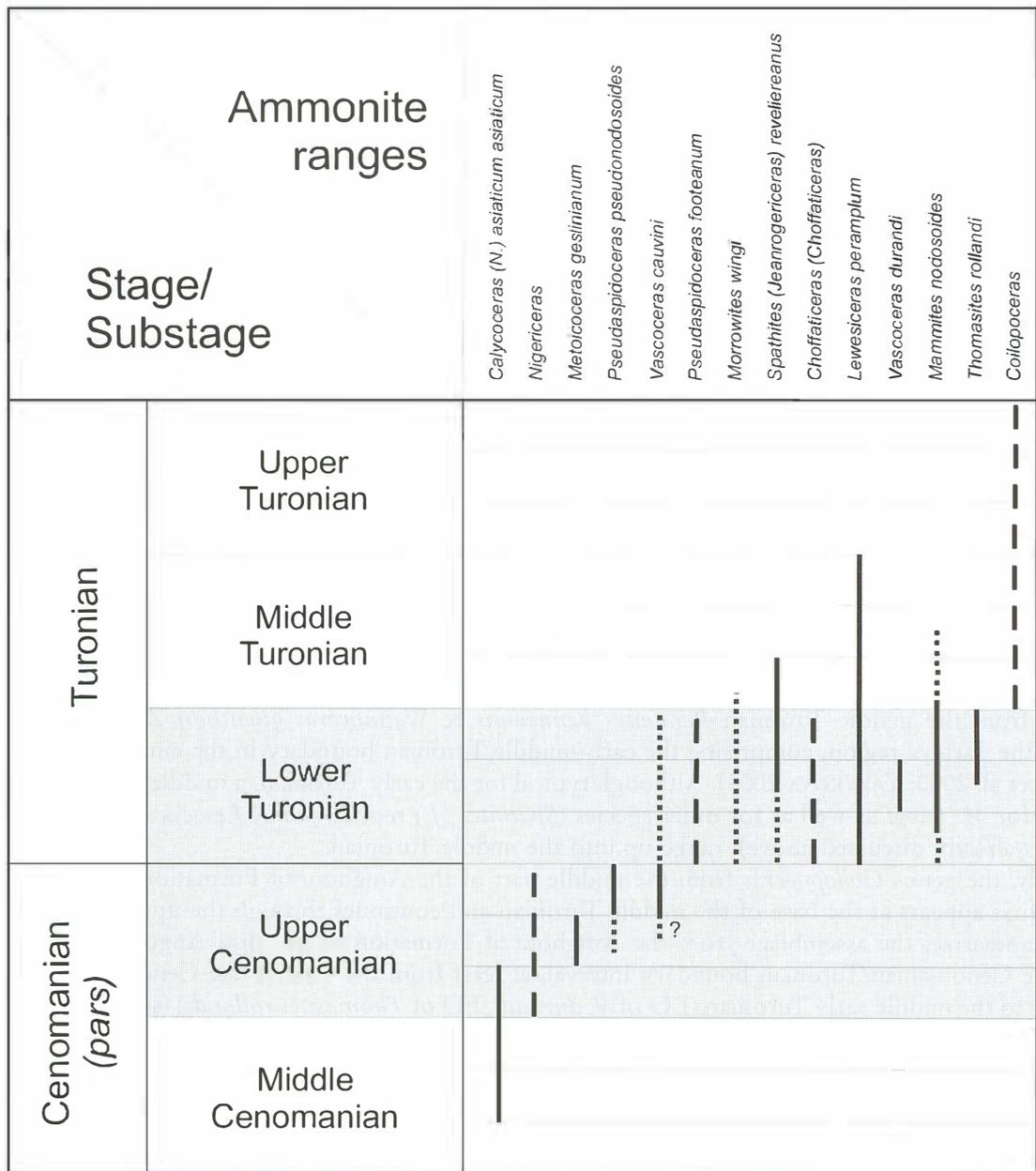
The Ait 'Sba of the Bou Angueur syncline is considered to represent a tidal mudflat environment. It was occasionally inundated by short-lived transgressions (ENSSLIN 1992; HERBIG & FECHNER 1994), indicated for example by the Late Campanian limestones and the recorded ammonites. The Late Campanian sea level rise also induced the record of ammonites and other organisms in other parts of North and West Africa (REYMENT & DINGLE 1987), and particularly of ammonites of the genus *Libyoceras* (ZABORSKI 1983).

An earlier, supposedly Coniacian transgressive interval indicated by ENSSLIN (1993) and ENSSLIN & SCHLAGINTWEIT (1999) must not be confused with the above. They recorded the calcareous algae *Heteroporella lepina* PRATURLON, 1967, *Milanovicella hammudai* RADOČIČ, 1964, *Neomeris* aff. *cretacea* STEINMANN, 1899, and *Boueina* cf. *pygmaea* PIA, 1936, from a 1.5 m thick oolitic-bioclastic grainstone to packstone about 10 m above the base of the formation at the Assaka-n-Aouam ridge. Age assignment was mostly based on the global eustatic curve of HAQ et al. (1987, 1988) and correlation with results of THEIN (1988) from the western and central High Atlas that indicate a major regression in the late Turonian followed by a new transgression attaining its first maximum at the Turonian/Coniacian boundary. However, the position of the Turonian/Coniacian boundary has shifted considerably in recent years and much of the previous lower Coniacian sediments should now be referred to the late Turonian (e.g. WALASZCZYK 2000; SIKORA et al. 2004). According to these papers there is still no GSSP (Global boundary Stratotype Section and Point), the general agreement is that the boundary should be placed at the first appearance of *Cremonoceras deformis erectus* in a suitable section. Although there are no inceramids known from our working-area yet this agrees with all taxa listed since they occur before the Coniacian. *Heteroporella lepina*, a taxon known from the southern Tethys realm in Italy, Egypt and Tunisia, was not recorded at all in the Coniacian. The single sample from Bou Angueur attributed to the Coniacian (fide ENSSLIN & SCHLAGINTWEIT 1999) might be in fact older according to the modern usage of the boundary mentioned above. Differing from THEIN (1988) the lowermost transgressive interval within the Ait 'Sba Formation probably needs to be placed in the late Turonian rather than in the interval around the Turonian/Coniacian boundary.

5. Ammonite biostratigraphy and age range of formations

5.1 Amghourzif Formation

The biostratigraphic scheme applied to the identified ammonite fauna from the Bou Angueur syncline is based on age ranges from Europe (mainly Boreal Realm) and northern Africa and the Middle East (Tethyan Realm). Accordingly, ammonites from the Amghourzif Formation syncline indicate an age range from the early late Cenomanian to the middle/late Turonian (Text-fig. 4). Within the overlying Ait ‘Sba Formation, a Campanian ammonite-bearing horizon was identified.



Text-fig. 4. Ammonite biostratigraphy of the Cenomanian-Turonian with age ranges of index taxa known from the Middle Atlas. The dashed lines represent ranges of genera (CHANCELLOR et al. 1994, KENNEDY & JUIGNET 1994a, 1994b, WRIGHT 1996). Dotted lines indicate that the ranges need improvement, additional question marks indicate doubtful range. The shaded area indicates the supposed stratigraphic range of the Assaka-n-Aouam section.

The oldest ammonites from the Amghourzif Formation, *Calycoceras* sp., and *Calycoceras (N.) asiaticum asiaticum* are early late Cenomanian in age. The existence of the middle Cenomanian, which might have been indicated by the first occurrence of *Calycoceras (N.) asiaticum asiaticum*, can be ruled out due to the presence of the late Cenomanian alveolinid foraminifers *Pseudorhipidionina casertana* and *Pseudorhapydionina laurinensis* in the uppermost Sidi Larbi Formation below the ammonite-bearing levels (CHARRIÈRE et al. 1998). Middle late Cenomanian is unequivocally indicated by the zonal index species *Metoicoceras geslinianum*, which allows correlation across the Tethys-Boreal transition (cf. chapters 6, 9). The FO and LO (first and last occurrence) of *M. geslinianum* are important concerning the discussion about the Cenomanian/Turonian boundary. These datums are some of the macrofossil arguments for defining the base of the Turonian stage in Pueblo, Colorado, USA, of the Global boundary Stratotype Section and Point (GSSP) proposed by KENNEDY et al. (2000 and 2005). The taxa mentioned above are the oldest ammonites recorded hitherto from the Amghourzif Formation of the Middle Atlas. *Neolobites vibrayeanus* recorded from the Amghourzif Formation of the Haute Moulouya (CHARRIÈRE et al. 1998) is of the same age interval (LEHMANN, in WIESE & SCHULZE 2005). *Pseudaspidoceras pseudonodosoides* and *Vascoceras cauvini*, which are accompanied by *Nigericeras?* sp. (CHARRIÈRE et al. 1998), a genus also identified herein, indicates the latest Cenomanian. Apparently, all late Cenomanian taxa are concentrated in a very thin horizon directly above the transgressional surface of the Amghourzif Formation, since early Turonian ammonites are found immediately above (see CHARRIÈRE 1998, fig. 2 and Text-fig. 3 herein).

The early Turonian is represented by a rich ammonite assemblage (Text-fig. 4). The Tethyan species *Vascoceras durandi*, which occurs together with *Pseudaspidoceras flexuosum* (CHARRIÈRE et al. 1998), indicates the earliest early Turonian. The occurrence of *P. flexuosum* especially is important in this context, since it is an index macrofossil occurring only about 1.5 m above the base of the Turonian sediments at the proposed GSSP in Pueblo (KENNEDY et al. 2005: above bed 90 in fig. 5 that is including the base of the *P. flexuosum* zone). Furthermore *Morrowites wingi* is a biostratigraphically important species of the Bou Angueur fauna; it occurs at the proposed GSSP in Pueblo about 2.0 m above the base of the Turonian sediments (KENNEDY et al. 2005: bed 99 in fig. 5).

Higher up in the section *Mammites nodosoides* indicates the later early Turonian (CHARRIÈRE et al. 1998; see also BENGTON 1996). The latter is a cosmopolitan species, allowing an interregional correlation (cf. chapter 6). However, e.g. POPOFF et al. (1986) and KUHNT et al. (1986) record *M. nodosoides*, widely used as an early Turonian index species in the Boreal realm, in the middle Turonian of the Tethyan realm, where it is co-occurring with pseudotissotiids and neoptychitids. The FO and LO of *M. nodosoides* are also known from the proposed GSSP section at Pueblo and there define an interval already well inside the lower Turonian sediments (KENNEDY et al. 2005; base of bed 101 and mid of bed 118 in fig. 9). The exact age range of *Pseudaspidoceras footeanum* is unknown, but if dated, it is early Turonian. *Morrowites wingi* is a rare but interesting species, since it is known in Morocco from the middle Turonian *Benueites benueensis* & *Watinoceras guentheri* Zone sensu COLLIGNON (1967) of the Tarfaya region, comprising the early-middle Turonian boundary in the current interpretation (e.g. KENNEDY et al. 2000; YAZYKOVA 2004). Although typical for the early Turonian, a middle Turonian age cannot be ruled out for *M. wingi* as well as for other species (*Spathites (J.) reveliereanus*, *Lewesiceras peramplum*, and *M. nodosoides* already discussed above), range up into the middle Turonian.

Finally, the genus *Coilopoceras* from the middle part of the Amghourzif Formation, eastern Bou Angueur syncline, first appears at the base of the middle Turonian and continues through the upper Turonian sequence.

To summarize, the assemblage from the Amghourzif Formation in the Bou Angueur syncline represents mainly the Cenomanian/Turonian boundary interval, at least from the earliest late Cenomanian (LO of *C. (N.) asiaticum*) to the middle early Turonian (LO of *V. durandi*, FO of *Thomasites rollandi*) (see also CHARRIÈRE et al. 1998). ENSSLIN (1993) suggested an Early Turonian base by facies correlation with sections from the Haute Moulouya, which are rich in nektonic crinoids. However, our observation of a very thin late Cenomanian ammonite horizon in the succession, indicates strong condensation at the base of the Turonian. Also the base of the lateral equivalent Ait Ben Ali Formation from the Tighboula syncline was considered to be early Turonian by means of ostracodes, pelagic foraminifers and a condensed bed with both Cenomanian and Turonian ammonites (ANDREU & CHARRIÈRE 1986; CHARRIÈRE 1990; ANDREU-BOUSSUT 1991; ANDREU 1993a; see above). From the Midelt region (southern Haute Moulouya), an unequivocal Late Cenomanian base of the Amghourzif Formation was proved by a separate ammonite-bearing unit and, therefore, CHARRIÈRE et al. (1998) deduced a diachronous transgression of the Amghourzif/Ait Ben Ali formations. However, our ammonite data stress an isochronous

transgression and varying intensities of condensation between the Haute Moulouya and the different Middle Atlas synclines.

The date of the top of the Amghourzif Formation is not known, but generally considered to be within the late Turonian (ENSSLIN 1992, 1993). Reevaluation of an algal microflora from the basal Ait ‘Sba Formation to be from the Turonian/Coniacian boundary interval corroborates that age (see above). Biostratigraphic data from the Ait ‘Sba Formation (ANDREU 1995; ANDREU et al. 1996) also infers a late Turonian date for the top of the underlying Ait Ben Ali. In conclusion, the end of predominant carbonate deposition at the top of the Amghourzif and Ait Ben Ali formations correlates well with the pronounced eustatic sea level fall in the late Turonian (HAQ et al. 1987, 1988), as already stressed by THEIN (1988) for equivalent Turonian carbonate successions of the western and central High Atlas realm, and by ENSSLIN (1992, 1993) for the Haute Moulouya and the Middle Atlas realm.

The most detailed biostratigraphic data available on ammonites from the Cenomanian-Turonian boundary interval in Morocco is from the Tarfaya basin (WIEDMANN & KUHN 1996). Although almost 30 taxa are recorded, a detailed correlation with the rich Bou Angueur fauna is impossible, since *Metioceras geslinianum* and *Mammites nodosoides* are the only species recorded in both areas. The ammonite age ranges from Tarfaya show some peculiarities: There is a small overlap of *Metioceras* cf. *geslinianum*, *Metioceras* is characteristic of the late Cenomanian, and *Watinoceras* sp., typical for the early Turonian. Furthermore, for Tarfaya, *Fagesia* is reported in the late Cenomanian, however, this might be based on a misidentified specimen of *Vascoceras*. Furthermore, *Proplacentoceras zeharensis*, possibly a synonym of *Wrightoceras munieri* following CHANCELLOR et al. (1994), is recorded throughout the Turonian of Tarfaya (COLLIGNON 1966) and late Cenomanian (WIEDMANN & KUHN 1996). If the later late Cenomanian record of ? *Wrightoceras munieri* is proved to be correctly *W. munieri* (not yet traced in the WIEDMANN collection in Tübingen), it represents the oldest hitherto known record of that species. *Lewesiceras mantelli* is a predominantly late Turonian species. Additionally, the occurrences of *Euomphaloceras euomphalum*, as far as is known characteristic of the early late Cenomanian, and *Metioceras* cf. *geslinianum*, hinting at the middle late Cenomanian, are remarkable, because both are recorded from just at the Cenomanian/Turonian boundary.

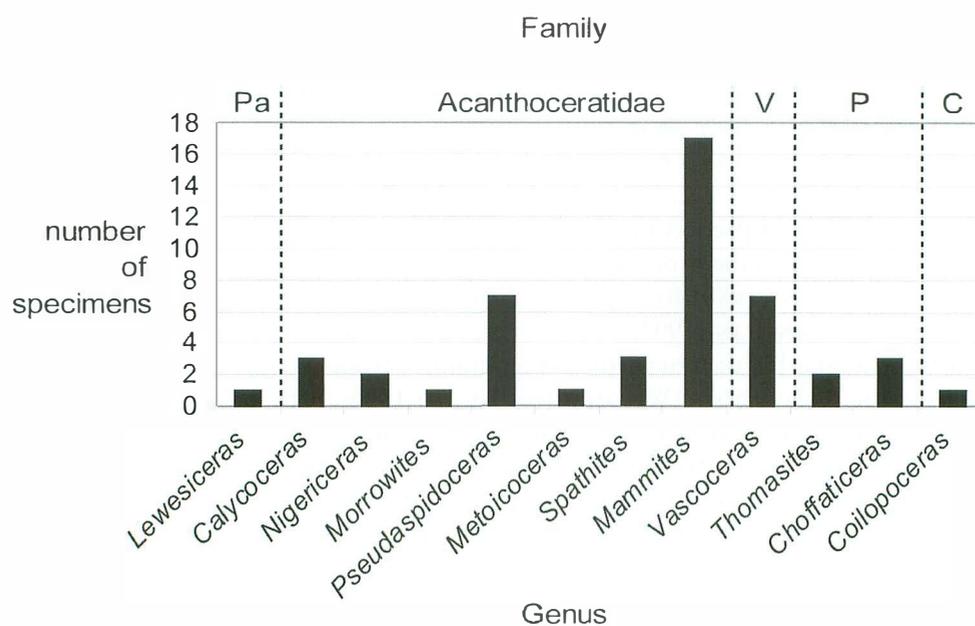
5.2 Ait ‘Sba Formation

The first ammonites recovered from the Ait ‘Sba Formation have been obtained from a level just below the prominent limestone ledge in the middle part of the formation. *Libyoceras* cf. *afikpoense* and *Libyoceras* cf. *ismaelis* indicate a Campanian-Maastrichtian age. *Libyoceras afikpoense* is late Campanian in Nigeria. *L. ismaelis* is widely distributed in North Africa from the late Campanian to the Maastrichtian. Since the Foum Kheneg Formation on top of the Ait ‘Sba in the northeastern Bou Angueur syncline is Campanian(?)/Maastrichtian, a Maastrichtian age can be ruled out. As discussed above, the limestone ledge above the ammonite-bearing horizon is correlated with the Late Campanian sea level highstand.

6. The upper Cenomanian-Turonian ammonite fauna

6.1 Composition

General aspects of the composition of the late Cenomanian/Turonian ammonite assemblage are shown in Text-fig. 5. The majority of ammonites belong to the Acanthoceratidae, together with a few representatives of the Pachydiscidae, Vascoceratidae, Pseudotissotiidae and Coilopoceratidae (Text-fig. 5). These ammonite families all belong to the suborder Ammonitina. Members of the characteristically smooth or sparsely ribbed representatives of the suborders Phylloceratina and Lytoceratina are missing, although they are important components in other ammonite assemblages in the Late Cretaceous of the Tethys. The Phylloceratina and Lytoceratina are interpreted as inhabiting mainly open-marine and pelagic environments rather than coastal areas (WESTERMANN 1996). Transport of empty shells into shallow environments is a rare phenomenon and only likely for the long-distance floating phylloceratids (LEHMANN 1995; MAEDA & SEILACHER 1996). In addition, the lack of heteromorph ammonites is significant bearing in mind that they are widely distributed and common in Cretaceous successions worldwide.



Text-fig. 5. Composition of the Cenomanian-Turonian ammonite fauna described herein, indicating a typical Tethyan assemblage. However, note the lack of any lycoceratids, phylloceratids and heteromorphs. Pa – Pachydiscidae, V – Vascoceratidae, P – Pseudotissotiidae, C – Coilopoceratidae. Based on 48 specimens that are determinable on the genus level, of a total of 84 ammonites collected in the field.

In summary, the fauna corresponds well to an open marine continental shelf, as proposed above for the Amghourzif/Ait Beni Ali Formation, which is typical for the shallow margins of the Tethys.

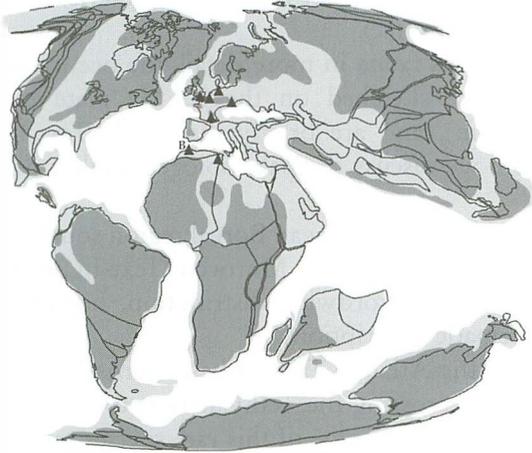
6.2 Palaeobiogeography and Tethyan bioprovinces

The distribution of Cretaceous ammonite faunas has been largely affected by the major global transgression of the late Early and early Late Cretaceous and the subsequent opening of marine gateways. Thus the rising sea level is believed to be the main factor for the general cosmopolitan character of ammonite faunas of the latest Early Cretaceous (e.g. WIEDMANN 1988; LEHMANN 2000). Although rising sea level eliminated geographical barriers and enabled wider distribution, in certain cases this might have led to a lower faunal exchange since a decline of shallow-water connections hindered migration of some ammonite groups (WIEDMANN 1988), which were bottom-related animals (e.g. WESTERMANN 1996). During continuously rising sea level an increased provincialism of faunas can be recognised in the late Cenomanian and early Turonian in the Tethys (WIEDMANN 1988). The faunas reflect a change from an expanded Tethyan bioprovince in the late Cenomanian to a restricted Tethyan bioprovince in the early Turonian (KUHN & WIEDMANN 1995). Following WIEDMANN (1988), the provincialism in the Turonian is expressed by a boreal Collignoniceratid Province (= Selwynoceratid association sensu e.g. WIEDMANN et al. 1978a, 1978b; EINSELE & WIEDMANN 1982; THURLOW et al. 1982) in the northern hemisphere, a Vascoceratid Province in the Tethys, and a Puzosiid Province in the southern oceans. The Bou-Angueur fauna lies in the girdle of WIEDMANN's (1988) Vascoceratid Province, but vascoceratids are by far outnumbered by acanthoceratids as mentioned earlier by LEHMANN & HERBIG (2003) and illustrated in Text-fig. 5.

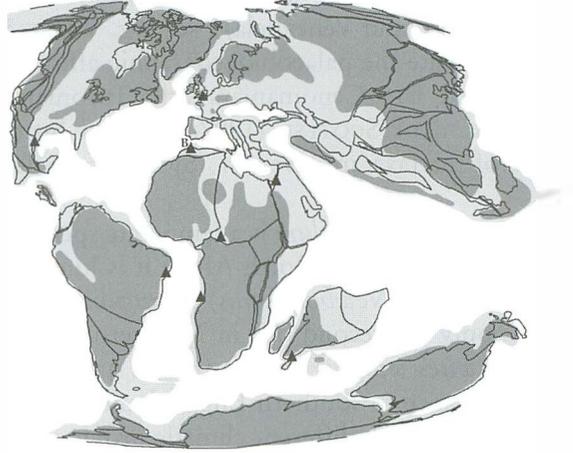
6.3 Palaeobiogeography of the Middle Atlas ammonite fauna

In the Middle Atlas hitherto only CHARRIÈRE et al. (1998) have discussed briefly the palaeogeographic affinities of some of the ammonites. The occurrence of *Vascoceras cauvini*, *Nigericeras*, *Pseudaspidoceras flexuosum* and *Mammites nodosoides* is included in our discussion below. *Neolobites vibrayeanus* is a patchily

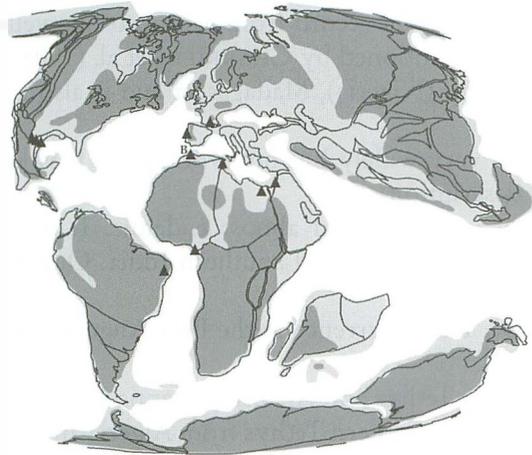
A *Lewesiceras peramplum*



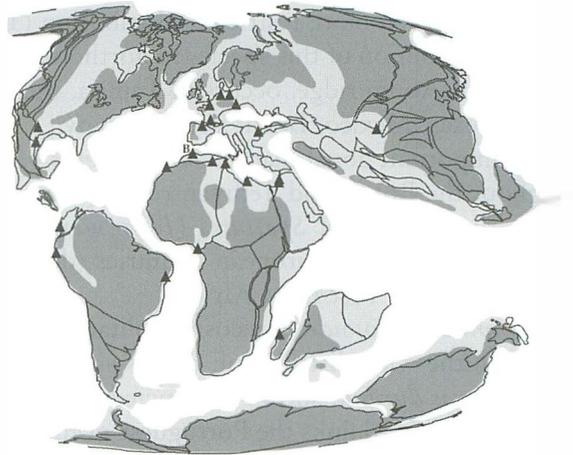
B *Pseudaspidoceras footeanum*



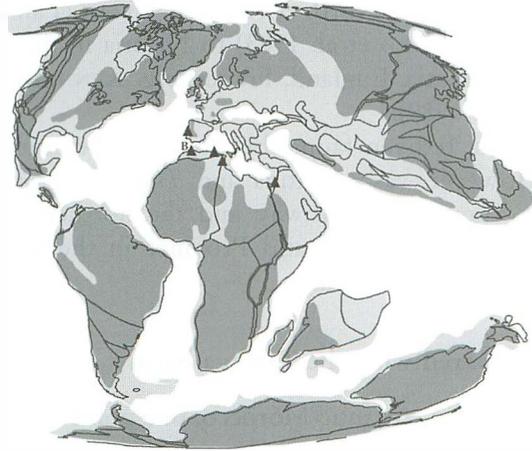
C *Pseudaspidoceras pseudonodosoides*



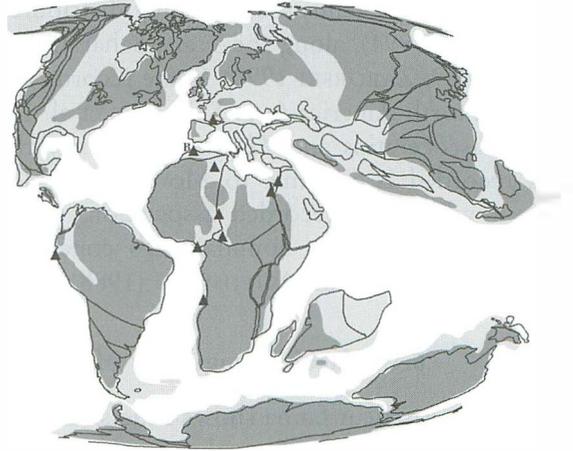
D *Mammites nodosoides*



E *Vascoceras durandi*



F *Vascoceras cauvini*



Text-fig. 6. Palaeobiogeographical distribution of the ammonite species found in the Bou-Angueur syncline (B) compared to their global record. Plate tectonic reconstruction is for 90 Ma (SCOTÈSE 1997).

distributed, albeit widespread taxon in North Africa including the Transsaharan seaway as far south as Niger, in the Middle East as well as in southwestern Europe (France, Iberian Peninsula) and South America (Bolivia, Colombia, Peru and Venezuela), see e.g. WIESE & SCHULZE (2005, cum lit.).

To elucidate the palaeobiogeographic affinities of the Middle Atlas fauna in more detail, the occurrences of the described late Cenomanian/early Turonian ammonite taxa are sketched on the 90 Ma plate tectonic reconstruction of SCOTESE (1997, see also <http://www.scotese.com>), and are briefly discussed (Text-fig. 6). Records of the taxa are given in “Systematic palaeontology”, here we discuss the palaeobiogeographic affinities only.

Lewesiceras peramplum is a temperate species widely distributed in the European Boreal region southward to southeastern France; in North Africa it is known from Egypt, central Tunisia and Morocco (Text-fig. 6 A).

Calycoceras (Newboldiceras) asiaticum asiaticum shows an almost worldwide distribution, however, our record is only the second one in Northern Africa (compare systematic description).

Morrowites wingi is known from a narrow belt running from the Atlantic Tarfaya basin across the Middle Atlas and France to southern England and the Czech Republic, thus crossing the Tethyan-Boreal boundary. Its distribution through different climatic provinces rather points to poor knowledge of this rare species rather than to an endemic distribution, since it occurs also in the southern part of the Interior Seaway, southwestern USA as well as in Japan.

There are three species of *Pseudaspidoceras* in the Bou-Angueur fauna. *P. footeanum* (Text-fig. 6 B) is a cosmopolitan species with records from the Boreal realm, India, the South Atlantic and the Pacific. Although widely distributed, it is uncommon and known from few countries only. The same is true for *P. pseudonodosoides* that shows an even more restricted distribution (Text-fig. 6 C). The present record from Morocco fits well with the main distribution of this species in northern Africa. *P. flexuosum*, mentioned by CHARRIÈRE et al. (1998) from the Assaka-n-Aoum ridge, occurs in Tunisia, the Transsaharan seaway (Nigeria), Madagascar and is also known from the Texas, Mexico, Brazil and Germany.

The important zonal marker *Metoicoceras geslinianum* occurs very widely but not worldwide. It is known throughout the Boreal and Tethyan realm (compare systematic description).

The distribution of *Spathites (Jeanrogericeras) reveliereanus* is patchy and almost endemic. It was only known from very few European countries (details see systematic description) and southern India. Our Middle Atlas record is the first from Africa.

Mammites nodosoides is a cosmopolitan species (Text-fig. 6 D). The occurrence in the Bou-Angueur area fits well within the wide distribution of this species in northern Africa.

Vascoceras durandi shows a restricted distribution in the western Tethys and adjacent Atlantic Portugal. The Bou Angueur record links the Portuguese occurrence to those along the southern Tethys from Algeria and Tunisia to Israel (Text-fig. 6 E). *Vascoceras cauvinii* is more widely distributed (Text-fig. 6 F). It occurs in a large part of Africa, but there are few records from Europe (France) and South America (Peru) only.

The records of *Thomasites rollandi* show a limited distribution, almost exclusively in northern Africa and the Near East (for details see systematic description). The occurrence in the Middle Atlas, which fits well into the known palaeobiogeographic distribution, extends the undoubted record of the species from Tunisia to Morocco.

Nigericeras is a genus that is mainly distributed in Africa, ranging from North Africa (e.g. CIZAK et al. 1999; MEISTER et al. 1994), along the Trans-Saharan seaway, over Niger (AMARD et al. 1983) to Nigeria in the south (MEISTER 1989; ZABORSKI 1990). Some records are from Europe (Croatia, England, France; e.g. KENNEDY et al. 2003) and North America (e.g. KENNEDY et al. 1989; COBBAN et al. 1989).

The vascoceratids and *Thomasites* classify the assemblage as a Tethyan fauna, but none of the ammonite species recorded is endemic to Morocco or North Africa. However, vascoceratids and *Thomasites* are less important within the recorded association, in contrast to the Trans-Sahara seaway and the northern South Atlantic, where they are dominant. To conclude, the typical Tethyan Vascoceratid Province in the sense of THUROW et al. (1982) and WIEDMANN (1988) is not developed in the Middle Atlas.

6.4 Palaeobiogeography of the Middle Atlas compared with the Tarfaya basin

The Bou Angueur fauna shows little similarity to the Tarfaya basin, Atlantic Morocco; one point is that the latter area contains a noteworthy proportion of endemic species. The Tarfaya faunas were described by

COLLIGNON (1967), the most detailed later contribution is WIEDMANN & KUHN (1996), who listed some additional taxa and gave exhaustive stratigraphic information. These papers need a comprehensive revision, since this area is a main source for the bioprovince interpretations in that time frame given for example by KUHN & WIEDMANN (1995) who interpret a global trend of provincialism in this time interval that might prove questionable. We neither see an intensive exchange of western Moroccan ammonite fauna with North America in the late Cenomanian compared to the early Turonian, nor an invasion of Boreal species in the early Turonian (compare WIEDMANN et al. 1978a; WIEDMANN 1988; KUHN & WIEDMANN 1995; WIEDMANN & KUHN 1996). The general trend of a distribution of northern temperate macrofaunas towards the equator during the early Turonian (KUHN & WIEDMANN 1995) is, however, reflected by the occurrence of genera like *Collignoniceras*, *Watinoceras* and *Lewesiceras*, as well as by inoceramids of the genus *Mytiloides* at Tarfaya (WIEDMANN & KUHN 1996). Nevertheless, already WIEDMANN et al. (1978b) noted the striking differences between the Tarfaya fauna and that of the Middle Atlas, with a lack of vascoceratids and *Neolobites*, but the presence of *Tarrantoceras* in Tarfaya.

6.5 Palaeobiogeographical conclusions

Five of eleven species show a rather restricted or patchy distribution at a global scale (*Lewesiceras peramplum*, *Morrowites wingi*, *Spathites (J.) reveliereanus*, *Vascoceras durandi*, *Thomasites rollandi*). Four species are cosmopolitan and indicate a not wholly endemic character of the assemblage (*Calycoceras (N.) asiaticum asiaticum*, *Pseudaspidoceras footeanum*, *Mammites nodosoides*, *Metoicoceras geslinianum*). The reason for this cosmopolitan influence are probably well developed marine connections of the Middle Atlas region, respectively of the Bou-Angueur syncline, during the late Cenomanian and early Turonian. WIEDMANN (1988) explained ammonite endemism, e. g. of the Trans-Sahara seaway, by development of numerous ecological niches in large epicontinental seas and seaways like the Western Interior basin or the Trans-Sahara seaway. This agrees with the particular composition of the Bou Angueur fauna, which thrived in an epicontinental seaway connecting Tethys and Atlantic along the Middle Atlas (see chapter 7, below). Its composition resembles that of the “boreal mammitid association” from deeper water facies in Northern Spain and Portugal (WIEDMANN 1988) rather than that of the expected “Mediterranean vascoceratid association”, which is supposed to testify shallower and warmer water.

The rather low number of cosmopolitan ammonite species in the late Cenomanian and early Turonian on a global scale distinguishes Tarfaya and Bou Angueur faunas (data compiled by JL). The latter is characterised by a large proportion of widely distributed species which occur mainly in the temperate realm. For Tarfaya, the occurrence of temperate taxa is explained by coastal upwelling (WIEDMANN 1988). This is not an appropriate explanation for the Middle Atlas fauna that was deposited far away from the continental margin. Probably the ammonite assemblages were strongly controlled by the supposed early Turonian cooling (KUHN & WIEDMANN 1995), additionally to the development of new niches during the drastically rising global sea level in the late Cenomanian and early Turonian (e. g. HAQ et al. 1987, 1988, peak at the lower-/middle Turonian boundary).

KLINGER & WIEDMANN (1983) demonstrated that ongoing research might significantly change the palaeogeographical distribution of taxa. This might be the case for *Thomasites rollandi*, where uncertain records indicate a significantly larger distribution. Taxonomic revisions and changing taxonomic concepts also account for changing distribution patterns. For example, contrary to our study KLINGER & WIEDMANN (1983) did not record *Metoicoceras geslinianum* from South America, although the records are based on data obtained prior to their study. Another important potential controlling factor might be post-mortem drift, especially to account for the wide distribution of some species along the extended shallow seas of the northern margin of the African continent. This might be particularly true for *Pseudaspidoceras pseudonodosoides*, *Mammites nodosoides*, *Vascoceras durandi*, *V. cauvini* and *Thomasites rollandi*. Shallow water leads to slow waterlogging of ammonite shells after death, because ambient pressures were not higher than cameral gas pressure (MAEDA & SEILACHER 1996). The buoyancy of shells might have been maintained until soft parts had been decayed or lost their connection to the shell. Afterwards, shells surfaced and drifted. It has to be stressed that several circumstances are known that cause drift of modern *Nautilus* shells (e. g. NEUFFER 1990) and that drift distances easily attain thousands of kilometres (HOUSE 1987; MAEDA & SEILACHER 1996).

7. Palaeogeographic evolution of the Middle Atlas and relations of the benthic biota

Early authors noted the extremely wide occurrence of the “barre calcaire du Cénomano-Turonien” in Morocco (CHOUBERT 1948; BASSE & CHOUBERT 1959; CHOUBERT & FAURE-MURET 1962; BUSSON 1969). In general, they recognise a vast emergent land mass called “Terre des Idrissides” by CHOUBERT & FAURE-MURET (1962), the “Terre sud-rifaine” by MICHARD (1976), which separate the Rif realm from the epicontinental sea of central and southern Morocco. This land mass includes among others, the Middle Atlas-Haute Moulouya-High Atlas realm, and its continuation into Saharan Algeria and Tunisia i. e. penetrating into the Tethys realm further east. ANDREU (1986) postulated a direct connection between the Middle Atlas and Rif realms (“rides sud-rifaines”) in the north across the “Terre des Idrissides”. ANDREU (1989) supported that assumption with combined stratigraphic and sedimentological studies. In a following study, ANDREU-BOUSSUT (1991; see also ANDREU 1993b; CHARRIÈRE et al. 1998) added palaeobiographic data from ostracodes, which showed the strong faunistic relations during the late Cenomanian between the Essaouira basin, the central High Atlas, the Middle Atlas, and to a lesser extent, the external Rif domain. CHARRIÈRE (1990, 1992, 1996) confirmed ANDREU’s assumptions, but envisaged a seaway orientated northeast, parallel to the strike of the Middle Atlas range, and probably related to deep-seated strike-slip lineaments like the Northern Middle Atlas Fault. As early as the Aptian, a transgression reached the western limits of the Tighboula-Oudiksou synclines, whereas a similar gulf extended from the Atlantic Essaouira basin eastward north of the axis of the High Atlas. Both gulfs joined during the late Cenomanian(?)/Turonian interval. Supposedly, an extended seaway formed, covering High Atlas, Middle Atlas, Moulouya and Hauts Plateaux (CANEROT et al. 2003). However, due to widespread erosion of Cretaceous strata and insufficient knowledge of regional facies developments, the real extent and internal organisation of that seaway is not known. The widely used reconstruction of PHILIP & FLOQUET (2000), which indicates an almost completely inundated Maghreb, east of the Moroccan Meseta, is surely oversimplified. Concerning the Middle Atlas, it has to be stressed that the pelagic faunal elements of the marly Ait Ben Ali Formation indicate more open marine facies than the carbonate platform facies of the Amghourzif Formation, thus demonstrating a remarkable influence from the Tethys in the northeast. It is noteworthy that ETTACHFINI et al. (2005) considered a late Cenomanian transgression prograding from the northeast, i. e. from the Tethys even for some synclines in the northern part of the central High Atlas south and east of Beni Mellal.

In the Middle Atlas, the marine connection to the Tethys persisted through the earlier phase of the late Late Cretaceous. Facies gradients show that the seaway was closed before the late Santonian. From that time on, sedimentation took place in an Atlantic-bound gulf (CHARRIÈRE 1996). This is also well documented for the deposition of the black shales of the Campanian(?) to Maastrichtian El Koubbat Formation (CHARRIÈRE 1992), and the Paleogene Bekrit-Timahdit Formation (HERBIG 1991). ANDREU (1995) supported that view in a study of trachyleberidid ostracodes from the Tighboula syncline, which indicate European affinities during the Albian–Santonian, but typical African affinities from the Late Santonian onwards.

In a more generalized frame, ANDREU-BOUSSUT (1991) and ANDREU (1993b) demonstrated very strong relations between Moroccan ostracodes and ostracodes from the southern Tethys shelf, especially from Algeria, Tunisia, Israel and Jordan, and to lesser degree as far as Oman and Somalia. The ostracodes define a North African-Middle East faunal province, already recognized by earlier authors. It came into existence during the Barremian/Aptian and reached its acme during the late Cenomanian/early Turonian. During the latter interval, Tethyan ostracodes predominate throughout most of Morocco and Atlantic species are restricted to the Atlantic coastal basins of Tarfaya, Agadir, western Essaouira, and the external Rif, where both fauna intermingled, Tarfaya excepted.

As discussed by ANDREU-BOUSSUT (1991), certain benthic greater foraminifers and calcareous algae show an identical North African-Middle East distribution pattern in the Early Cretaceous. The continued presence of that province during the Cenomanian-Turonian seems logical and is corroborated by the occurrence of a few calcareous algae in the Bou Angueur syncline, which are also well documented from various localities in Egypt, Libya and Tunisia (ENSSLIN & SCHLAGINTWEIT 1999). The same holds true for late Cenomanian benthonic foraminifers (Rhapidionininae) known from the Middle Atlas synclines and the Haute Moulouya (ENSSLIN 1993; CHARRIÈRE et al. 1998), which are widely distributed across Northern Africa and the Middle East, and locally even reach the northern border of the Tethys. Associated *Spirocyclus atlantica* is known from various localities in the Moroccan High Atlas and Middle Atlas, and from southwestern Libya (CHARRIÈRE et al. 1998).

The continued, though less expressed persistence of the North African-Middle East ostracode province and its strong influence within the Middle Atlas (syncline of Tighboula) was indicated in a study of upper Turonian(?) to Santonian ostracodes by ANDREU (1996). They accord well with Algerian faunas. These similarities largely vanish east of Tunisia except for the occurrence of some cosmopolitan forms.

8. Palaeobiogeographic conclusions

Concerning the late Cenomanian-early Turonian Middle Atlas ammonite fauna, three surprising results have to be stressed.

Firstly, the ammonite fauna does not accord with the pronounced southern Tethys relations indicated by facies gradients and benthic biota, especially by ostracodes, foraminifers and calcareous algae, although minor portions of vascoceratids and *Thomasites* classify the assemblage as western/central Tethyan.

Secondly, the fauna is dominated by cosmopolitan species, namely *Calycoceras* (*N. asiaticum asiaticum*), *Pseudaspidoceras footeanum*, *Mammites nodosoides* and *Metoicoceras geslinianum*, whereas the late Cenomanian/early Turonian Tarfaya fauna follows the global trend of provincialism in this time interval. Moreover, none of the recorded taxa is endemic. Both facts are still more surprising since Tarfaya faces the open Atlantic Ocean, whereas the Middle Atlas fauna inhabited an extended intracontinental seaway.

Thirdly, during the early Turonian, the immigration of typically northern temperate genera into low latitudes is expressed by *Collignonoceras*, *Watinoceras* and *Lewesiceras* at Tarfaya, though it is not explicitly reflected by an invasion of Boreal ammonite species (compare WIEDMANN et al. 1978a; WIEDMANN 1988; KUHNT & WIEDMANN 1995; WIEDMANN & KUHNT 1996). *Lewesiceras peramplum* is the only early Turonian ammonite species found in the Bou Angueur syncline that is a form otherwise restricted to the northern temperate realm, but occurs very exceptionally out of its home realm.

Concerning, the two Campanian *Libyoceras* species from the Ait'Sba Formation, the palaeogeographic evolution of the Middle Atlas seaway indicates that they lived in an Atlantic-bound gulf without connection to the Tethys. This coincides with their palaeobiogeographic distribution in the Near East, Northeast Africa and Nigeria and is well corroborated by the African affinities of Late Santonian and younger ostracodes from the Tighboula syncline (ANDREU 1995).

9. Systematic palaeontology

Altogether 84 ammonites were originally collected in the field, 75 of which are determinable. In the systematic part we describe the most significant 31 ammonites. The following abbreviations are used to indicate the repositories of specimens dealt with in the present paper:

GSUB: Geosciences Collection of the University of Bremen, Germany.

The suture terminology follows WEDEKIND (1916), as used by KULLMANN & WIEDMANN (1970) and revised in parts by KORN et al. (2003); E – external lobe, A – adventive lobe (= L of former nomenclature), U – umbilical lobe, I – internal lobe. E/A (= E/L of former nomenclature) is the saddle between E and A; A/U (= L/U of former nomenclature) corresponds to the saddle between A and U.

Measurements are as follows: wh – whorl height, wb/wh ratio – ratio whorl height to whorl breadth.

All figured specimens were coated with ammonium chloride to highlight morphological details. Arrows indicate the approximate transition between phragmocone and body chamber where determination was possible. The comparisons of present material to specimens in the literature always refer to specimens of equal size if not stated otherwise.

Suborder Ammonitina HYATT, 1889

Superfamily Desmocerataceae VON ZITTEL, 1895

Family Pachydiscidae SPATH, 1922

Genus *Lewesiceras* SPATH, 1939

Lewesiceras peramplum (MANTELL 1822)

(Plate 1, figs. H–I)

- 1822 *Ammonites peramplus* – MANTELL, p. 200.
1939 *Lewesiceras peramplum* (MANTELL) – SPATH, p. 296.
1997 *Lewesiceras peramplum* (MANTELL) – IMMEL et al., p. 164; Plate 6, figs. 1–2.
1998a *Lewesiceras lewesiense* (MANTELL) – LEHMANN, p. 416 (and synonymy).
1998b *Lewesiceras lewesiense* (MANTELL) – LEHMANN, p. 16.
2003 *Lewesiceras peramplum* MANTELL – WITTLER & ROTH, p. 272; text-fig. 6.
2003 *Lewesiceras mantelli* (WRIGHT & WRIGHT) – WITTLER & ROTH, p. 272; text-fig. 7.

Material: GSUB C2535

Description: A single fragmentary specimen (GSUB C2535) with a maximum diameter of almost 75 mm is worn, but the ornamentation is still visible. There are prominent, rather rounded than elongated, umbilical bullae that give rise to flat and fold-like radiate primary ribs. In between the primary ribs there are 1–3 secondary ribs intercalated that appear not before the outer third of the flank. Both ribs cross the venter with the same strength and are only slightly bent forward. The whorl section is compressed, distinctly higher than broad (about 32 mm) and narrowly rounded.

Discussion: This well-known species has been revised by WRIGHT & KENNEDY (1981) who also give a comparison to other species. The validity of *L. peramplum* was questioned erroneously by LEHMANN (1998a, b).

Occurrence: *Lewesiceras peramplum* occurs for certain in the lower Turonian *Mammites nodosoides* Zone and the middle Turonian *Collignoniceras woollgari* Zone of England, France, Germany and Czech Republic (e.g. WRIGHT & KENNEDY 1981). It has been reported by CHANCELLOR et al. (1994) from the undifferentiated Turonian of Oued Faour in central Tunisia and has been earlier mentioned from Morocco without description (e.g. CHOUBERT 1939; BASSE & CHOUBERT 1959).

Superfamily Acanthocerataceae DE GROSSOUVRE, 1894

Family Acanthoceratidae DE GROSSOUVRE, 1894

Subfamily Acanthoceratinae DE GROSSOUVRE, 1894

Genus *Calycoceras* HYATT, 1900

Calycoceras (*Newboldiceras*) *asiaticum asiaticum* (JIMBO 1894)

(Plate 1, figs. A–B)

- 1894 *Acanthoceras rotomagense* DEFRANCE var. n. *asiatica* – JIMBO, p. 177; Plate 20, figs. 1, 1a.
1937 *Calycoceras* (*Eucalycoceras*) *Newboldi* KOSSMAT – COLLIGNON, p. 38 (14).
1994a *Calycoceras* (*Newboldiceras*) *asiaticum asiaticum* (JIMBO) – KENNEDY & JUIGNET, p. 40; text-figs. 1d, 6c, 6f, 6g, 6h, 6i, 11a & b, 12a–c, 13a–c, 14a–d, 23a–c.
2004 *Calycoceras* (*Newboldiceras*) *asiaticum asiaticum* (JIMBO) – KENNEDY & JOLKICEV, p. 375; Plate 3, fig. 1; Plate 4, figs. 6–7; Plate 5, figs. 1–4 (and synonymy).
2004 *Calycoceras* (*Newboldiceras*) *asiaticum spinosum* (KOSSMAT) – KENNEDY & JOLKICEV, p. 376; Plate 3, figs. 7, 10, 11; Plate 4, figs. 1–5; Plate 5, figs. 6–11 (and synonymy).

Material: GSUB C2573

Description: GSUB C2573 is a fragmentary specimen with a diameter of 90 mm. On the last two ribs, ribbing crosses the venter consistently strongly, slightly projecting forward. There are about 20 rursiradiate primary and secondary ribs per half a whorl, with the secondary ribs arising at about $\frac{2}{3}$ of the flank height. The tuberculation consists of umbilical bullae and one row of hardly recognizable outer ventrolateral tubercles. The whorl section is compressed (wh/wb ratio about 1.28) with flanks that are almost flat and only slightly inflated.

The ventrolateral facets and a flat venter between the ventrolateral tubercles give a polygonal appearance. The siphonal tubercles are visible at the last rib that is well-preserved throughout the ventral portion. The coiling is evolute, with a comparatively large umbilicus.

Discussion: Our specimen can be best compared with *Calycoceras (Newboldiceras) asiaticum* by its polygonal cross section, dense ribbing (about 20 ribs per $\frac{1}{2}$ a whorl as typical at this diameter, e. g. KOSSMAT 1895; KENNEDY & JUIGNET 1994a), with umbilical and outer ventrolateral bullae as well as siphonal tubercles. It differs from *C. (N.) asiaticum spinosum* (KOSSMAT 1897), by its persistent strong tuberculation and narrower ribbing (see also KENNEDY & JUIGNET 1994a). *Calycoceras (N.) asiaticum hunteri* (KOSSMAT 1897) differs by slowly expanding subquadrate whorls and uniform single ribs during middle and late ontogeny (KENNEDY & JUIGNET 1994a).

Occurrence: *Calycoceras (N.) asiaticum asiaticum* occurs from the middle Middle to early late Cenomanian of France, England, Romania, Tunisia, South Africa, Madagascar, South India, Japan and California; doubtful are the records in Tibet, Poland, Israel and China (e. g. KENNEDY & JUIGNET 1994a).

Genus *Nigericeras* SCHNEEGANS, 1943

Nigericeras cf. *gadeni* (CHUDEAU 1909)

(Plate 1, figs. F–G; Text-fig. 7 A)

cf. 1909 *Acanthoceras* (?) *gadeni* – CHUDEAU, Plate 3, fig. 6.

cf. 1943 *Nigericeras gadeni* (CHUDEAU) – SCHNEEGANS, p. 123; Plate 7, figs. 3–4.

cf. 1990 *Nigericeras gadeni* (CHUDEAU) – ZABORSKI, figs. 4–7.

cf. 1992 *Nigericeras gadeni* (CHUDEAU) – MEISTER et al., p. 67; Plate 3, figs. 1–3, 5 & 7; Plate 4, fig. 1; text-fig. 13 (and synonymy).

cf. 1994 *Nigericeras gadeni* (CHUDEAU) – KENNEDY & WRIGHT, Plate 1, figs. 1–3; Plate 2, figs. 2–3, 6–8.

Material: GSUB C2574

Description: GSUB C2574 is moderately involute with a suboval cross section and an almost vertical umbilical wall (Text-fig. 7A). Broad, fold-like radial ribs that are broad and dense are visible on the venter and ventrolateral shoulder of the last part of the fragment.

Discussion: Our material fits well to a densely ribbed specimen figured by MEISTER (1989: Plate 3, fig. 1). Earlier authors include *Nigericeras lamberti*, *N. gignouxii* and *N. jaqueti* described by SCHNEEGANS into *Nigericeras gadeni* (CHUDEAU 1909), a species that is believed to be pretty variable in ornamentation (SCHÖBEL 1975; ZABORSKI 1990; THOMEL 1992). Since GSUB C2574 shows fewer features compared to well-preserved *Nigericeras* (SCHÖBEL 1975; MEISTER 1989; MEISTER et al. 1992; ZABORSKI 1990), it is referred to as *Nigericeras* cf. *gadeni*.

Occurrence: *Nigericeras gadeni* is characteristic of the lowermost zone of the Cenomanian of Nigeria (ZABORSKI 1990), probably corresponding to the lower or middle part of the late Cenomanian. It also occurs in Algeria (AMARD et al. 1983) and the *V. gadeni* and basal *V. cauvini* zones of Niger (SCHÖBEL 1975; MEISTER et al. 1992).

Subfamily Euomphaloceratinae COOPER 1978

Genus *Morrowites* COBBAN & HOOK, 1983

Morrowites wingi (MORROW 1935)

(Plate 2, figs. O–P)

1935 *Mammites wingi* – MORROW, p. 467; Plate 51, fig. 2; Plate 52, figs. 2a–c; Text-fig. 2.

1935 *Mammites rectangulatus* – MORROW, p. 468; Plate 53, fig. 6; Text-fig. 6.

1983 *Morrowites wingi* (MORROW) v COBBAN & HOOK, p. 9; Text-figs. 3–4 (and synonymy).

1983 *Pseudaspidoceras michelobensis* (LAUBE & BRUDER) – KONEČNÝ & VAŠÍČEK, p. 171; Plates 1–2; Plate 3, fig. 2; Text-fig. 1.

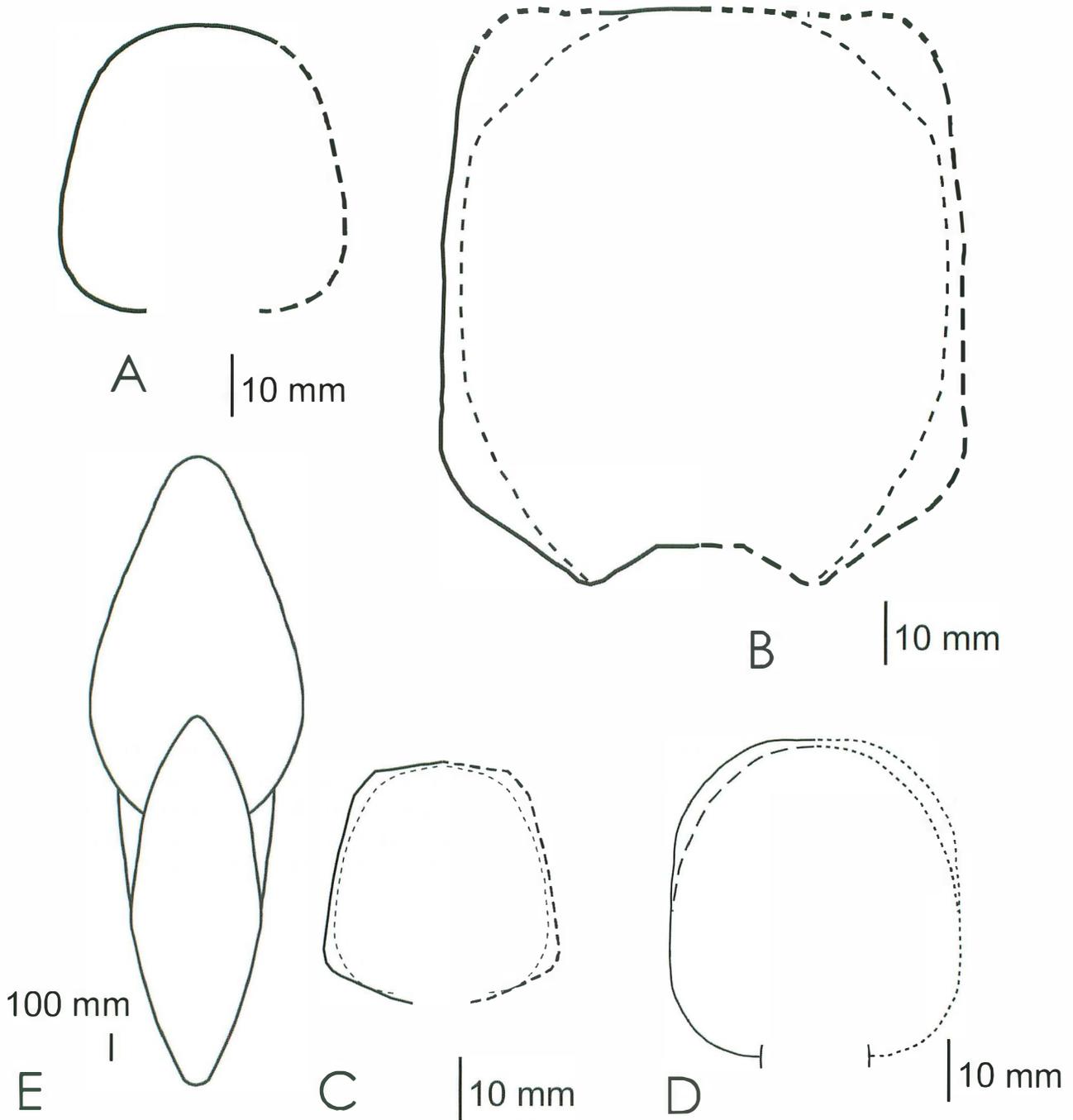
1985 *Morrowites wingi* (MORROW) – AMÉDRO & HANCOCK, figs. 8e–f.

non 1987 *Morrowites michelobensis* (LAUBE ET BRUDER) – KONEČNÝ & VAŠÍČEK, p. 85; Plate 3; Plate 4, fig. 1; Plate 5, fig. 1 (= *Mammites nodosoides*).

? 1989 *Morrowites* cf. *wingi* (MORROW) – KENNEDY et al., p. 72.

1992 *Morrowites michelobensis* (LAUBE & BRUDER) – THOMEL, Plates 100–101; Plate 102, fig. 1 (Plate 104, figs. 1–2 = *Mammites nodosoides*).

Material: GSUB C2584



Text-fig. 7. A-E Whorl sections of A *Nigericeras* cf. *gadeni* (CHUDEAU 1909), GSUB C2574, B *Pseudaspidoceras footeanum* (STOLICZKA 1864), GSUB C2501, C *Pseudaspidoceras pseudonodosoides* (CHOFFAT 1898), GSUB C2580, D *Vascoceras cauvini* CHUDEAU, 1909, GSUB C2566, E *Coilopoceras* sp., GSUB C2500.

Description: GSUB C2584 is a fragment with a maximum wh of about 50 mm and a quadrate whorl section. The prominent sidewardly directed ventrolateral horns are connected by flat, fold-like and almost radial ribs on the lateral side with very prominent umbilical bullae. There are four ribs per quarter whorl. Although the ventral side is worn, it can be seen that the ribs cross the venter as broad flat folds.

Discussion: Our material fits excellently with the type material of *Mammites chouberti* COLLIGNON, 1967 (COLLIGNON 1967) from Tarfaya in western Morocco with its sidewardly projected ventrolateral horns, prominent umbilical tubercles, simple, fold-like ribs and a quadrate whorl section. This species has been later synonymized with *Morrowites wingi* by WRIGHT & KENNEDY (1981).

GSUB C2584 can be easily distinguished from *Mammites nodosoides* by its sidewardly directed horns, its quadrate whorl section and comparatively denser ribbing. *Morrowites powelli* KENNEDY et al. 1987 from the United States and *Morrowites dixeyi* (REYMENT 1955) from Nigeria are much smaller and lack the excessive horns of adult shells. In contrast to *Morrowites mohovanensis* (BÖSE 1920) the ventrolateral tuberculation of our material is more prominent; these are ventrolateral horns instead of tubercles. Additionally, GSUB C2584 shows greater evolute coiling; it lacks secondary ribs and the intercalated ventrolateral tubercles (one ventrolateral horn corresponds to each umbilical tubercle), are clavate horns rather than rounded; the ribbing is much wider spaced than in *M. mohovanensis*.

The English *Mammites wingi revelieroides* WRIGHT & KENNEDY, 1981, supposedly representing a separate species of *Morrowites* (KONEČNÝ & VAŠÍČEK 1987), is distinguished by its trapezoidal whorl section and the equal distance between inner, outer and umbilical tubercles. The two American species *Morrowites depressus* (POWELL 1963) and *Morrowites subdepressus* COBBAN & HOOK, 1983, can be separated by a whorl section that is clearly broader than high in contrast to the quadrate section in GSUB C2584 (compare COBBAN & HOOK 1983: figs. 3, 5A, 7A).

Morrowites prokopensis KONEČNÝ & VAŠÍČEK, 1987, from the Czech Republic shows a denser ribbing, distinctly smaller tubercles and intercalated secondary ribs (KONEČNÝ & VAŠÍČEK 1987). The whorl section is not quadrate like in GSUB C2584, but higher than broad at all growth stages.

Mammites michelobensis is a species of LAUBE & BRUDER (1887) described from Bohemia. It is figured on their Plate 26, fig. 2a, b, but the explanation of plate states *Mammites michelobensis* is figured on Plate 25, fig. 2a, b. Since the description on p. 231 perfectly fits their figure on Plate 25, fig. 2a, b, this is apparently a typing error. The specimen figured either represents a crushed *Mammites nodosoides* (SCHLÜTER 1871), as concluded by WRIGHT & KENNEDY (1981) and BARROSO-BARCENILLA (2007), or a separate *Morrowites* species (KONEČNÝ & VAŠÍČEK 1987). All authors agree that the specimen is badly crushed, of small size and with three keels. If these keels represent a diagnostic feature as claimed by KONEČNÝ & VAŠÍČEK (1983), it cannot be decided as long as the original material of LAUBE & BRUDER (1887) is missing (probably lost, pers. comm. F. WIESE, Berlin, October 2002). WRIGHT & KENNEDY (1981) give further arguments that *michelobensis* is actually based on *M. nodosoides* specimens referring to the LAUBE & BRUDER (1887) paper, but these were not considered by KONEČNÝ & VAŠÍČEK (1983). As long as the specific characters of *Mammites michelobensis* are doubtful, the usage of this name should be avoided.

Beyond this, GSUB C2584 is distinguished from the lectotype of *Mammites michelobensis* and *Mammites nodosoides* by its more depressed, quadrate, whorl section. Even the specimens described by KONEČNÝ & VAŠÍČEK, 1987, and referred to as being conspecific with *Mammites michelobensis*, do not show a quadrate whorl section before a diameter of 230 mm.

Occurrence: It is known from the lower Turonian *M. nodosoides* Zone of England and France (e.g. WRIGHT & KENNEDY 1981; AMÉDRO & HANCOCK 1985). In France it occurs in the upper part of the *M. nodosoides* Zone (AMÉDRO & HANCOCK 1985). This species is also known from Kansas (COBBAN & HOOK 1983) and Japan (*Mammites costatus* sp. nov. of MATSUMOTO et al. 1978, later assigned to *M. wingi* by WRIGHT & KENNEDY 1981). From Morocco it is recorded from the Tarfaya region (COLLIGNON 1967) from the base of the *Benueites benueensis* & *Watinoceras guentheri* Zone of the earliest middle Turonian, a zone above the *M. nodosoides* Zone sensu COLLIGNON (1967).

Genus *Pseudaspidoceras* HYATT, 1903

Pseudaspidoceras footeanum (STOLICZKA 1864)

(Plate 1, figs. P–Q; Text-fig. 7 B)

1864 *Ammonites Footeanus* – STOLICZKA, p. 101; Plate 52, figs. 1–2.

1903 *Pseudaspidoceras footeanum* (STOLICZKA) – HYATT, p. 106.

- 1982 *Pseudaspidoceras footeanum* (STOLICZKA) – CHANCELLOR, p. 92; text-figs. 2a, 24 & 25.
1983 *Pseudaspidoceras footeanum* (STOLICZKA) – PHANSALKAR, p. 181.
1985 *Pseudaspidoceras footeanum* (STOLICZKA) – HOWARTH, p. 98; text-figs. 30–33.
1989 *Pseudaspidoceras paganum* REYMENT – MEISTER, p. 6; Plate 1, fig. 1; text-fig. 3.
1995 *Pseudaspidoceras footeanum* (STOLICZKA) – ZABORSKI, p. 59; text-figs. 6, 7, 9 & 10.
2005 *Pseudaspidoceras paganum* REYMENT – MEISTER & ABDALLAH, p. 127; Plate 6, fig. 2.

Material: GSUB C2501

Description: The fragment (GSUB C2501) of a phragmocone and a partial body chamber shows a subquadrate whorl section (wb/wh ratio 0.93) with a slightly convex venter (Text-fig. 7 B). There are strong umbilical bullae giving rise to somewhat flexuous ribs. The hardly discernible proradiate ribs give rise to prominent ventrolateral tubercles.

Discussion: Our material represents an outer whorl and can be easily distinguished from *Pseudaspidoceras pseudonodosoides* (CHOFFAT 1898) and *Pseudaspidoceras tassaraensis* (*P. pseudonodosoides*: KENNEDY et al. 1989; HOOK & COBBAN 1981; *P. tassaraensis*: MEISTER et al. 1992). *Pseudaspidoceras flexuosum* POWELL, 1963, is more closely allied and differs only in minor details of the cross section and ribbing (WRIGHT & KENNEDY 1981).

The Nigerian species *Pseudaspidoceras paganum* REYMENT, 1954, is also close to *P. footeanum* compared to STOLICZKA's (1864) original drawings of the latter, it is more closely ribbed and to have ribs present across the venter (WRIGHT & KENNEDY 1981). A plaster cast of the lectotype of *P. footeanum* (see KENNEDY et al. 1987) allows us to compare both at the same growth stage. There are smaller, but more accentuated ventrolateral tubercles (nodes) in the type of *P. paganum*, rather than prominent ventrolateral tubercles. The rounded, large and prominent tubercles and indistinct flat swellings across the venter in *P. paganum* differ from less accentuated umbilical bullae and less broad (bar-like) ribs in *P. footeanum*. However, the ribbing is also swell-like in STOLICZKA's (1864) figures of the type material of *P. footeanum* and in that of MEISTER (1989). As a whole in our opinion the features listed do not constitute a convincing reason for distinguishing both species and also the square whorl section of *P. footeanum* versus a subquadrate in *P. paganum*, as claimed by MEISTER & ABDALLAH (2005), appears not to be significant.

Pseudaspidoceras barberi MEISTER, 1989, is another species from Nigeria and Tunisia (MEISTER & ABDALLAH 2005) with differences not adequately discussed. At late mid growth (wh around 50 mm) *P. barberi* is considerably more compressed than *P. footeanum* (BARBER 1957: Plate 1, fig. 1b; STOLICZKA 1864: Plate 52, fig. 1a; KENNEDY et al. 1987: text-fig. 4), and slightly more compressed than *P. paganum* (REYMENT 1954: text-fig. 4; COURVILLE 1992). The strong ventrolateral tubercles of the holotype of *P. barberi* (not accentuated as in the lectotype of *P. footeanum*), is intermediate in strength between the type material of *P. paganum* and *P. footeanum* at the same size. The ribbing of *P. barberi* is smoother with almost smooth flanks (holotype and BARBER 1957: Plate 1, fig. 2a; MEISTER 1989: Plate 2, figs. 2, 5) and evolve in contrast to MEISTER (1989: p. 8) who interpreted a narrower umbilicus than in *P. footeanum* and *P. paganum*.

Occurrence: *P. footeanum* occurs in the lower Turonian of England, Brazil, Mexico, India, Israel, Angola (e.g. HOWARTH 1985) and Nigeria (*P. paganum* of MEISTER 1989). It has been mentioned from the Moroccan Meseta by WIEDMANN et al. (1978, 1982).

Pseudaspidoceras aff. *footeanum* (STOLICZKA 1864)

Specimen GSUB C2517 (Plate 1, figs. L–M) is a fragmentary specimen with a maximum whorl height of 37 mm. The distorted specimen shows a compressed whorl section. Very flat folds (not worn) are present at the umbilical edge, corresponding in number over the smooth flanks (not worn either) to the ventrolateral tubercles. On the ventrolateral edge there are five rounded to slightly clavate ventrolateral tubercles per quarter whorl. On the last part of the whorl a change of ornamentation takes place; the ultimate part of the shell being smooth. The venter lacks ornamentation which appears to be an original character.

The lack of ribs and umbilical tubercles, except for weak umbilical folds, distinguishes GSUB C2517 from all other species of *Pseudaspidoceras* and places it close to *P. footeanum*. It differs by a compressed whorl section. The very weak ornamentation of GSUB C2517 of umbilical folds and moderately strong ventrolateral tubercles, is similar to *Pseudaspidoceras paganum* REYMENT of MEISTER (1989: Plate 1, fig. 1 = *P. footeanum*, see discussion above), but differs by the lack of intercalated inner ventrolateral tubercles as also visible in the lectotype of *P. footeanum*.

Pseudaspidoceras pseudonodosoides (CHOFFAT 1898)

(Plate 2, figs. C–D; Text-fig. 7 C)

- 1898 *Acanthoceras* (?) *pseudonodosoides* – CHOFFAT, p. 65; Plate 16, figs. 5–8; Plate 22, figs. 32–33.
2004 *Pseudaspidoceras pseudonodosoides* (CHOFFAT) – ABDEL-GAWAD et al., Plate 4, fig. 1.
2005 *Pseudaspidoceras pseudonodosoides* (CHOFFAT) – AMÉDRO et al., p. 161; text-figs. 5i, 6c–d (and synonymy).
2005 *Pseudaspidoceras pseudonodosoides* (CHOFFAT) – GALE et al., p. 179; text-figs. 6g, 8b–e.
2005 *Pseudaspidoceras* gr. *pseudonodosoides* (CHOFFAT) – MEISTER & ABDALLAH, p. 126; Plate 5, fig. 3.
2006 *Pseudaspidoceras pseudonodosoides* (CHOFFAT) – EL QOT, p. 117; Plate 25, fig. 1.

Material: GSUB C2511 and C2580

Description: GSUB C2580 and GSUB C2511 are fragments of the inner whorls with parts of the penultimate whorl, with a maximum wh of 42 mm and 51 mm. The intracostal whorl section is almost quadrate (wb/wh ratio about 0.95 in GSUB C2580) with broadly rounded flanks and the greatest breadth at mid-flank (Text-fig. 7 C). The flanks converge to the venter from distinct ventrolateral shoulders that are narrowly rounded. The venter is feebly convex. The intercostal whorl section is almost quadrate, converging from the prominent umbilical and ventrolateral tubercles to a mid flank that is somewhat concave (GSUB C2511).

Very faint radiate ribs (GSUB C2580, partly worn in) or flexuous ribs (GSUB C2511) connect the tubercles at the umbilical edge (proradiately prolonged in GSUB C2511, inducing the flexuous course of the ribs), with the larger ones at the ventrolateral shoulder. The fragment of the penultimate whorl (GSUB C2580) shows proradiate ribs, every second rib bears a pronounced ventrolateral tubercle.

Discussion: Our material is comparable in size to the lectotype of “*Acanthoceras* (?) *pseudonodosoides*” CHOFFAT, 1898 (CHOFFAT 1898: Plate 16, fig. 5) and differs only slightly in size. It shows the typical simple straight, distant ribbing pattern (particularly “bar-like” ribs of KENNEDY et al. 1989), single ventrolateral tubercles that are each linked to a distinct umbilical tubercle and a quadrate whorl section. Furthermore, the tubercles of both rows are equally sized, as in the lectotype. The umbilical tubercles (GSUB C2511) are similar to those in the lectotype, but are less rounded and smaller. A forward bend of the umbilical tubercle in GSUB C2511, nearly forms a clavi and continues in a flexuous rib, is characteristic of our material.

Compared to the holotype of *Pseudaspidoceras flexuosum* POWELL, 1963, GSUB C2580 is of equal size and distinguished by simpler, straight ribs and the lack of secondary ribs in contrast to flexuous ribs with primary and intercalated secondary ribs (see also KENNEDY et al. 1987: Plate 2, fig. 17; text-fig. 5; text-fig. 6 C & D; text-fig. 7 A–C).

The lectotype of *Pseudaspidoceras footeanum* (STOLICZKA 1864) shows somewhat smaller, but more accentuated ventrolateral tubercles (nodes) than our material at the same whorl height at about 40 mm (text-fig. 4 in KENNEDY et al. 1987). The latter author’s also discussed the relationship between the figure of the present-day lectotype and STOLICZKA’s (1865) figure 1b on his Plate 52.

Our material can easily be distinguished from *Pseudaspidoceras tassaraensis* MEISTER et al., 1992, by the presence of umbilical and ventrolateral tubercles at a greater whorl height than is recorded in *P. tassaraensis* and their whorl sections that are not rounded as in the latter species. For differences to other species or accordant references see above under *P. footeanum*.

Occurrence: This species occurs in the European *Neocardioceras juddii* Zone and correlatives and has been described from Portugal, New Mexico, Arizona, Trans-Pecos Texas, Tunisia and Israel (e.g. KENNEDY et al. 1989), as well as from southern France (ROMAN 1912). In Africa it is known also from Nigeria (MEISTER 1989; COURVILLE 1992) and Egypt (GRECO 1915). It has been furthermore mentioned from Brazil (KOUTSOUKOS & BENGTSON 1993).

In Tunisia *Pseudaspidoceras pseudonodosoides* occurs in the homonymous late Cenomanian zone, corresponding to the *N. juddii* Zone in northern Europe and the Western Interior (CHANCELLOR et al. 1994). In Nigeria this species characterises a part of the late Cenomanian *Nigericeras gadeni* Zone (MEISTER 1989).

Subfamily Mammitinae HYATT, 1900

Genus *Metioceras* HYATT, 1903

Metioceras geslinianum (D’ORBIGNY 1850)

(Plate 1, figs. T–U)

- 1841 *Ammonites catillus* SOWERBY – D'ORBIGNY, p. 325; Plate 97, figs. 1–2.
1850 *Ammonites Geslinianus* D'ORBIGNY – D'ORBIGNY, p. 146.
1962 *Metoicoceras geslinianum* (D'ORBIGNY) – JEFFERIES, Plate 77, fig. 19.
1998b *Metoicoceras geslinianum* (D'ORBIGNY) – LEHMANN, p. 28; Plate 3, fig. 3 (and synonymy).
1999 *Metoicoceras geslinianum* (D'ORBIGNY) – LEHMANN, Plate 4, fig. 3.
2004 *Metoicoceras geslinianum* (D'ORBIGNY) – BARROSO-BARCENILA, p. 96; Plate 1, fig. 5 a–c; Plate 2, fig. 1.
2005 *Metoicoceras geslinianum* (D'ORBIGNY) – GALE, KENNEDY, VOIGT & WALASZCZYK, text-fig. 9F & G; text-fig. 12C.
2005 *Metoicoceras geslinianum* (D'ORBIGNY) – MEISTER & ABDALLAH, p. 128; Plate 8, fig. 1 (and synonymy).

Material: GSUB C2558

Description: The present specimen shows a compressed whorl section, with faint ribs, outer ventrolateral clavi and inner ventrolateral bullae. Its early whorls (wh 30 mm) occasionally bears umbilical bullae.

Discussion: This species is very variable in morphology; for a full systematic account see WRIGHT & KENNEDY (1981), KENNEDY (1988) and KENNEDY & JUIGNET (1994b). A multivariate analysis based on coiling, dimensions and ornament, has been applied by REYMENT & KENNEDY (2000) to check the traditional taxonomy. This indicates that quantitative procedures reproduce traditional methods to a conspicuous degree, with the added advantage of objective repeatability. Furthermore, doubtful phylogenetic relationships have been resolved and new information on dimorphism has been obtained.

Occurrence: *Metoicoceras geslinianum* is the index fossil of the middle late Cenomanian *M. geslinianum* Zone. There are records from the United States, Mexico, Brazil, Colombia, Morocco, Nigeria, Angola, Spain, France, Germany, and England (e.g. LEHMANN 1998b) as well as from Tunisia (MEISTER & ABDALLAH 2005).

Genus *Spathites* KUMMEL & DECKER, 1954

Subgenus *Spathites* (*Jeanrogericeras*) WIEDMANN, 1960

Spathites (*Jeanrogericeras*) *reveliereanus* (COURTILLER 1860)

(Plate 1, figs. C–E)

- 1860 *Ammonites revelieranus* – COURTILLER, p. 249; Plate 2, figs. 5–8.
1980 *Spathites* (*Jeanrogericeras*) *reveliereanus* (COURTILLER) – KENNEDY et al., p. 826; Plate 105, figs. 1–12; Plate 106, figs. 1–2; text-figs. 3–6 (and synonymy).
2007 *Spathites* (*Jeanrogericeras*) *reveliereanus* (COURTILLER) – BARROSO-BARCENILLA, p. 138; Plate 4, fig. g; Plate 5, figs. a–d; text-figs. 6a–b (and synonymy)

Material: GSUB C2556

Description: GSUB C2556 is a phragmocone with a maximum diameter of about 110 mm. There are very strong umbilical bullae that give rise to very feeble flat folds on the flank and inner and outer ventrolateral clavi. On the initial part of the ultimate whorl, the outer ventrolateral clavi are as big as the inner ventrolateral clavi, however, the outer ones quickly become larger and are about as big as the umbilical bullae at the end of the ultimate whorl. There are 12 inner ventrolateral clavi, but only 8 umbilical bullae. On the venter a depression forms a discontinuous ridge. The ventrolateral shoulder is well-rounded. The coiling is involute, the umbilicus small (about 20% of the diameter).

Discussion: GSUB C2556 falls into the broad variation of *Spathites* (*Jeanrogericeras*) *reveliereanus* (COURTILLER 1860), the sulcate venter is characteristic (KENNEDY et al. 1980; ROBASZYNSKI et al. 1982; WIESE 1997). GSUB C2556 shows continuously strong inner ventrolateral clavi at a diameter of around 100 mm, corresponding to that figured by THOMEL (1992: Plate 118, figs. 3–4; Plate 119, fig. 1) and ROMAN (1912: Plate 1, fig. 1 & 1a).

GSUB C2556 resembles equally sized representatives of the probable successor of *Spathites*, *Mammites nodosoides* (SCHLÜTER 1871), in its tuberculation, but differs by the depression on the venter, a feature also occurring in *Spathites* (*S.*) *chispaensis* KUMMEL & DECKER, 1954. *Spathites* (*S.*) *chispaensis* differs from our material by an almost angular ventrolateral shoulder as well as the lack of ornament at this growth stage, typical for the subgenus *Spathites*. In contrast to the present material, the ventral ridge is much more prominent and deeper in *Spathites* (*S.*) *riensis* POWELL, 1963, and *Spathites* (*S.*) *puercoensis* (HERRICK & JOHNSON 1900) also from North America that are, additionally, more closely tuberculated and stronger ornamented than GSUB C2556 (COBBAN & HOOK 1979; HOOK & COBBAN 1982; COBBAN 1988; KENNEDY & COBBAN 1988).

Spathites (Jeanrogericeras) combesi (SORNAY 1951) lacks ventrolateral tubercles and shows a broadly rounded venter without a depression, in contrast to GSUB C2556 at the same size (KENNEDY 1994; BARROSO-BARCENILLA 2007). *Spathites (Jeanrogericeras) tavense* (FARAUD 1940) is distinguished from GSUB C2556 by the strong umbilical bullae and prominent inner ventrolateral clavi (for further discussions see BARROSO-BARCENILLA 2007). The types of *Spathites (Jeanrogericeras) robustus robustus* (WIEDMANN 1960) and *S. (J.) robustus elegans* (WIEDMANN 1960) from Spain (compare KENNEDY et al. 1980) were re-investigated by us, since the inner whorls are not visible in WIEDMANN's original figures (WIEDMANN 1960: Plate 3, fig. 4; 1964: fig. 13d). *S. (J.) robustus robustus* shows circular, rather than elongated umbilical tubercles; the inner ventrolateral tubercles are smaller on the first part of the ultimate whorl of the phragmocone and absent on the slightly worn last part of the ultimate whorl where they are very prominent in GSUB C2556. These features distinguish it also from the holotype of *S. (J.) robustus elegans* WIEDMANN, 1960. *Spathites (Jeanrogericeras) obliquus* (WIEDMANN 1960) differs from GSUB C2556 just by the lack of prominent inner ventrolateral clavi and by lacking a concave depression on the very broadly rounded venter, for a discussion of this species see BARROSO-BARCENILLA (2007). *Spathites (Jeanrogericeras) subconciatus* (CHOFFAT 1898) shows weak ventral ribs and lacks the very prominent inner ventrolateral clavi (e. g. BERTHOU et al. 1985).

Occurrence: Early middle Turonian, associated with early *Collignoniceras woollgari* and *Kamerunoceras turoniense* in France, Spain, the Czech Republic and India (e. g. KENNEDY et al. 1980) and possibly in Tunisia (MEISTER & ABDALLAH 2005). Records dated unequivocally as early Turonian are a single record from southern France (THOMEL 1992) and those from northern Spain (KÜCHLER 1998; BARROSO-BARCENILLA 2007). A further record is from Romania (SZÁSZ 1986).

Spathites (Jeanrogericeras) cf. postsaenzi (WIEDMANN 1960)

(Plate 1, figs. N–O)

cf. 1960 *Paramammites* (?) *postsaenzi* – WIEDMANN, p. 754; Plate 5, figs. 7–8; text-fig. 10.

cf. 1994 *Paramammites* ? *postsaenzi* WIEDMANN – CHANCELLOR et al., p. 42.

cf. 2007 *Spathites (Jeanrogericeras) postsaenzi* (WIEDMANN) – BARROSO-BARCENILLA, p. 135; Plate 3, figs. a–f (and synonymy).

Material: GSUB C2570

Description: GSUB C2570 shows on the penultimate whorl a very prominent tubercle with its centre at the umbilical edge and extending upward to about half the space of the whorl height. There are bullae at the umbilical edge of the last whorl, giving rise to single or pairs of prominent ribs; 7 ribs per quarter whorl. The pairs of ribs consist of an almost radial primary and slightly retroradiate secondary ribs. Whorl section is broad and compressed.

Discussion: We follow BARROSO-BARCENILLA (2007) in transferring this rare species to *Spathites (Jeanrogericeras)*. The very prominent umbilical tubercles on the penultimate whorl are a distinct feature (GSUB C2570; compare also CHANCELLOR et al. 1994). Our specimen furthermore shares the more open umbilicus and the absence of tubercles at the mid-flank seen in *S. (J.) postsaenzi* in contrast to *S. (J.) saenzi* (WIEDMANN 1960; WIEDMANN 1964; BARROSO-BARCENILLA 2007). However, we use open nomenclature since it does not show a ventral sulcus as in *S. (J.) saenzi* and *S. (J.) postsaenzi* (WIEDMANN 1960: p. 753; Plate 5, figs. 5–8; text-fig. 10; refigured by WIEDMANN 1964: p. 137; figs. 24–26; THOMEL 1969: p. 117; Plate C). *Paramammites polymorphus* (PERVINQUIÈRE 1907), is a taxon that is superficially similar by virtue of the character of its ventral sulcus, but in that species, it is only moderately developed in adults (CHANCELLOR et al. 1994; PERVINQUIÈRE 1907). Because of the missing ventral sulcus our material is only referred to *S. (J.) cf. postsaenzi*.

Occurrence: In northern Spain this early Turonian species was originally described from the “zone IV, partie supérieur” of WIEDMANN (1964; wrongly stated as zone III in WIEDMANN 1960: p. 154, compare explanation to Plate 5, figs. 7, 8 in the same paper). This corresponds to the upper part of the *Choffaticeras* (C.) *quasi* Zone of BARROSO-BARCENILLA, 2007, and BARROSO-BARCENILLA & GOY (2007).

Genus *Mammites* LAUBE & BRUDER, 1887

Mammites nodosoides (SCHLÜTER 1871)

(Plate 1, figs. J–K, R–S)

1871 *Ammonites nodosoides* – SCHLÜTER, p. 19; Plate 8, figs. 1–4.

1887 *Mammites nodosoides* SCHLOTHEIM – LAUBE & BRUDER, p. 229; Plate 25, figs. 1a–b; upper text-fig. on p. 230.

- 1987 *Morrowites michelobensis* (LAUBE ET BRUDER) – KONEČNÝ & VAŠÍČEK, p. 85; Plate 3; Plate 4, fig. 1; Plate 5, fig. 1.
1998b *Mammites nodosoides* (SCHLÜTER) – LEHMANN, p. 28; Plate 5, fig. 2 (and synonymy).
2002 *Mammites nodosoides* (SCHLÜTER) – EL-HEDENY, p. 402; fig. 3c.
2003 *Mammites nodosoides* (SCHLOTHEIM) – WITTLER & ROTH, p. 273; text-fig. 17.
2007 *Mammites nodosoides* (SCHLÜTER, 1871) – BARROSO-BARCENILLA, p. 148; Plate 11, figs. a–d (and synonymy).

Material: 10 specimens, GSUB C2504–2509, C2562 and C2564

Description: Whorl section clearly higher than wide; most specimens show distinct ventrolateral horns that develop from ventrolateral tubercles at a whorl height >40 mm. The ventrolateral horns are projected obliquely upwards. Occasionally (GSUB C2508) there are two pairs of ventrolateral tubercles instead of ventrolateral horns at mid growth (wh 60–70 mm). The number of ventrolateral tubercles relative to horns is 10 or less in specimens larger than a diameter of 130 mm. Umbilical bullae are prominent, rounded to conical. Faint lateral ribs are present on all specimens, but ornamentation is clearly dominated by ventrolateral horns and umbilical bullae in our assemblage that represent specimens of mid growth.

Discussion: At mid growth stage *M. nodosoides* usually shows a comparatively weak ornamentation with oblique up- and outwardly directed ventrolateral horns as well as rounded to somewhat conical umbilical bullae (e.g. GSUB C2504 to C2507 and C2509). Our specimens are similar to the lectotype of the same size (figured by WRIGHT & KENNEDY 1981: text-fig. 23) and the intensively illustrated material from England and France (WRIGHT & KENNEDY 1981; THOMEL 1992). Typically, the ventrolateral horns and the umbilical bullae are continuously becoming more prominent on the more mature body chamber. GSUB C2505 differs by suddenly developing a weaker ornamentation with moderately strong ventrolateral tubercles (instead of horns), losing umbilical bullae and ribs that are denser than is normal at mid growth stage (intercostal whorl height of about 80 mm). This smoothing of the ornament usually indicates maturity in ammonites. Variants of *M. nodosoides* showing pairs of ventrolateral tubercles still present at mid growth, instead of developing horns, are not rare in the material from the Bou-Angueur syncline (GSUB C2559 and C2563 at wh 30–55 mm; GSUB C2508 and C2564 at wh 60–70 mm). In GSUB C2508 the rows of ventrolateral tubercles is shifted inwards, with the inner ventrolateral tubercles on the outer third of the flank and the outer ventrolateral tubercles at the ventrolateral shoulder. This differs from the other specimens in our material and in the literature (COBBAN & HOOK 1983: Plate 5, fig. 1 and WRIGHT & KENNEDY 1981: Plate 24, fig. 2a & b).

Species of *Mammites* are similar to that of the allied genus *Morrowites*. For differences between *M. nodosoides* and *Morrowites wingi* as well as *M. mohovanensis* BÖSE, 1920, see WRIGHT & KENNEDY (1981); for those to *Morrowites powelli* KENNEDY et al., 1987, and *Morrowites dixeyi* (REYMENT 1955) see KENNEDY et al. (1987). *Morrowites depressus* (POWELL 1963) is much more evolute and has a depressed whorl section in contrast to *M. nodosoides* (compare COBBAN & HOOK 1979). *Morrowites prokopensis* KONEČNÝ & VAŠÍČEK, 1987, described from the Czech Republic, is distinctly different from *M. nodosoides* by its pattern of initially irregular and later regular alternating primary and secondary ribs, a denser ribbing as well as conspicuously smaller tubercles.

More recently *Mammites michelobensis* LAUBE & BRUDER, 1887, has been attributed to *Morrowites* and treated as a separate species again (THOMEL 1992; KONEČNÝ & VAŠÍČEK 1987). However, we synonymize the material described as *Morrowites michelobensis* by KONEČNÝ & VAŠÍČEK (1987) with *M. nodosoides* herein, in accordance with WRIGHT & KENNEDY (1981) and BARROSO-BARCENILLA (2007) who believes that the original descriptions of *M. tischeri* and *M. michelobensis* are based on specimens of *M. nodosoides*. GSUB C2506 resembles in most aspects the compressed specimen of KONEČNÝ & VAŠÍČEK (1987) on Plate 3, compared at the same growth stage (closely comparable at wh 44–63 mm). One exception is the more clavate and slightly larger ventrolateral tubercles in our material. GSUB C2506 shows ventrolateral horns directed sideways as in *Morrowites* species rather than obliquely upwards. In GSUB C2506 this changes at a whorl height of 62 mm, and later (wh about 80 mm) the unequivocal *Mammites nodosoides* style of ventrolateral horns can be observed. This, our opinion, supports the inclusion of *Morrowites michelobensis* of KONEČNÝ & VAŠÍČEK (1987) in *Mammites nodosoides*.

Occurrence: This species is typical for the early Turonian *M. nodosoides* Zone in several European countries, Turkestan, central United States, Middle- and South America; a questionable record from England is early Turonian, *W. coloradoense* Zone in age (e.g. WRIGHT & KENNEDY 1981). In Africa and the Near East it is known from Algeria, Syria, Tunisia, Nigeria, Madagascar, Lebanon, Israel (e.g. BARROSO-BARCENILLA 2007), and also has been previously reported from Morocco (e.g. CHANCELLOR et al. 1994; CHARRIÈRE et al. 1998). For the Tethyan realm KUHNT et al. (1986: Table 1), WIEDMANN et al. (1978a) and POPOFF et al. (1986) state that it co-occurs with

pseudotissotiids, *Neoptychites* and allied genera in the early Turonian and that it ranges high up into the middle Turonian as already stated by COLLIGNON (1967).

Family Vasoceratidae H. DOUVILLÉ, 1912

Genus *Vascoceras* CHOFFAT, 1898

Vascoceras durandi (THOMAS & PERON 1889)

(Plate 2, figs. G–H)

- 1889 *Pachydiscus durandi* – THOMAS & PERON, p. 27; Plate 18, figs. 5–8.
1907 *Vascoceras durandi* THOMAS & PERON – PERVINQUIÈRE, p. 332; Plate 21, figs. 1a–b; text-fig. 125.
? 1996 *Vascoceras* (*Paravascoceras*) aff. *durandi* (THOMAS & PERON) – MEISTER & ABDALLAH, p. 10; Plate 4, fig. 1; Plate 5, fig. 2; text-fig. 5c (and synonymy).
? 2004 *Vascoceras* cf. *durandi* (THOMAS & PERON) – ABDEL-GAWAD et al.; Plate 4, fig. 4.
2005 *Vascoceras durandi* (THOMAS & PERON) – MEISTER & ABDALLAH, p. 135; Plate 14, fig. 1; Plate 26, fig. 1; Plate 27, fig. 1 (and synonymy).

Material: GSUB C2523 and C2526

Description: Our material is GSUB C2523 with a diameter of 55 mm, and GSUB C2526, a fragment with a total length of 58 mm. The coiling is involute, with a deep umbilicus and a steep umbilical wall. Section widest at the rounded umbilical rim (at the lowermost $\frac{1}{4}$ of the wh), ratio wh (25 mm)/wb (36 mm) is approximately 0.69 at the umbilical bullae. Blunt, but prominent umbilical bullae, two per half whorl. Ribs arise either from the bullae or at the umbilical rim. Six low and fairly strong radial ribs can be counted on the last quarter (GSUB C2523), crossing the venter almost straight.

Discussion: As summarized by KENNEDY et al. (1987) extensive descriptions of vasoceratine taxa are useful only if they cover abundant material and are under tight stratigraphic control. Furthermore, many features strongly change during ontogeny in this group and our specimens represent early whorls only.

The present specimens fit well in ribbing, size and frequency of the umbilical bullae, whorl section and coiling with a specimen figured by CHOFFAT (1898: Plate 11, fig. 5 a–c) as *Vascoceras douvillei* CHOFFAT (= *Vascoceras durandi*, see BERTHOU et al. 1985), except for less distinct ribbing on the last quarter of CHOFFAT's specimen (possibly worn) and aspects of the whorl section. However, *Vascoceras durandi* shows a considerable variation in inflation (CHANCELLOR et al. 1994). Small growth stages like that represented by the present specimens are sparsely figured in the literature, but ornamentation ranges from strong umbilical tubercles with distinct ribs (GSUB C2523 and CHOFFAT 1898: Plate 11, fig. 5 a–c and Plate 12, fig. 2) to umbilical bullae only (CHANCELLOR et al. 1994: Plate 14, figs. 2 & 5).

Insufficient knowledge of the ontogeny has been recognized as a general problem in the Vasoceratidae (WRIGHT & KENNEDY 1981). BARBER (1957) and ZABORSKI (1990, 1996) figured a series of well preserved juveniles or nuclei of *Vascoceras* from Nigeria. ZABORSKI (1996) synonymized *Vascoceras* sp. juv. of BARBER (1957) in his new species *Vascoceras woodsi*, a species with a depressed whorl section like the present material (cross sections in BARBER 1957: Plate 27), but with a more evolute whorl section and less distinct ribs. *Pseudovascoceras nigeriense* (WOODS 1911) has a depressed whorl section and distinct umbilical bullae too, but a multituberculate ornament characterises the genus. All other *Vascoceras* from Nigeria described by ZABORSKI (1996) are more compressed and/or smoothly ornamented (ZABORSKI 1996).

Some specimens of *Vascoceras diartianum* (D'ORBIGNY) from the Eibrunn Marls in South Germany (FÖRSTER et al. 1983) show fairly prominent ribs on the inner two thirds of the whorl flank, arising from the umbilical bullae that are more prominent. The ribs of these specimens are more distinct than the very low ribs of the type (KENNEDY & JUIGNET 1977: Plate 1). However, the present material differs by distinct ribs on the whorl flank that cross the venter.

Earlier whorls of *Vascoceras venezolanum* RENZ, 1982, from Venezuela show a wide range of variation, but after a strongly ornamented juvenile stage (up to a diameter of about 35 mm) they are distinguishable from GSUB C2523 by a more compressed whorl section and a smoother ornamentation (RENZ 1982: Plates 23–25 pars). In some *V. venezolanum* the stronger ribbing persists to an equal diameter of GSUB C2523 (RENZ 1982: Plate 25, figs. 3, 5; *V. venezolanum* forma e), but they show a much denser and more delicate ribbing plus a more compressed whorl section in contrast to the robust ribbing of the present specimens.

Occurrence: In central Tunisia *Vascoceras durandi* occurs in the *Pseudaspidoceras flexuosum* Zone and *Thomasites rollandi* Zone of the early Turonian, with a maximum in the lower part of the latter. It also occurs in Algeria, Israel, Portugal (e.g. CHANCELLOR et al. 1994; MEISTER & ABDALLAH 2005). It is recorded here from Morocco for the first time.

Vascoceras cauvini CHUDEAU, 1909

(Plate 2, figs. A–B, M–N)

- 1909 *Vascoceras cauvini* – CHUDEAU, Plate 1, figs. 1–2; Plate 2, figs. 3, 5; Plate 3, figs. 1, 4.
1996 *Paravascoceras cauvini* (CHUDEAU) – ZABORSKI, p. 65; figs. 2–8 (for full synonymy).
2002 *Vascoceras cauvini* CHUDEAU – EL-HEDENY, p. 406; text-figs. 4b–c, 7f.
2004 *Vascoceras cauvini* CHUDEAU – ABDEL-GAWAD et al., Plate 4, figs. 2, 3, 5.
2006 *Vascoceras cauvini* CHUDEAU – EL QOT, p. 117; Plate 25, figs. 2, 3, 5.

Material: GSUB C2566 and C2571

Description: GSUB C2566 and GSUB C2571 are distorted specimens with a total diameter of 103 and 105 mm. The inner whorls show smooth flanks at the transition from the penultimate to the ultimate whorl (to some extent freshly revealed in GSUB C2571 and C2566). The final half of the last whorl shows prominent radial ribbing, long and short alternating in GSUB C2571, on the outer half of the flank. There are about 12 ribs per half a whorl that cross the venter in a straight line, either slightly less prominent (GSUB C2566) or with the same strength (GSUB C2571). The inner flanks are smooth, except for a rib at 46 mm whorl height in GSUB C2571 that stems from a bulla close to the umbilical edge. The whorl section is compressed and subrectangular (Text-fig. 7 D; wb/wh ratio 1.09; GSUB C2571 is obliquely distorted). There is an almost angular cross section with subparallel flanks at the ribs and at the transition from the flank to the ventrolateral shoulder. The section between ribs is more rounded.

Discussion: Our specimens of *Vascoceras* are characterised by strong ribbing on the venter, ventrolateral shoulder and on the uppermost flank, falling within the variability of *Vascoceras cauvini* sensu MEISTER et al. (1992). They differ from the material figured by MEISTER et al. (1992) from Niger, however, by a more distant ribbing that appears more robust. In this aspect our material resembles the strong and robust ornamentation of *Vascoceras* figured as *Paravascoceras chevalieri* (FURON 1935) by SCHNEEGANS (1943: Plate 4, fig. 7). This type of ornament is slightly more prominent than in other strongly ornamented specimens of the genus (e.g. *Vascoceras cauvini* var. *evoluta* in SCHNEEGANS 1943: Plate 8, fig. 2; *Paravascoceras cauvini* in FREUND & RAAB 1969: Plate 3, figs. 1–3 and in ZABORSKI 1996: fig. 3; *V. obscurum* BARBER in ZABORSKI 1996: figs. 61, 62; *V. rumeaui* COLLIGNON in FREUND & RAAB 1969: figs. 4–5 and LUGER & GRÖSCHKE 1989: Plate 41, figs. 5–6). Strong ribbing as in *V. (P.) chevalieri* occurs, however, in the type material of *Vascoceras cauvini* CHUDEAU, 1909, and more prominently in specimens subsequently referred to this species (FURON 1935: Plate 4, fig. 3; Plate 5, fig. 1a & b). Consequently, we follow MEISTER et al. (1992) in regarding *Vascoceras (Paracanthoceras) chevalieri* FURON, 1935, as a synonym of a morphologically variable *Vascoceras cauvini* CHUDEAU, 1909, based on excellent material. We can support this particularly by GSUB C2566, that clearly differs from *V. (P.) chevalieri* by the continuously strong ribbing in contrast to the irregular stronger and less stronger ribs on the phragmocone of the holotype of FURON (1935, at wh <45 mm). The whorl section was compared with a plaster cast (= GSUB C2094) of the holotype of *V. (P.) chevalieri* (FURON 1935). The holotype shows a maximum breadth at the umbilical edge (wb/wh ratio about 1.13), with flanks continuously diverging from this point towards the venter on the ribs as well as between the ribs. GSUB C2566 differs by a cross section with almost parallel flanks on the ribs at the same stage and nearly parallel flanks restricted to the lower half of the flank between the ribs. The comparatively broadly rounded venter of GSUB C2566 contrasts with the narrowly rounded venter of the type with a trapezoidal, almost trigonal section, but all differences fall into the wide variation of sections observed in *V. cauvini* (MEISTER et al. 1992). The umbilicus varies between 22 and 29% of the diameter in the type series and 21% in GSUB C2566.

Paravascoceras aff. *chevalieri* of REYMENT (1955: Plate 14, fig. 1a & b), referred to as *P. chevalieri* by AMARD et al. (1983), is clearly different from this species. ZABORSKI (1996) noted already three rows of tubercles upon the ventral ribs rather resembling a form of *Thomasites gongilensis*. GSUB C2566 additionally differs by its broader cross section with a broadly rounded venter, a less distinct ribbing and a closer umbilicus (20% of the diameter).

Occurrence: *V. cauvini* was described originally from Niger. Based on recently collected material from this country MEISTER et al. (1992) defined the uppermost ammonite zone of the late Cenomanian on the range of this species. *V. cauvini* is also known from a level

above the European *Metioceras geslinianum* Zone in Nigeria (ZABORSKI 1996). It occurs in Angola (COOPER 1978), Egypt (e.g. LUGER & GRÖSCHKE 1978; EL-HEDENY 2002) and Israel (FREUND & RAAB 1969). A co-occurrence with the late Cenomanian zonal index species *M. geslinianum* in Israel (LEWY et al. 1984) is, however, somewhat problematic since these specimens possess broad flank ribbing and umbilical bulges at mid growth, more typical of *Nigericeras* and possibly a transitional form (ZABORSKI 1996). *V. cauvini* also occurs in the Algerian Sahara, stated as early Turonian in age (AMARD et al. 1983), but the rich associated vascoceratid fauna is stratigraphically less significant. Out of Africa there are records from France (FARAUD 1940) and Peru (BENAVIDES-CÁCERES 1956).

This species is described from Morocco for the first time. Earlier, ANDREU (1989), ANDREU-BOUSSUT (1991), CHARRIÈRE et al. (1998) and CISZAK et al. (1999) mentioned the occurrence of *Vascoceras* gr. *cauvini* (respectively *V. sp. gr. cauvini*) from the Middle Atlas.

Family Pseudotissotiidae HYATT, 1903

Subfamily Pseudotissotiinae HYATT, 1903

Genus *Thomasites* PERVINQUIÈRE, 1907

Thomasites rollandi (THOMAS & PERON 1889)

(Plate 2, figs. E–F)

- 1889 *Pachydiscus Rollandi* THOMAS & PERON; p. 25; Plate 17, figs. 1–3.
1907 *Thomasites Rollandi* THOMAS & PERON; PERVINQUIÈRE, p. 341; Plate 22, figs. 1–7; figs. 127–130.
1994 *Thomasites rollandi* (THOMAS & PÉRON) – CHANCELLOR et al., p. 75; Plate 19, figs. 1–2; Plate 20, figs. 1–12; Plate 21, figs. 1–9; Plate 22, figs. 1–6, Plate 23, figs. 1–9; text-figs. 14a–f (and synonymy).
1996 *Thomasites rollandi* (THOMAS & PERON) – MEISTER & ABDALLAH, p. 12; Plate 7, figs. 1–2; Plate 11, fig. 2; text-figs. 5h–i, k.
1996 *Thomasites rollandi* forme *jordani* PERVINQUIÈRE – MEISTER & ABDALLAH, p. 12; Plate 6, fig. 2; text-fig. 5j.
1996 *Thomasites rollandi* forme *meslei* PERVINQUIÈRE – MEISTER & ABDALLAH, p. 13; Plate 8, figs. 1–3; Plate 9, fig. 2; Plate 10, fig. 2; text-figs. 6a–d.
2005 *Thomasites rollandi rollandi* (THOMAS & PERON) – MEISTER & ABDALLAH, p. 137; Plate 18, figs. 1, 3.
2004 *Thomasites rollandi* (THOMAS & PERON) – ABDEL-GAWAD et al., Plate 2, figs. 4, 5; Plate 3, fig. 1.
2005 *Thomasites rollandi* forme *jordani* PERVINQUIÈRE – MEISTER & ABDALLAH, p. 137; Plate 17, figs. 1, 6.
2005 *Thomasites rollandi* forme *meslei* PERVINQUIÈRE – MEISTER & ABDALLAH, p. 138; Plate 17, figs. 2, 3, 5, 7.
2006 *Thomasites rollandi* (THOMAS & PERON) – EL QOT, p. 122; Plate 27, figs. 4, 5; Plate 28, fig. 1.

Material: GSUB C2527

Description: GSUB C2527 is an incomplete phragmocone with a reconstructed diameter of almost 100 mm (wh approx. 50 mm). The umbilicus is narrow, varies between 11 and 13% of the diameter. Although the phragmocone is consistently worn, the venter and upper flank of the beginning of the penultimate whorl of the phragmocone (wh about 38 mm) are well-enough preserved to show a row of closely spaced rounded ventrolateral tubercles. The distance between the tubercles is approximately equal or less than that of their own diameter. There is typically a siphonal ridge, but it is not clear if this is accompanied by a row of tubercles. The moderately inflated triangular whorl section at the beginning of the penultimate whorl shows the greatest breadth close to the umbilical rim, with flanks that are strongly divergent to the narrowly rounded venter. Towards the end of the phragmocone the whorl sections become distinctly inflated and triangular. The ventral portion at this stage is too strongly worn to show any ornamentation, but appears even more narrowly rounded in cross section.

Discussion: *Thomasites rollandi* has been extensively revised by CHANCELLOR et al. (1994), who also synonymized PERVINQUIÈRE's (1907) *Thomasites meslei*, but not *Thomasites gongilensis* WOODS, 1911, originally described from Nigeria who referred to its specific differences. In particular the inflated triangular whorl section of GSUB C2527 allows us to refer our specimen to *T. rollandi*; our material resembles a variant of *T. rollandi* described as *Thomasites jordani* var. *laevis* by PERVINQUIÈRE (1907).

Occurrence: *Thomasites rollandi* is the most common ammonite in the eponymous zone in Tunisia (CHANCELLOR et al. 1994), but also occurs in the succeeding *M. nodosoides* Zone (ROBASZYNSKI et al. 1990). It is widely distributed in Northern Africa and the Near East, namely in Algeria, Jordan, Syria, Israel (throughout the early Turonian after FREUND & RAAB 1969), Lebanon and Egypt (e.g. CHANCELLOR et al. 1994). In Europe this species is unequivocally known from southern and northern France only (KENNEDY et al. 2003). WIEDMANN, 1960, 1964, mentioned it from the Turonian VI of northern Spain, but this needs further confirmation. It might occur in Colombia, Tadjikistan and England; an undescribed record from Madagascar seems to be definite (CHANCELLOR et al. 1994). It has been mentioned from Morocco only by CHOUBERT (1939).

Thomasites cf. gongilensis (WOODS 1911)

(Plate 2, figs. K–L)

- cf. 1911 *Vascoceras gongilensis* – WOODS, p. 282; Plate 21, fig. 7; Plate 22, fig. 1.
cf. 1981 *Thomasites gongilensis* (WOODS) – WRIGHT & KENNEDY, p. 100; Plate 24, fig. 1; Plate 25, fig. 1.
cf. 1989 *Thomasites gongilensis* (WOODS) – MEISTER, p. 38; Plate 16, figs. 3–5; Plate 17, figs. 1–6; Plate 18, figs. 1–3; Plate 19, figs. 1–5; Plate 20, figs. 1–5; Plate 21, figs. 1–3; text-figs. 27a–m, 28 (and synonymy).
cf. 1992 *Thomasites gongilensis* (WOODS) – COURVILLE, Plate 1, figs. 1–3; text-figs. 4–7, text-fig. 7.
cf. 2002 *Thomasites gongilensis* (WOODS) – EL-HEDENY, p. 408; text-figs. 4d–e, 7h.
cf. 2003 *Thomasites gongilensis* (WOODS) – KENNEDY et al., p. 12; Plate 5, figs. 1–3.

Material: GSUB C2524

Description: GSUB C2524 is an incomplete specimen with a diameter of about 90 mm. At around 30 mm it shows a compressed whorl section, with rounded flanks and the greatest breadth at the lower third of the flank. Its venter is narrowly rounded; the specimen is smooth, the umbilicus is narrow (about 14% of the diameter).

Discussion: GSUB C2524 resembles Nigerian taxa, in particular BARBER's (1957) subspecies *Gombeoceras gongilense compressum*, later referred to as *Thomasites gongilensis* (e.g. MEISTER 1989). It represents a smooth, compressed morphotype with a narrowly rounded venter of this very variable species (COURVILLE & THIERRY 1993).

Thomasites nigeriensis of MEISTER et al., 1992 (= "*Pseudotissotia*" *nigeriensis* (WOODS) of MEISTER 1989) and *Pseudotissotia nigeriensis* of COURVILLE (1992) is similar to *Thomasites gongilensis* in general shell shape. Its venter is flat, slightly bi- or tricarinate or – more rarely – broadly rounded (MEISTER 1989: fig. 31).

Occurrence: *Thomasites gongilensis* is hitherto known from the early Turonian of Nigeria and N-Spain (lower Turonian III sensu WIEDMANN 1964) as well as the late Cenomanian *N. juddii* Zone of S-England (WRIGHT & KENNEDY 1981).

Genus *Choffaticeras* HYATT, 1903

Subgenus *Choffaticeras* (*Choffaticeras*) HYATT, 1903

Choffaticeras (*Choffaticeras*) n. sp.

(Plate 2, figs. I–J)

Material: GSUB C2532

Description: This is a specimen with a maximum diameter of 94 mm, comprising the phragmocone and the initial body chamber. Most of the latter has been broken away to reveal parts of the flank and venter that are not worn. The specimen lacks any ornamentation, except for a shallow ventral keel and two less distinct ventrolateral keels (sharp ventrolateral edges) that all produce a tricarinate venter. The whorl section is compressed, with the maximum breadth close to the umbilical margin. The venter is very small, even considering that the specimen is distorted. Its umbilicus is less than 9% of the diameter.

Discussion: Following CHANCELLOR et al. (1994) distinction from the closely allied genus *Pseudotissotia* is the central problem in the taxonomy of *Choffaticeras*. Distinguishing GSUB C2532 from *Pseudotissotia* is, however, easy since representatives of the latter show a broader whorl section.

The present specimen differs by its tricarinate venter from species of the subgenus *Choffaticeras* (*Leoniceras*) as well as from most species of *Choffaticeras* (*Choffaticeras*), e.g. *C. (C.) barjonai* CHOFFAT, 1898, *C. (C.) philippii* (SOLGER 1903), *C. (C.) quaasi* (PERON 1904), and maybe *C? dowvillei* PERON, 1897. *C. (C.) sinaiticum* DOUVILLÉ, 1929, is also tricarinate in section, but the ventrolateral keels disappear at a very early stage and the section is sharp from a diameter of 60 mm onwards in contrast to our specimen.

C. (C.) segne (SOLGER 1903) is monocarinate, with ventrolateral edges rather than carinae, and 25–40 ribs per whorl at an early growth stage (diameter about 10–100 mm, FREUND & RAAB 1969). Additionally, *C. (C.) segne* differs from GSUB C2532 by umbilical tubercles. The tricarinate *C. (C.) pavillieri* (PERVINQUIÈRE 1907) is distinct from all other species of *Choffaticeras* by its ribbed early whorls and usually strong involution and compression. BARROSO-BARCENILLA & GOY (2007), however, demonstrated that the size ratio of the umbilicus varies more significantly (between 5.2 and 6.6% in PERVINQUIÈRE's specimens, see CHANCELLOR et al. 1994) and

varies between 9 and 10% of diameter in the Spanish specimens. *C. (C.) pavillieri* also shows delicate ventrolateral clavi at a small diameter. GSUB C2532 shares a tricarinate venter and a compressed whorl section, but it differs by the lack of any ornamentation.

C. (C.) meslei (PERON 1897), is also tricarinate and very variable in terms of whorl section, ornament and particularly umbilical width (CHANCELLOR et al. 1994). It differs usually by possessing a trigonal and significantly broader whorl section at a diameter comparable to the present specimen (e. g. PERON 1896: Plate 15 (2), fig. 2; Plate 16 (3), fig. 2 and FREUND & RAAB 1969: Plate 9, fig. 2; text-fig. 10i). A much slender variant, similar to our material from Morocco, is represented by the paralectotype (CHANCELLOR et al. 1994). The latter differs by its acutely fastigate and monocarinate venter and its low folds on the flanks that end in incipient nodes on the terminal phragmocone.

We hesitate to give a species name on the account of a single, partly worn specimen. Nevertheless, the features are suitable enough to be certain that it most probably represents a new taxon.

Family Coilopoceratidae HYATT, 1903

Genus *Coilopoceras* HYATT, 1903

Coilopoceras n. sp.

(Text-fig. 7 E; Text-fig. 8 E–F)

Material: GSUB C2500

Description: The specimen is a smooth phragmocone that is still septate up to the maximum diameter of 245 mm. Its disc-shaped oxycone shell is highly compressed in cross section, with a narrowly rounded venter (Text-fig. 7 E) and reaches its greatest breadth at about $\frac{1}{3}$ of the whorl height. The umbilicus is very small (about 14 mm, 5.71% of the diameter) with an umbilical edge that is narrowly rounded. Parts of the calcitic shell were polished off to reveal the suture line close to the ultimate part (Text-fig. 8 F). The E/A saddle is narrow, small compared to the other saddles, but high and fairly well divided by mostly long branches. The E/A is much higher than the adventitious lobes on A (former L, see KORN et al. 2003) and conspicuously strangulated at its base. There is a very broad and shallow lateral lobe that is divided by two long accessory saddles; its first ventral branch shows a deep and broad bifurcation. The A/U saddle is broad, characteristically asymmetric, with very few incisions and frills only. The three umbilical lobes are divided by two comparatively broad and large saddles. General aspects are that the E/A and the lobes in a lateral and umbilical position show more prominent incisions, whereas the umbilical saddles have a frilling only. Particularly the incisions of the umbilical lobes look like the spread fingers of a hand. In general the saddles are narrowly denticulated.

Discussion: A disc-shape without ornamentation can be encountered in many Late Cretaceous ammonites, especially in the families Sphenodiscidae and Coilopoceratidae. Our specimen can be attributed to the latter, with its comparatively small E/A and its very broad and shallow A and excludes the Sphenodiscidae, with their wider and subdivided E/A rather than the lateral lobe (cf. WRIGHT 1996). Within the Coilopoceratidae the recent Treatise (WRIGHT 1996) includes three genera: *Erichsenites*, *Hoplitoides*, and *Coilopoceras*. *Erichsenites* is probably a subgenus of *Hoplitoides* (WRIGHT 1996) and *Coilopoceras* was probably derived from *Hoplitoides* by “a progressive reduction in the extent of venter truncation and finally its disappearance” (COBBAN & HOOK 1980: p. 13). *Coilopoceras* is the only genus of the three genera mentioned including species similar to our specimen, with no ornamentation and a narrowly rounded venter that is not truncated or tabulate. Most species of *Coilopoceras* bear at least smooth ribs or swellings. *Coilopoceras brasiliensis* OLIVEIRA & BRITO, 1969, is a smooth species that has a narrowly rounded venter, but differs from GSUB C2500 by a larger umbilicus (16% in contrast to 5.7%) and by saddles that are not denticulated, a distinctly broader and lower E/A saddle (not strangulated at the base) that is divided by a couple of incisions only (no long branches). *Hoplitoides hourcqui* COLLIGNON, 1965, is a species from the Turonian of Algeria that is probably better placed in *Coilopoceras*. It shows the same narrowly rounded venter and usually a smooth shell like GSUB C2500 (COLLIGNON 1965), but differs by a smaller whorl section, and a larger umbilicus (14.5% of diameter in contrast to 5.7%). Additionally its A lobe is significantly smaller and the E/A saddle is about as high as the adventitious lobe on A. The E/A saddle of the Algerian material is broader and not strangulated at the base like in GSUB C2500.

Although the suture helps to characterise species that are very similar in terms of external features, the affinities between the species of the Coilopoceratidae cannot be determined in this way. Most authors were choosing subjectively very few sutural characteristics for comparison within this group of ammonites and for most species the intraspecific variability of the suture line is unknown. Nonetheless the suture line of GSUB C2500 is closely comparable to the Venezuelan species *Coilopoceras stephani* RENZ, 1982 (RENZ 1982: text-fig. 77d). It corresponds in the combination of following features:

- Almost all saddles are narrowly denticulated
- Narrow and high E/A saddle, much divided by long branches
- E/A much higher than adventitious lobes on A
- E/A conspicuously strangulated in the lower part of the lobe
- Very broad lateral lobe
- First ventral branch of the lateral lobe with very deep bifurcation

GSUB C2500 differs by a distinctly larger A/U saddle that is almost as big as the E /A saddle in *C. stephani*, the spread endings of the umbilical saddles being in contrast to the almost rectangular outline in the present specimen. The different shape of the branches of the lateral lobe, with mushroom-shaped endings of the adventitious saddles in *C. stephani* differs from the club-shape in GSUB C2500. There are also several features in common with *Coilopoceras newelli* BENAVIDES-CÁCERES, 1956, but GSUB C2500 differs by the lack of narrowly denticulated saddles, whereas the distinctly asymmetric A/U that is supposed to characterise *C. newelli*, falls within the intraspecific variation (BENAVIDES-CÁCERES 1956).

Occurrence: The genus occurs in the middle to upper Turonian of France, Spain, N- and W-Africa, Madagascar, Lebanon, Israel, Baluchistan, USA, Mexico, Trinidad, Venezuela, Ecuador, Colombia, Brazil and Peru (OLIVEIRA & BRITO 1969; WRIGHT 1996).

Family Sphenodiscidae HYATT, 1900

Subfamily Sphenodiscinae HYATT, 1900

Genus *Libyoceras* HYATT, 1900

Libyoceras cf. *afikpoense* REYMENT, 1955

(Text-fig. 8 C–D)

cf. 1955 *Libyoceras afikpoense* – REYMENT, p. 89; Plate 21, figs. 1, 2a–b; Plate 22, figs. 6a–b; Plate 23, fig. 2; text-figs. 45a–d.

cf. 1982 *Libyoceras afikpoense* REYMENT – ZABORSKI, p. 308; text-figs. 4, 7–8, 10, 14 (and synonymy).

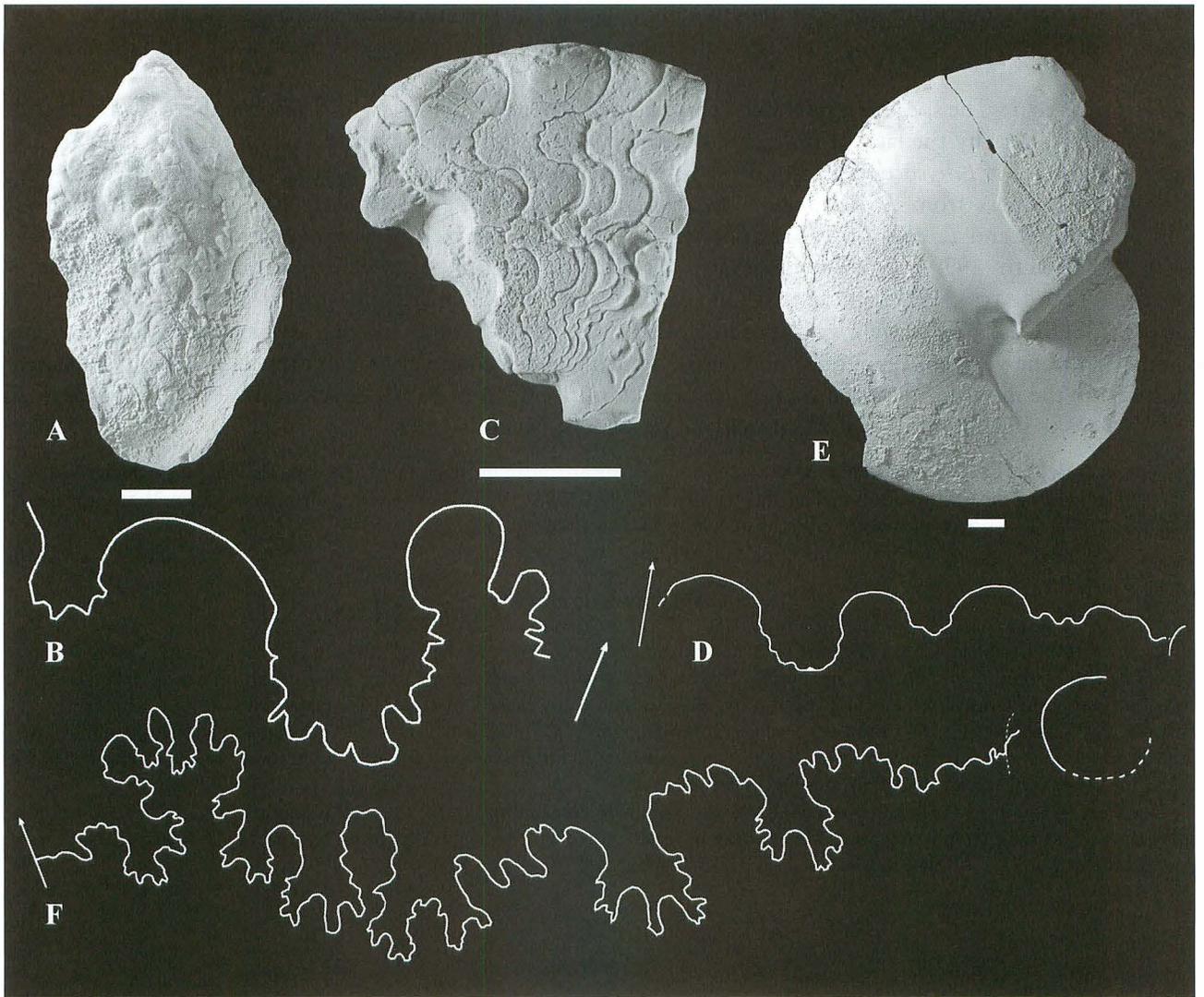
cf. 1999 *Libyoceras afikpoense* REYMENT – ZABORSKI & MORRIS, text-fig. 6a.

Material: GSUB C2521

Description: This specimen with a whorl height of 52 mm shows a compressed whorl section, flat flanks and blunt ventrolateral clavi. The umbilical edge is well-rounded, the umbilicus is narrow and the coiling involute. The venter is deeply eroded and therefore, its tabulate shape does not represent its original shape. The cross-section can be reconstructed as broad. Its suture line (Text-fig. 8 D) is simple and shows broad and entire saddles, a total of four can be counted with the supposed E/A as the largest one. The lobes are weakly denticulate, the supposed E/A is much larger than the others.

Discussion: The cross-section of GSUB C2521 is broad, this places it close to *Libyoceras afikpoense* REYMENT, 1955, and *Libyoceras crossense* ZABORSKI, 1982. Both species differ, however, by possessing a somewhat larger umbilicus and medional and ventrolateral tubercles. Although the medional tubercles of *L. crossense* and *L. afikpoense* are lost during ontogeny and only in the latter swellings remain on the adult shell, GSUB C2521 can be clearly distinguished by its ventrolateral tubercles. Its venter places GSUB C2521 more closely to *L. afikpoense* (for insignificant differences see ZABORSKI 1982). The characteristic external part of the suture line (ZABORSKI 1982) is unfortunately worn in GSUB C2521 and the supposed E/A may be rather an auxiliary saddle than the “true” E/A (Text-fig. 8D).

Occurrence: This specimen is recorded currently only from the late Campanian of Nigeria (e.g. ZABORSKI & MORRIS 1999).



Text-fig. 8. A–B *Libycoceras* cf. *ismaelis* (VON ZITTEL 1884), GSUB C2567, A lateral view and B suture line; C–D *Libycoceras* cf. *afikpoense* REYMENT, 1955, GSUB C2521, C lateral view and D suture line; E–F *Coilopoceras* n. sp., GSUB C2500, E lateral view and F suture line.

Libycoceras cf. *ismaelis* (VON ZITTEL 1884)

(Text-figs. 8 A–B)

cf. 1884 *Sphenodiscus ismaelis* – ZITTEL, p. 451; fig. 631.

cf. 1902 *Libycoceras ismaëli* ZITTEL – QUAAAS, p. 302; Plate 29, figs. 3–7; Plate 30, figs. 1a–b.

cf. 1996 *Libycoceras ismaelis* (ZITTEL) – WIESE et al., p. 109; Plate 2, fig. 1 (and synonymy).

cf. 1999 *Libycoceras ismaelis* (ZITTEL) var. *soudanense* PÉRÉBASKINE, ZABORSKI & MORRIS, text-figs. 4/9–10.

Material: GSUB C2567

Description: A worn fragment with a maximum whorl height of 67 mm, shows a compressed, lanceolate whorl section. The ventral side is completely worn, but its originally sharp keel is indicated by the surrounding matrix. The coiling is involute. The only superficially worn flanks are smooth, with the greatest breadth at about two thirds of the flank height. The preserved part of the suture line (Text-fig. 8B) is simple, with a comparatively slender and high supposed E/A that is distinctly asymmetric, showing one very large, rounded and entire (non-denticulated) branch on the ventrolateral shoulder that is separated by a deep and broad incision from a relatively very small branch close to the keel. Compared to the first lobe at a lateral position (A?) the E/A is somewhat

broader and continuously but not very densely denticulated. The second saddle at a lateral position is as broad as the first lateral lobe, but it is completely smooth (entire); a small umbilical lobe is present with few denticulations only.

Discussion: The specimen resembles *L. ismaelis* in aspects of coiling, whorl section, the lack of ribs and its suture line. It differs by the lack of tubercles, but this might be due to its poor preservation. LEWY (1977) states that several species of *Libycoceras* are doubtful, later ZABORSKI (1982) and WIESE et al. (1996) discussed the genus. GSUB C2567 differs from *L. afikpoense*, *L. crossense*, *L. dandense* (HOWARTH 1965) and *L. acutodorsatus* (NOETLING 1897) and *L. chargense* BLANCKENHORN, 1900, by the lack of ornamentation (cf. ZABORSKI 1982; FATMI & KENNEDY 1999). *L. chareense* is also distinct by the lack of a ventrolateral shoulder. *Libycoceras angolaense* HAUGHTON, 1924, shows a second lateral saddle that is markedly smaller than in *L. ismaelis*. The suture of GSUB C2567 fits well with those of other *Libycoceras*. The markedly asymmetric saddle at a lateral position, with one very large, rounded and entire branch and a second very small branch is a feature detected as falling within the intraspecific variation (e.g. *L. acutodorsatus*, fig. 5 of FATMI & KENNEDY 1999; *L. dandense*, fig. 20 of ZABORSKI 1982 and fig. 5 of *L. crossense* ZABORSKI & MORRIS 1999).

Occurrence: The species occurs in the late Campanian to Maastrichtian in Israel, Egypt, Jordan, Tunisia, Libya, Sudan (e.g. WIESE et al. 1996) and also in the Maastrichtian of Nigeria (WOZNY & KOGBE 1983). A single early Campanian record from N-Spain is based on WIESE et al. (1996). It has been mentioned from Morocco by SALVAN (1959: p. 49 & 52).

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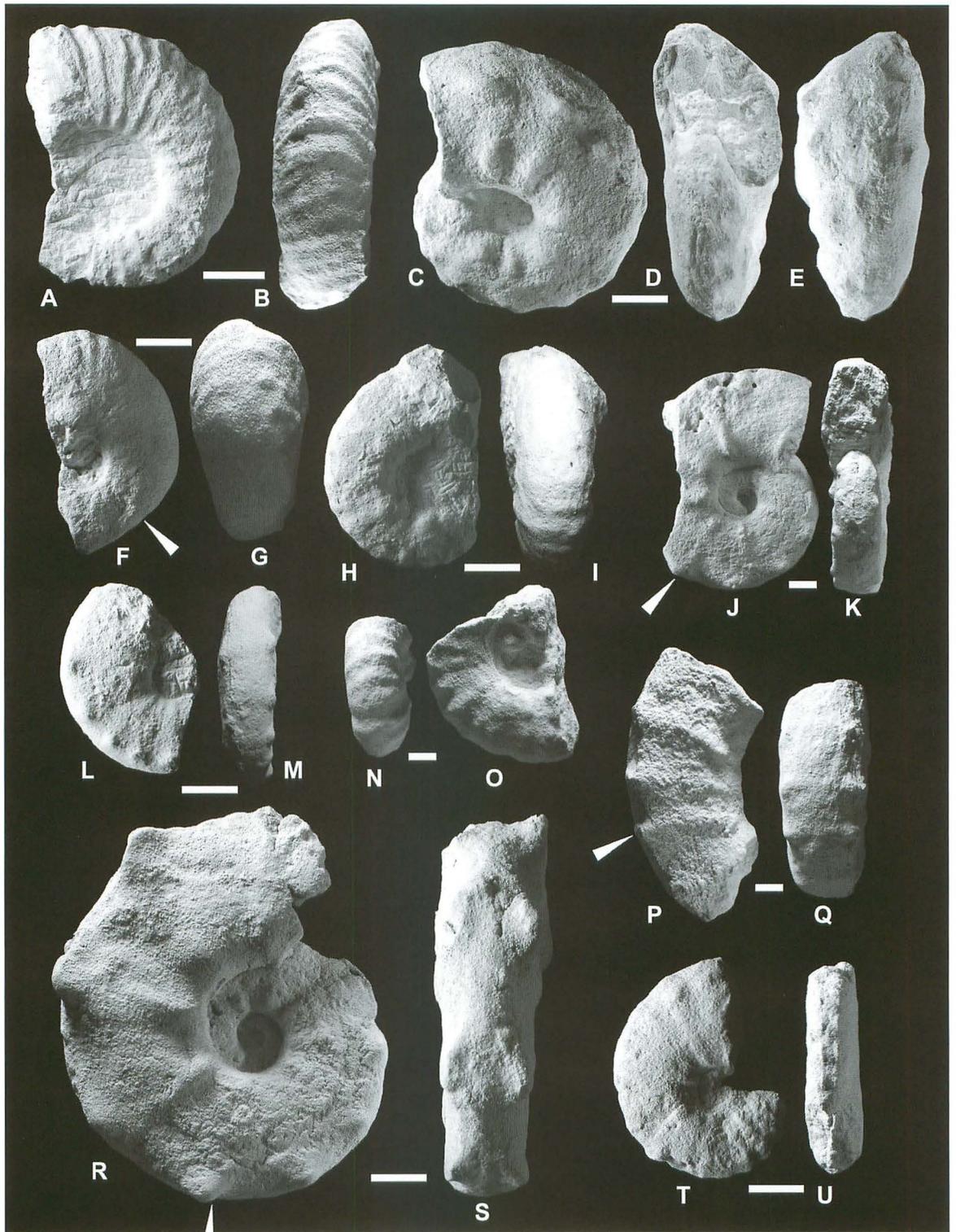
Explanation to Plates

Plate 1

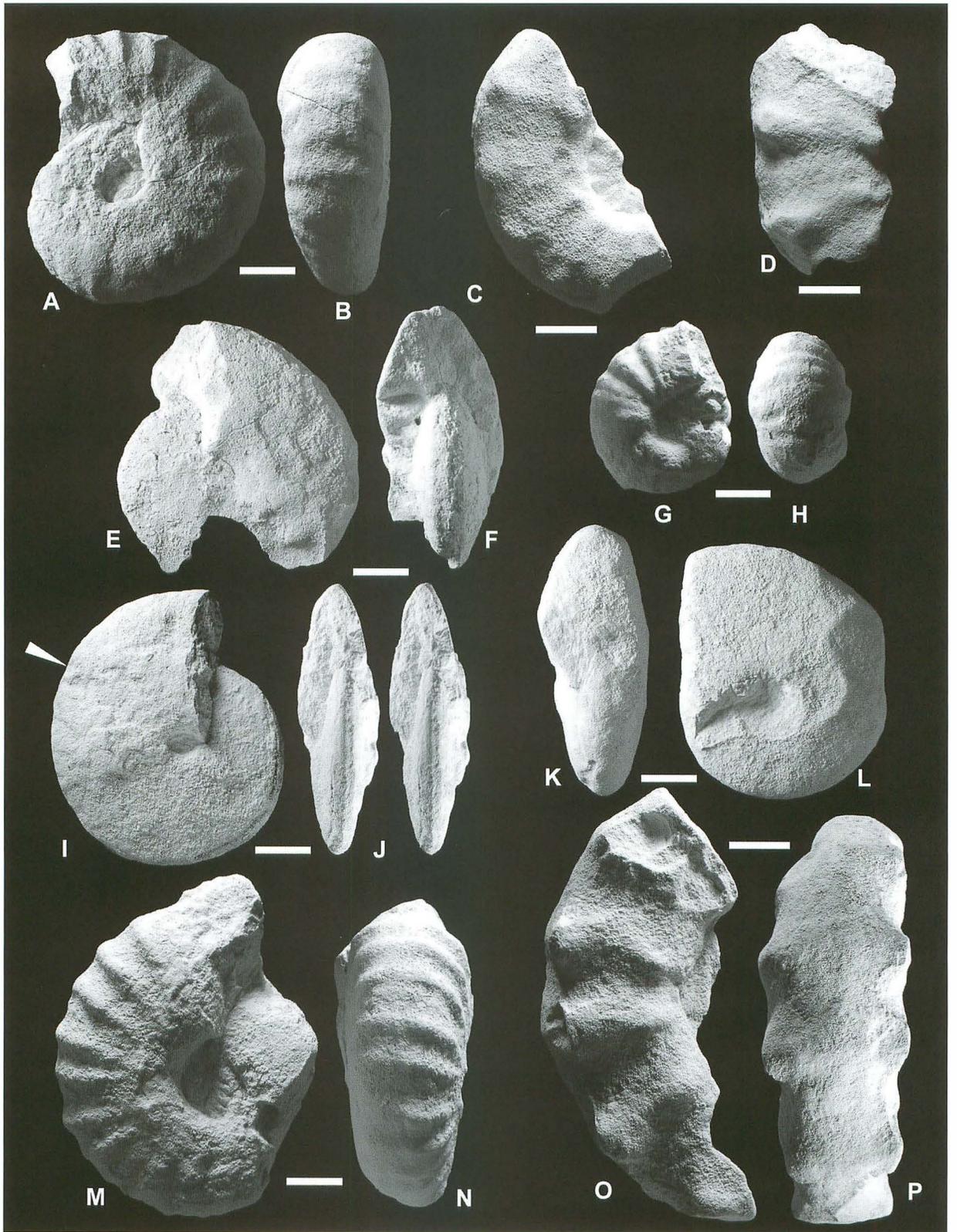
- Calycoceras (Newboldiceras) asiaticum asiaticum* (JIMBO 1894) – A, B, lateral and ventral view of GSUB C2573.
- Spathites (Jeanrogericeras) reveleerianus* (COURTILLER 1860) – C, D, E, lateral, ventral and apertural view of GSUB C2556.
- Nigericeras cf. gadeni* (CHUDEAU 1909) – F, G, lateral and ventral view of GSUB C2574.
- Lewesiceras peramplum* (MANTELL 1822) – H, I, lateral and ventral view of GSUB C2535.
- Mammites nodosoides* (SCHLÜTER 1871) – J, K, lateral and apertural view of GSUB C2506.
- Pseudaspidoceras aff. footeanum* (STOLICZKA 1864) – L, M, lateral view and ventral view of GSUB C2517.
- Spathites (Jeanrogericeras) cf. postsaenzi* (WIEDMANN 1960) – N, O, lateral and ventral view of GSUB C2570.
- Pseudaspidoceras footeanum* (STOLICZKA 1864) – P, Q, lateral and ventral view of GSUB C2501.
- Mammites nodosoides* (SCHLÜTER 1871) – R, S, lateral and ventral view of GSUB C2504.
- Metoicoceras geslinianum* (D'ORBIGNY 1850) – T, U, lateral and ventral view of GSUB C2558. Scale bar each 20 mm.

Plate 2

- Vascoceras cauvini* CHUDEAU, 1909 – A, B, lateral and ventral view of GSUB C2571. M, N, lateral and ventral view of GSUB C2566.
- Pseudaspidoceras pseudonodosoides* (CHOFFAT 1898) – C, lateral view of GSUB C2580. D, lateral view of GSUB C2511.
- Thomasites rollandi* (THOMAS & PERON 1889) – E, F, lateral and apertural view of GSUB C2527.
- Vascoceras durandi* (THOMAS & PERON 1889) – G, H, lateral and ventral view of GSUB C2523.
- Choffaticeras (Choffaticeras) n. sp.* – I, J, lateral and apertural view of GSUB C2532.
- Thomasites cf. gongilensis* (WOODS 1911) – K, L, lateral and apertural view of GSUB C2524.
- Morrowites wingi* (MORROW 1935) – O, P, lateral and ventral view of GSUB C2584. Scale bar each 20 mm.



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