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Aptian (Lower Cretaceous) biostratigraphy and cephalopods from north central Tunisia

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ABSTRACT

Thick Aptian deposits in north central Tunisia comprise hemipelagic lower Aptian, reflecting the sea-level rise of OAE 1a, and an upper Aptian shallow marine environment characterized by the establishment of a carbonate platform facies. Carbon stable isotope data permit recognition of the OAE 1a event in the Djebel Serdj section. Cephalopods are rare throughout these successions, but occurrences are sufficient to date the facies changes and the position of the OAE1a event. Ammonite genera include lower Aptian *Deshayesites*, *Dufrenoyia*, *Pseudohaploceras*, *Toxoceratoides* and ?*Ancyloceras*; and upper Aptian *Zuercherella, Riedelites* and *Parahoplites.* Correlation of carbon isotope data with those of other Tethyan sections is undertaken together with the integration of planktonic foraminiferal data.

1. Introduction

In the lower Aptian, superplume activity in the Pacific realm probably triggered greenhouse conditions and major global changes in the ocean/climate system (e.g. Larson and Erba, 1999). The most obvious reflection of these environmental changes is the Oceanic Anoxic Event 1a (OAE 1a), a time-interval of deposition under low oxygen conditions mainly in the hemipelagic realm and the deep ocean, and consequently research of the last decades focused mainly on this event (e.g. Menegatti et al., 1998; Leckie et al., 2002). Recently the effect of major palaeoceanographic and palaeobiological changes on shallow marine environments has attracted further research (Graziano, 2000; Bernaus et al., 2003; Bachmann and Hirsch, 2006; Luciani et al., 2006).

Ammonites are important in the precise dating of the OAE 1a and other Aptian environmental changes, but their occurrence is often scattered within the lithostratigraphic successions and are satisfactory only in a few areas within the Mediterranean Tethyan province (e.g. Aguado et al., 1999; Ropolo et al., 2006). As a rule, Aptian ammonites decrease in occurrence from the hemipelagic realm to the shallow-marine environment. In the hemipelagic facies, they are usually present but uncommon in black shale, limestone, marlstone or claystone facies (e.g. Bernaus et al., 2003); distal carbonate shelf settings often contain at least poor faunas (e.g. Aguado et al., 1999; de Gea et al., 2003), but proximal carbonate platform deposits are frequently undated by ammonites (e.g. Tasli et al., 2006; Memmi, 1999).

The first comprehensive documentation of ammonites and other cephalopods from Tunisia is that of Pervinquière (1907), which also included descriptions of a few Aptian species. More recent papers focused on less-expanded sections and aimed to establish a biostratigraphy for this realm (e.g. Memmi, 1999). The data were presented mainly as species lists, and the ammonites collected were not documented. Here, we present a study of thick and well-exposed successions in the study area dated by rare ammonite occurrences. This includes, on the one hand, material from the lower Aptian OAE 1a interval represented within the hemipelagic facies by 45 m of sediments (Fig. 1A) and, on the other, by specimens obtained from the upper Aptian shallow-marine carbonate platform (Fig. 1B), a facies predominantly avoided by cephalopods. This permits dating of the late Aptian re-establishment of a carbonate platform, after the early Aptian crisis.

The lower Aptian ammonite fauna in north central Tunisia contains deshayesitids and *Pseudohaploceras* spp., and is, therefore, typical of the shelf environmental regions of the Tethys. This hemipelagic fauna shows affinities with faunas from the western and central Tethys as well as the Boreal region. Ammonites with a supposed pelagic mode of life that occur in more distal Tethyan

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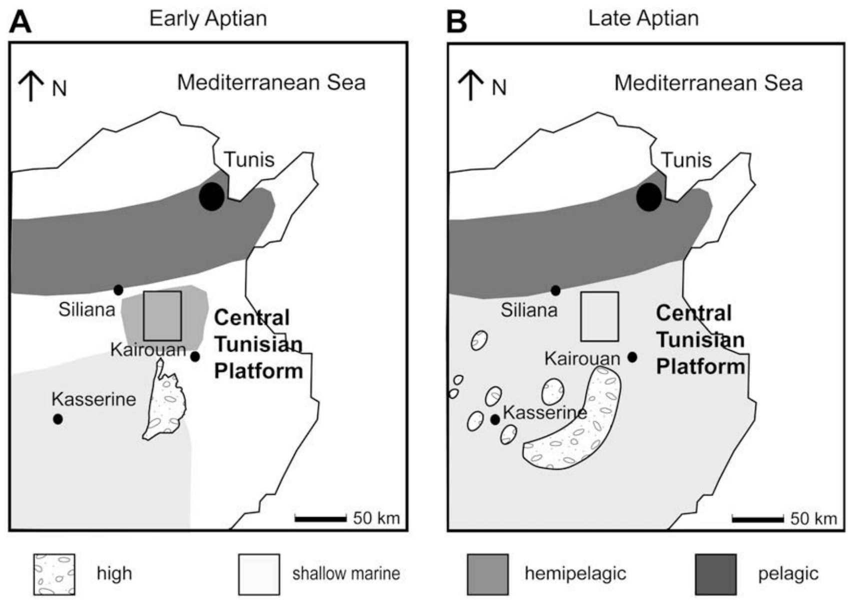

Fig. 1. Palaeogeography for the early Aptian (A) and late Aptian (B) of central Tunisia with rectangle indicating the location of the study area enlarged in the topographic map in Fig. 2. Map simplified after Ben Ferjani et al., 1990.

environments, such as lytoceratids, phylloceratids and heteromorphs, are a minor component, if present at all. In the late Aptian, large parahoplitid specimens are found in the inner ramp, lagoonal facies. A comparison with other regions suggests that this group of ammonites inhabited shallow-water areas rather than the shells having been transported to a proximal position by post-mortem drift. In the lagoonal upper Aptian the palaeobiogeographic affinities persist and additional records from the Americas hint at a more global distribution of taxa.

2. Locality details, profiles, and conventions

The present account is based on two outcrops in north central Tunisia. The main localities are located in the Siliana region, along Djebel Serdj (Fig. 2), where three major sections close to the villages of Beskra, Sodga and Sidi Hamada have been measured and sampled for microfacies, planktonic and benthic foraminifera and stable isotope geochemistry. The sections cover two formations, the Hamada Formation and the Serdj Formation, that were previously dated by planktonic and benthic foraminifera (Tlatli, 1980). The Hamada Formation is subdivided into three members, which cover the whole lower Aptian and the beginning of the upper Aptian (Fig. 3).

The lowermost part of the Hamada Formation belongs to carbon isotope segment C1, which is attributed to the latest Barremian (compare Menegatti et al., 1998; Heldt et al., 2008). Its top lies close to the upper part of segment C8, indicating an early late Aptian age that is confirmed by planktonic foraminiferal data (Heldt et al., 2008). Consequently, the base of the overlying Serdj Formation is of late Aptian age; the upper limit of the Formation is already early Albian in age (Tlatli, 1980) but is not further considered here because of insufficient outcrops.

For a detailed dataset focusing on the environmental reconstruction and in particular the development around OAE 1a, see Heldt et al. (2008). In Fig. 3 we present a schematic profile based on the Djebel Serdj succession, which includes microfacies and carbon isotope data together with planktonic foraminiferal data obtained from fieldwork of the present project. The stratigraphic range of the OAE 1a is based on the mass occurrence of radiolaria in the Hamada Formation (Heldt et al., 2008) and is in agreement with stable carbon isotope data. The δ^{13} C-curve can be divided into segments

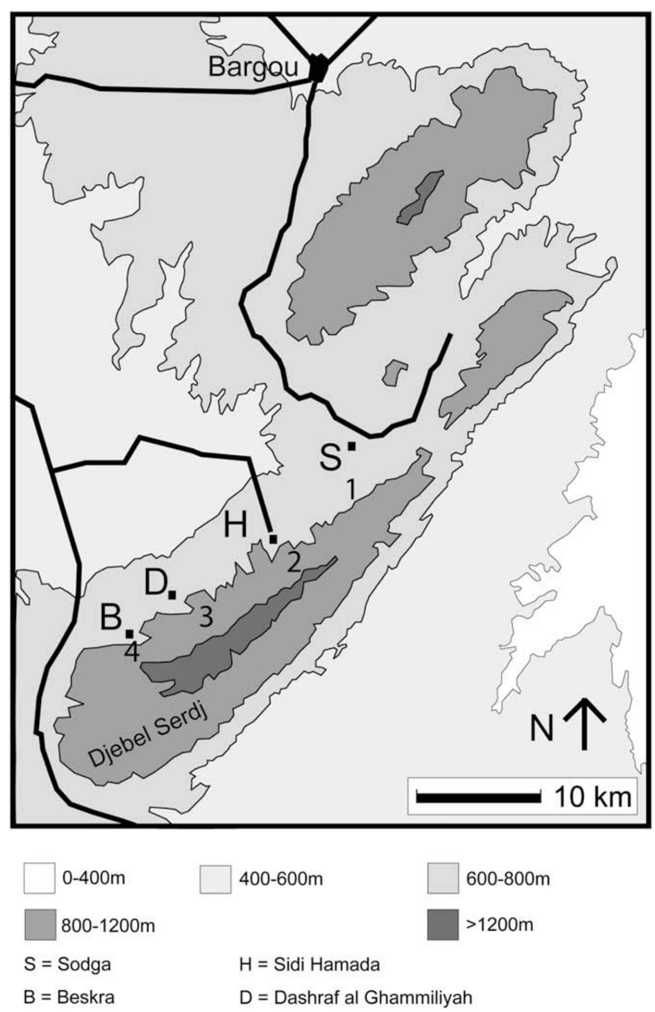

Fig. 2. Main study area at Djebel Serdj in north central Tunisia, with villages and sampling localities (localities 1–4 in Table 1).

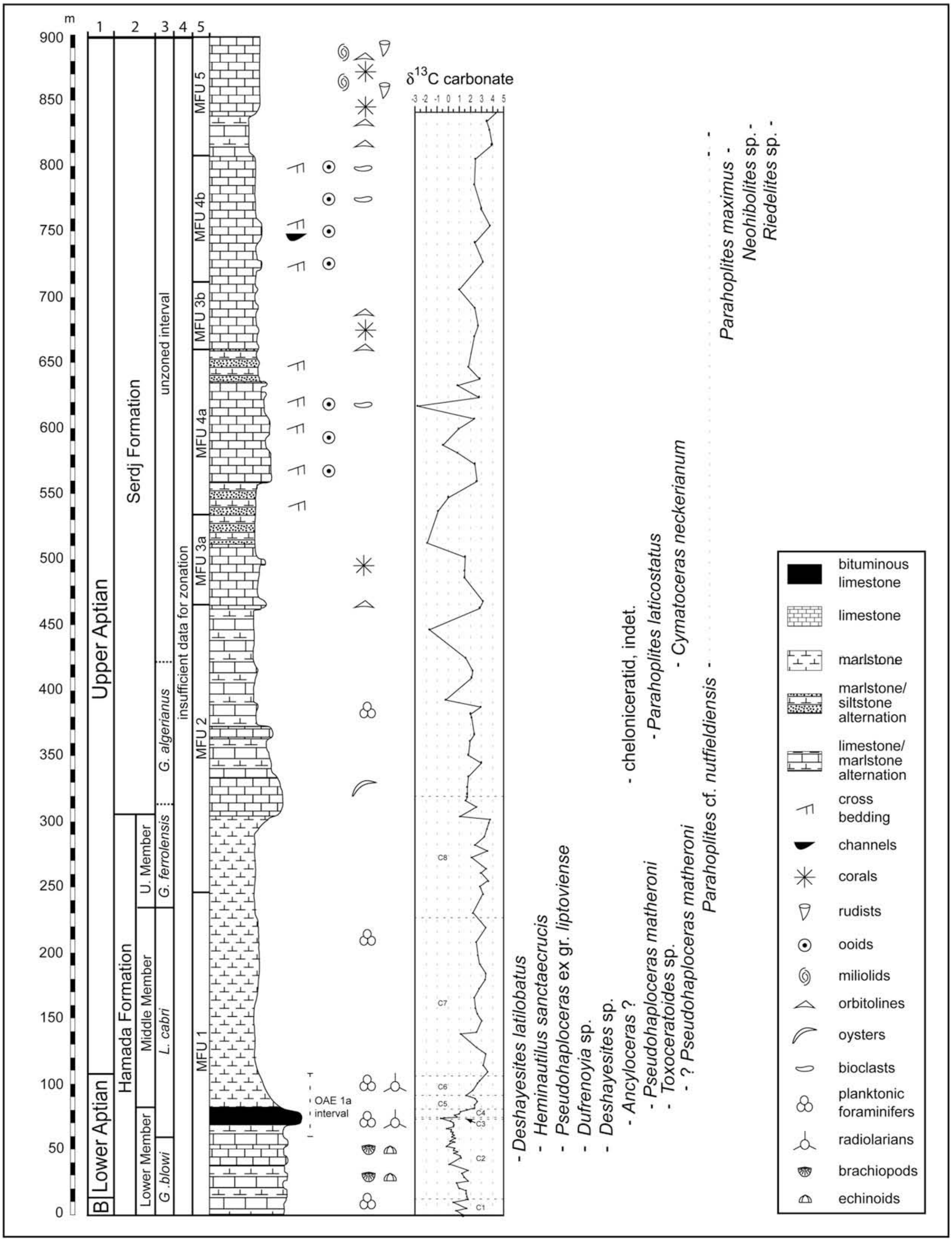

Fig. 3. Simplified section for the uppermost Barremian and Aptian in north central Tunisia. The stratigraphic range of the OAE 1a is defined by the mass occurrence of radiolaria (Heldt et al., 2008); the subdivision of carbon isotope curve into segments C1-C8 follows Heldt et al. (2008) and is based on Menegatti et al. (1998). 1. Substages, "B" = uppermost Barremian. 2. Formations and Members. 3. Planktonic foraminiferal zones; the "unzoned interval" lacks planktonic foraminifera. 4. Ammonite zones. 5. Microfacies units.

representing distinctive isotopic excursions as proposed by Menegatti et al. (1998), for a full discussion and definition of the OAE 1a in our working area see Heldt et al. (2008). Correlation on the base of stable carbon isotopes is possible with time-equivalent sections, for example in the Swiss Préalps and in the southern Alps of northern Italy (Menegatti et al., 1998). Additionally, although

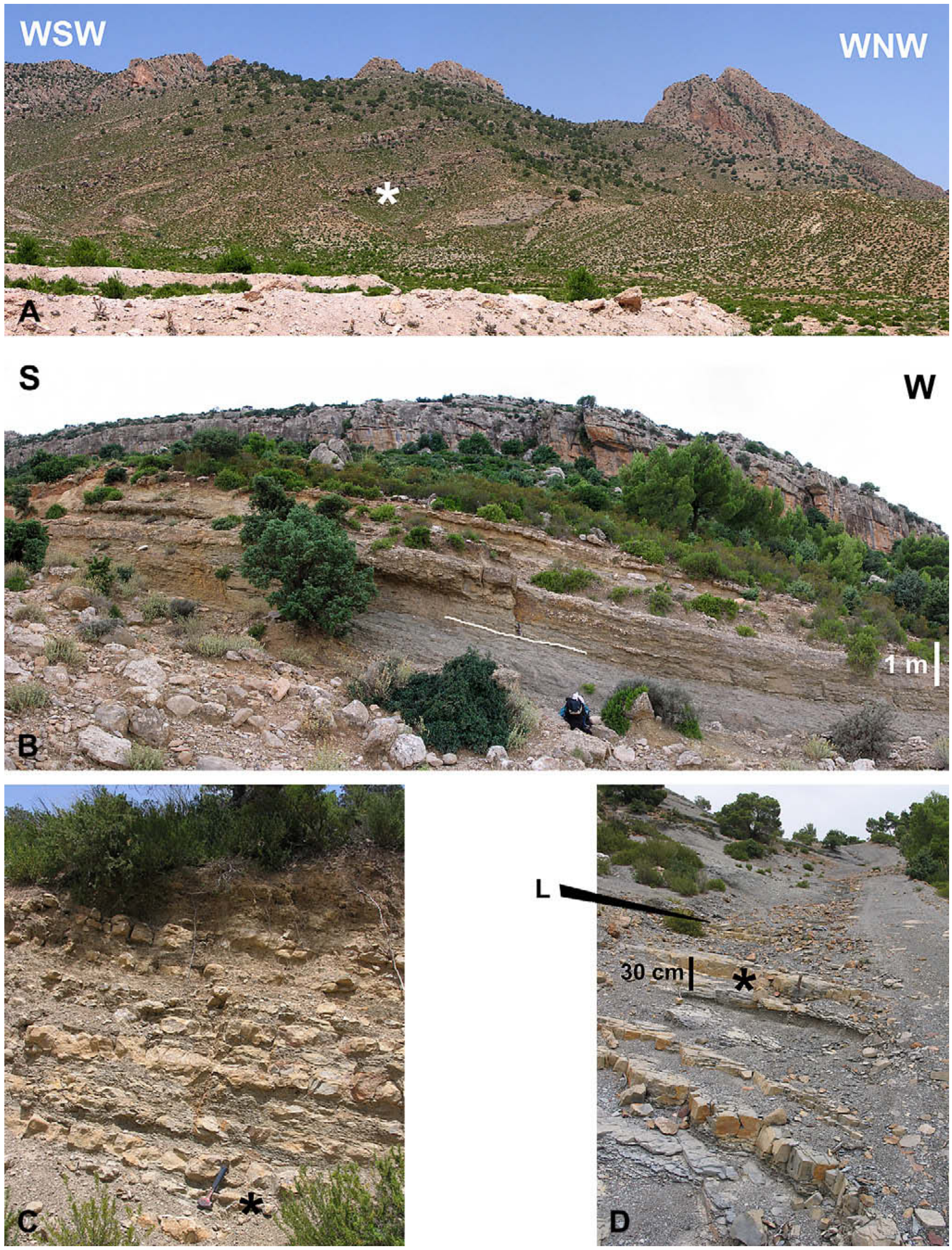

Fig. 4. Aptian ammonite localities in northern central Tunisia. A, Panoramic view of Aptian at Djebel Slata with an asterisk for locality 5 that yielded *Zuercherella* sp. and *Parahoplites* cf. *nutfieldiensis* (Table 1; GSUB C4040, C4041). GPS point: N35.86623°, E008.48003°, 669 m height. About 80 km NNW of Kasserine, west-central Tunisia. B–D, Djebel Serdj near Siliana, north central Tunisia. B, Outcrop south of Beskra village, Panoramic view of silty peloidal marlstones (wacke- to packstone) of the upper Aptian that are rich in macrofossils. A large specimen of *Parahoplites* cf. *nutfieldiensis* (GSUB C4043) from the level indicated by the white line. GPS point: N35.92276°, E009.48326°, 776 m height. C, Outcrop southeast of Sidi Hamada village of echinoid- and brachiopod-bearing silty marlstone-limestone couplets, bioclastic wacke- and packstones of the lower Aptian with horizon (asterisk) yielding the large ammonite *Deshayesites latilobatus* (GSUB C4038). GPS point: N35.95490°, E009.56371°, 778 m height. D, Laminated bioclastic wacke- and packstones of the lower Aptian OAE 1a interval southeast of Sidi Hamada village. Transition from the limestone-marlstone alternation to the pure marlstones above; the last indurated wacke-/packstone bed is indicated (L). The asterisk indicates the bed with many ammonites (? *Pseudohaploceras matheroni*) in this area, which is otherwise poor in fossil cephalopods. GPS point N35.95566°, E009.56524°, 831 m height.

a large part of the Djebel Serdj succession was deposited in a shallow-marine depositional environment, it yielded an ammonite fauna. This dataset was supplemented by ammonites collected from similar upper Aptian shallow-water facies at Djebel Slata, also in northern Tunisia, about 100 km WSW of the Siliana area in the vicinity of Kalaat Senan, close to the Algerian border. The subdivision of the carbon isotope curve into segments C1–C8 used in the text and in Fig. 3 is following Heldt et al. (2008).

The microfacies of the sections investigated was subdivided into five units, abbreviated MFU 1 to 5, with further subdivisions into a and b for MFU 3 and 4 (see Table 2). This classification has been established on the frequency of characteristic palaeoenvironmental components like ooids, cortoids, foraminifera, as well as on criteria such as sorting and rounding of components. It uses common carbonate rock microfacies analysis (e.g. Flügel, 2004). A reinvestigation of the microfacies, chemostratigraphy, facies, palaeoenvironment and some palaeontological aspects of the Aptian of north central Tunisia, as a whole, is currently in progress, with some results from the lower Aptian succession having been completed (Heldt et al., 2008).

The abbreviation GSUB (Geosciences Collection of the University of Bremen, Germany) used in relation to the cephalopod occurrences recorded here, indicates the repository of specimens dealt with in the present paper. The material considered herein is sampled from five different areas, for each specimen represented by the inventory number the GPS positions are given in the following table.

3. Ammonite biostratigraphy

3.1. Previous work

Early authors in general have noted the scarcity of ammonites in the hemipelagic to pelagic facies of the Aptian deposits of Tunisia (Krenkel, 1911), but an ammonite zonal scheme for the region was developed by Stranik et al. (1970, 1974), Biely et al. (1973) and Memmi (1979, 1981, 1999). Pervinquière (1903) first described the Djebel Serdj section in outline and mentioned the occurrence of a few Aptian macrofossils, including the cephalopods '*Douvilleiceras*' *martini* d'Orbigny, '*Hoplites*' *fissicostatus* Phillips, a nautiloid he referred to the group of *Nautilus neocomiensis* and *N. neckerianus* (=*Nautilus* aff. *neocomiensis* in the species list of Pervinquière, 1903) as well as undetermined belemnites. To the north of Djebel Serdj, at Djebel Bargou, Pervinquière (1903) additionally mentioned *Belemnites* (*Hibolites*) *semicanaliculatus* Blainville and, from the wider Bargou area, *Parahoplites uhligi* Anthula. On the basis of our own material we were able to identify the nautiloid species from Djebel Serdj mentioned by Pervinquière (1903, 1907) as *Cymatoceras neckerianus* (Pictet, 1847). The belemnite is *Neohibolites semicanaliculatus* (Blainville, 1827) in current nomenclature, an Aptian species with a wide geographical range (Gauthier, 2006). However, Pervinquière (1903) obviously was unsure about this identification, since he subsequently (Pervinquière, 1907) mentioned the Albian species *Belemnites* (*Hibolites*) *minimus* from Djebel Bargou, refering to the same material in his monograph.

Pervinquière's ammonite determinations, although in need of complete revision, indicate the presence of lower Aptian and upper Aptian sediments in this area of Tunisia. Whatever the taxonomic position of his *Hoplites fissicostatus*, the occurrence is sufficient to indicate the presence of lower Aptian sediments (Casey, 1964 showed that the records of *Hoplites* cf. *fissicostatus* (*Deshayesites*) by Pervinquière, 1903, 1907 were based on a misidentification). His records of '*Parahoplites*' *weissi* (Djebel Serdj) and '*Parahoplites*' *consobrinoides* (Bou Tis, North of Bargou) (Pervinquière, 1907), are both species of *Deshayesites* (e.g. Ropolo et al., 2006) and therefore lower Aptian index ammonites, but Pervinquière's account are insufficient to be certain about the identity of his specimens from a modern taxonomic point of view.

Pervinquière's record of '*Douvilleiceras*' *martini*, whether or not it is correctly identified in modern nomenclature, is an *Epicheloniceras* indicating upper Aptian sediments. Equally, his record of '*Parahoplites*' *uhligi*, a species of *Hypacanthoplites*, indicates a latest Aptian age (e.g. Immel et al., 1997).

From Djebel Slata Pervinquière (1903) mentioned no cephalopods except for undetermined belemnites; according to Pervinquière's (1907) monograph the cephalopods obtained were Albian and Cenomanian in age only.

3.2. Present work

The compound uppermost Barremian to Aptian section shown here (Fig. 3) includes the Hamada Formation and a large part of the Serdj Formation. The ammonite zonation of the Mediterranean Tethyan region and the European province equivalents is shown in

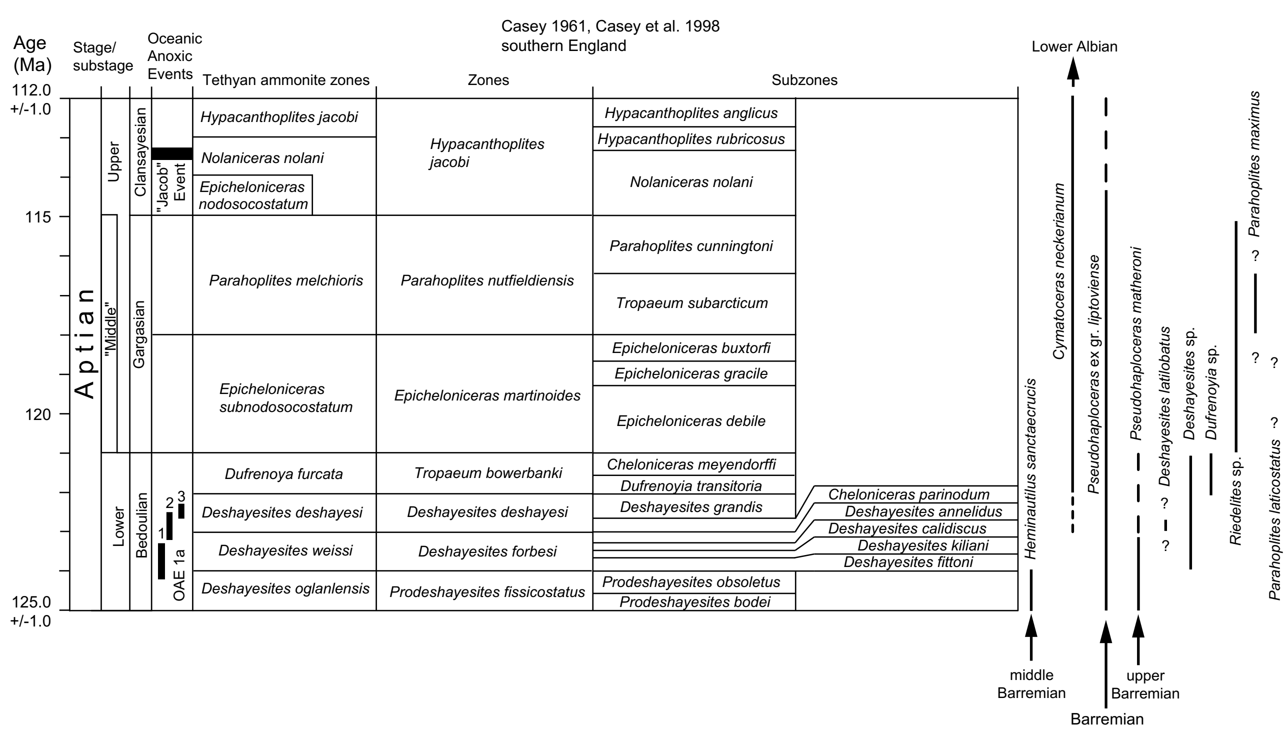

Fig. 5. Ammonite biozonal scheme for the Aptian and range of the important taxa recorded herein. The range of OAE 1a in the context of ammonite biostratigraphy is applied differently by various authors. 1: Ogg et al. (2004) for Boreal and Tethys, 2: Landra et al. (2000) and Erba (1996) for the Tethys; Mutterlose (1992) and Keupp and Mutterlose (1994 for the Boreal. 3: Renard et al. (2005) and Moullade et al. (1998) for the Bedoulian type section. The "*Deshayesites weissi*" zone is inappropriate, but provisionally retained until a new index is proven following Reboulet et al. (2006). For references to ammonite ranges see systematic part.

Table 1
Locality details of material investigated

Coordinates	Inventory number	Determination
Locality 1: South of Sodga village, Djebel Serdj		
N35.96949°, E009.58941°	GSUB C4053	*Parahoplites* cf. *nutfieldiensis*
	GSUB C4054, C4055	*Cymatoceras neckerianum*
N35.96735°, E009.59497°	GSUB C4050	*Parahoplites* sp.
	GSUB C4051	*Riedelites* sp.
	GSUB C4052	*Parahoplites* ?
N35.96667°, E009.59447°	GSUB C4048	*Parahoplites* cf. *nutfieldiensis*
N35.96674°, E009.59452°	GSUB C4049	*Neohibolites* sp.
N35.97048°, E009.58233°	GSUB C4031	*Dufrenoyia* sp.
	GSUB C4032	*Toxoceratoides* sp.
	GSUB C4033	*Deshayesites* sp.
	GSUB C4034	*Pseudohaploceras* ex gr. *liptoviense*
	GSUB C4035	*Heminautilus sanctaecrucis*
N35.97091°, E009.58276°	GSUB C4037	? *Toxoceratoides*
	GSUB C4044	*Pseudohaploceras matheroni*
N35.97070°, E009.58271°	GSUB C4036	*Ancyloceras* ?
Locality 2: Uphill (=southeast) of Sidi Hamada Village, Djebel Serdj, see also Fig. 4C, D		
N35.95500°, E009.56435°	GSUB C4039	Deshayesitidae, gen. et sp. non det
N35.95490°, E009.56371°	GSUB C4038	*Deshayesites latilobatus*
N35.95566°, E009.56524°	GSUB C4045, C4046	? *Pseudohaploceras matheroni*
Locality 3: Djebel Serdj mountainside, vicinity of Dashraf al Ghammiliyah		
N35.93897°, E009.54068°	GSUB C4047	*Parahoplites laticostatus*
N35.93230°, E009,53427°	GSUB C4083	cheloniceratid, indet.
Locality 4: Uphill (south) of Beskra village, djebel Serdj, see also Fig. 4B		
N35.92228°, E009.48446°	GSUB C4042	*Parahoplites maximus*
N35.92276°, E009.48326°	GSUB C4043	*Parahoplites* cf. *nutfieldiensis*
Locality 5: Djebel Slata, about 80 km NNW of Kasserine, see also Fig. 4A		
N35.86747°, E008.47315°	GSUB C4040	*Zuercherella* sp.
N35.86745°, E008.47361°	GSUB C4041, C4081	*Parahoplites* cf. *nutfieldiensis*
	GSUB C4082	*Parahoplites* sp. 1

Fig. 5, together with the occurrence and ranges of the cephalopods collected from the study area listed separately in Table 1. The ammonite occurrences, although sparse, permit a correlation with similar ranges known from other areas in the European and Tethyan provinces and further correlation using chemostratigraphy and planktonic foraminiferal data, in particular, permit a comparison with the standard ammonite zonation (Fig. 5).

In the lower Aptian part of the Hamada Formation, the lowermost level yielding ammonites contains *Deshayesites latilobatus* (Sinzov) (Fig. 7H). This horizon lies about 30 m below the OAE 1a interval, in the lower half of carbon isotope segment C2, and corresponds to one of the lowermost two ammonite zones of the Aptian of the European province (*Deshayesites forbesi* or *Prodeshayesites fissicostatus*), but probably within the *Deshayesites weissi* Zone of the current Tethyan province zonation (Reboulet et al., 2006). However, the only other well-calibrated records of *D. latilobatus* are from the *Cheloniceras parinodum* Subzone of the *Deshayesites deshayesi* Zone s.l. in southern England (Casey, 1980).

An interval yielding mainly *Heminautilus sanctaecrucis* (Conte) (Fig. 7M), *Pseudohaploceras* ex gr. *liptoviense* (Zeuschner) (Fig. 7L), *Dufrenoyia* sp. (Fig. 7A) and *Deshayesites* sp. (Fig. 7J) can be attributed to the transition between carbon isotope segments C2 and C3,

Table 2
Microfacies, interpretation of palaeoenvironment and associated cephalopod occurrences in the Aptian of north central Tunisia. MFU = Microfacies unit, for details see conventions

MFU	Rock classification	Main and diagnostic components	Component sorting / rounding	Main macrofossils	Cephalopod occurrences	Palaeoenvironment
1	Bioclastic and peloidal mud- to packstones, marlstones	shells, mud-peloids, planktic-and small benthic foraminifers. During OAE1a additionally radiolarians and sponge spiculae	poorly to moderately sorted, angular to subrounded shapes	brachiopods, echinoids	1 – Deshayesitids-*Pseudohaploceras*	outer ramp
2	Bioclastic to peloidal wacke-to packstone, marlstones	shells, mud-peloids, planktic-and small benthic foraminifers	moderately to well sorted, angular to rounded shapes	oysters, other bivalves	2 – *Cymatoceras*-*Parahoplites*	mid-ramp
3	peloidal to bioclastic wacke- to packstones, marlstones, coral framestones, siltstones	mud-peloids, shells, cortoids, quartz grains, small benthic foraminifers (e.g. miliolids), orbitolines, large agglutinating foraminifers, diverse bioclasts (e.g. of bryozoans, echinoderms)	poorly to well sorted, angular to well rounded shapes	oysters, other bivalves, colonial corals	—	inner ramp/open marine
4	Bioclastic to oolitic grainstones, siltstones	ooids, quartz grains, shells, cortoids, bioclasts (e.g. of echinoderms. Algae, bryozoans, orbitolines)	well sorted and rounded	large bivalve shells	—	inner ramp/high energy shoal
5	Bioclastic to peloidal/ lithoclastic wacke-to grainstones, coral framestones, framestones, rudist bafflestones, menial mudstones, marlstones	shells, mud-peloids, cortoids, diverse bioclasts (e.g. of echinoderms, algae and bryozoans), small benthic foraminifers (e.g. miliolids), orbitolines	poorly to moderately sorted, subangular-well rounded shapes	colonial corals, rudists, other bivalves, gastropods	3 – *Parahoplites* (3a = southwestern – 3b = northeastern Djebel Serdj)	inner ramp/lagoon (restricted lagoon in parts of the SW section of the working area)

only a few metres below the OAE 1a interval (Fig. 3). *H. sanctaecrucis* and *P.* ex gr. *liptoviense* are of limited stratigraphic value, both being recorded from Barremian as well as lower Aptian strata (Conte, 1980; González-Arreola et al., 1996). The record of *Dufrenoyia* sp. hints at a late early Aptian age, since *Dufrenoyia* evolved from *Deshayesites*, and both genera have been previously recorded to overlap in the uppermost *D. deshayesi* Zone only (Bogdanova and Michailova, 2004). In most shallow marine sections, including the historical Aptian stratotype at La Bedoule (e.g. Ropolo et al., 2006), both genera do not occur in the same beds. However, in the Aralar section in northern Spain, a significant overlap can be observed in the interval containing OAE 1a (García-Mondéjar et al., 2009). This correlates with the Tunisian section, since the corresponding interval with the equivalent of OAE 1a contains *Dufrenoyia* sp. as well as *Deshayesites* sp. (Fig. 3).

There are a few ammonite records from the OAE 1a interval, including ?*Ancyloceras* (Fig. 7C) and *Pseudohaploceras matheroni* (d'Orbigny) (Fig. 7D). They do not allow a high-resolution biostratigraphy, since *P. matheroni* occurs from the upper Barremian to the lower Aptian (Vašícek and Summesberger, 2004) and the forms attributed to ?*Ancyloceras* probably suggest an early Aptian age (Förster and Weier, 1983).

In summary, the lower part of the Hamada Formation at Djebel Serdj is early Aptian in age on the basis of the ammonites. From the geochemical evidence, the Hamada Formation also includes OAE 1a. The occurrence data are insufficient to establish an ammonite zonal scheme.

Above the OAE 1a horizon, there are no ammonite records for the following 230 m of section. Consequently, the lower-upper Aptian boundary in our standard section (Fig. 3) is based on the succession of planktonic foraminifera (Heldt et al., 2008). The lowermost upper Aptian ammonite record is an indeterminate cheloniceratid (Fig. 3). Additionally, *Parahoplites laticostatus* has been recorded from this part of the upper Aptian section at Djebel Serdj, dating the lowermost part of the Serdj Formation as late Aptian (Fig. 3). The lowermost record of *Parahoplites* cf. *nutfieldiensis* in our compound section might suggest a *P. nutfieldiensis* Zone age for the lower part of the Serdj Formation but this is unlikely, for the reasons discussed below. The record of *P.* cf. *nutfieldiensis* in the lowermost Serdj Formation is associated with an abundant occurrence of the nautiloid *Cymatoceras neckerianum,* a nautiloid ranging in age from late early Aptian (Calzada and Viader, 1980) to early Albian (e.g. Weidich et al., 1983). The overlying, almost 390 m of the section did not yield cephalopods. An interval in the higher part of the Serdj Formation, at a height between 500 and 525 m above the base, yielded the ammonites *P.* cf. *nutfieldiensis*, *Parahoplites maximus*, *Riedelites* sp. and the belemnite *Neohibolites* sp. Of these fossils, the best species for dating is *P. maximus.* This species is restricted to the *Tropaeum subarcticum* Subzone in England, which corresponds to the lower half of the *P. nutfieldiensis* Zone of Casey (1965). If the record of *P.* cf. *nutfieldiensis* from the lower part of the Serdj Formation is correct, it would make the thickness of the *P. nutfieldiensis* Zone sediments at Djebel Serdj a total of 400 m out of the total thickness of 650–700 m of this Formation. A trend to higher carbon isotope values above a height of 700 m in this section (Fig. 3) might be correlated with a general increase reported for the *P. nutfieldiensis* Zone or its correlatives e.g. by Weissert et al. (1998), Föllmi et al. (2006).

4. Regional facies and palaeoenvironment

In the lower Aptian a carbonate platform called the Central Tunisian Platform can be recognised (Ben Ferjani et al., 1990; Fig. 1A). A narrow hemipelagic zone can be traced between Siliana and Kairouan, followed to the south by a broad shallow marine area, with only one large high south of Kairouan. The lower Aptian part of the fauna described herein was obtained mainly from an interval slightly below OAE 1a (Fig. 3). Together with the remaining cephalopods from the uppermost Barremian–lower Aptian part of the section, this fauna can be attributed to microfacies unit 1 (MFU in the following, see conventions; Table 2). MFU 1 suggests an outer ramp palaeoenvironment, as indicated by mud- to packstones containing planktonic foraminifera and radiolaria as well as cephalopods (Fig. 3). This is a deshayesitid-*Pseudohaploceras* cephalopod occurrence (occurrence 1 in Fig. 6).

In the late Aptian, carbonate production took place on an expanded Central Tunisian Platform under shallow marine conditions, with more numerous islands than in the early Aptian

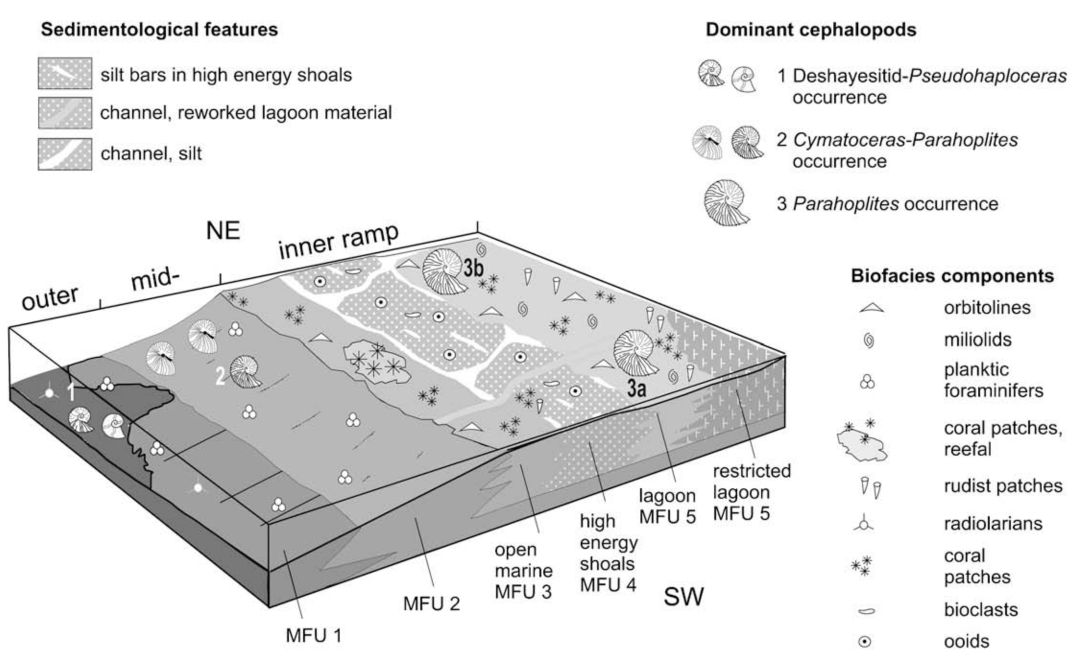

Fig. 6. Facies diagram for the Aptian of north central Tunisia with distribution of ammonite occurrences.

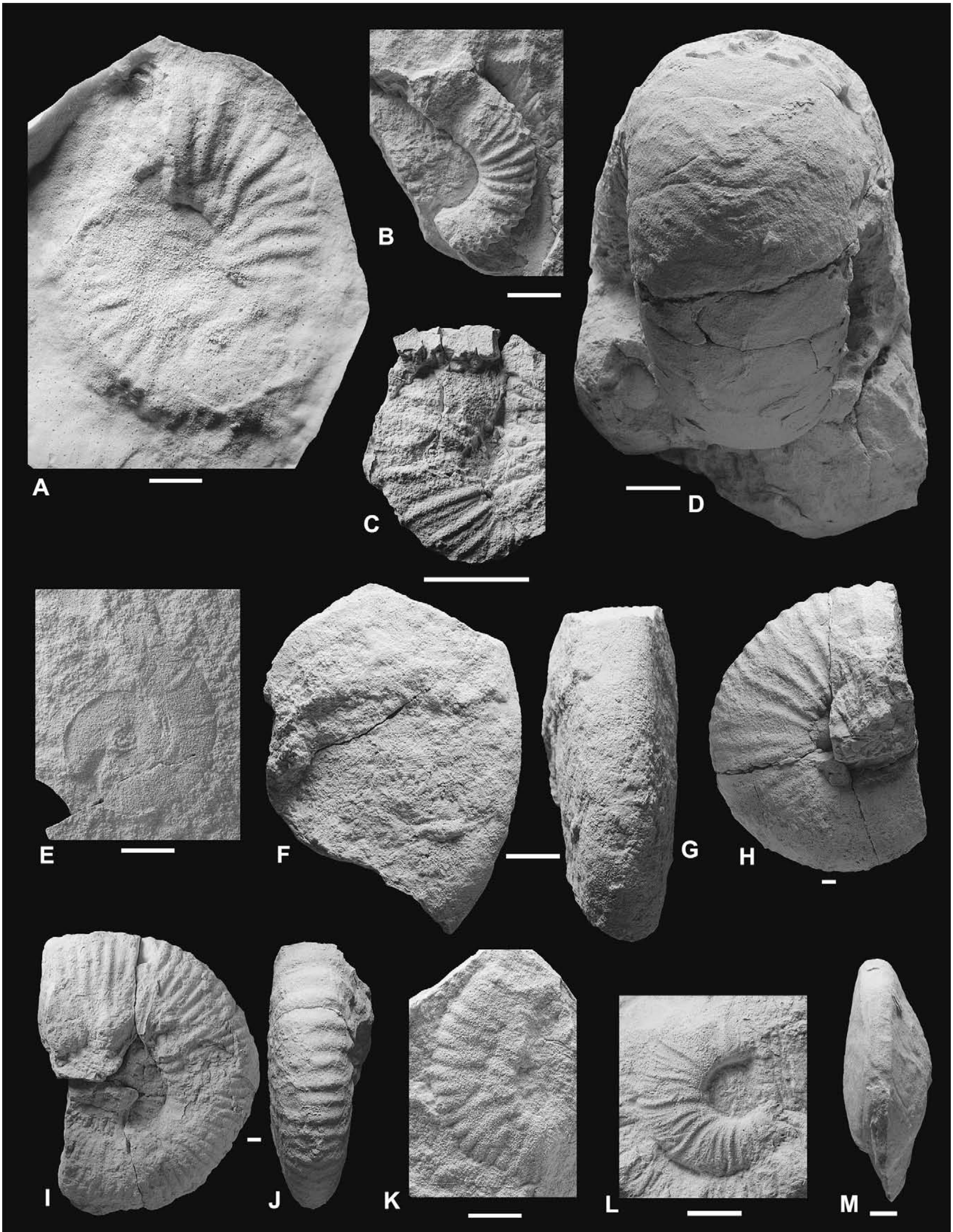

Fig. 7. Cephalopods from the Aptian of northern Tunisia. A, *Dufrenoyia* sp., GSUB C4031. B, *Toxoceratoides* sp., GSUB C4032. C, ?*Ancyloceras*, GSUB C4036. D, *Cymatoceras neckerianum* (Pictet, 1847), GSUB C4055. E, *Pseudohaploceras matheroni* (d'Orbigny, 1841), GSUB C4044. F, G, *Zuercherella* sp., GSUB C4040. H, *Deshayesites latilobatus* (Sinzow, 1909), GSUB C4038. I, J, *Parahoplites* cf. *nutfieldiensis* (J. Sowerby, 1815), GSUB C4043. K, *Deshayesites* sp., GSUB C4033. L, *Pseudohaploceras* ex gr. *liptoviense* (Zeuschner, 1856), GSUB C4034. M, *Heminautilus sanctaecrucis* Conte, 1980, GSUB C4035. Scale bar 10 mm.

(Ben Ferjani et al., 1990; Fig. 1). On this platform large-size and medium-size parahoplitids occur (*P. maximus*, *P.* cf. *nutfieldiensis*, *P. laticostatus*; occurrences 2 to 4 in Fig. 6).

At the base of the upper Aptian section, the nautiloid *Cymatoceras neckerianum* occurs with an undetermined cheloniceratid, *Parahoplites laticostatus* and *Parahoplites* cf. *nutfieldiensis* (Fig. 6). Specimens of *C. neckerianum* are accumulated in a prominent bioclastic to peloidal wacke- and packstone ledge in the lower part of the Serdj Formation. These limestones can be interpreted as mid ramp environment MFU2, as indicated by moderately to well sorted, angular to round components such as sporadic oyster shells, mud-peloids, and planktonic and small benthic foraminifers (Table 2). The occurrence of *C. neckerianum* can be attributed to a general change from hemipelagic to inner ramp deposits (Fig. 6).

Cephalopod occurrence 3 is stratigraphically the highest (Fig. 3) and is characterized by parahoplitids in a very variable carbonate facies, mainly of wacke- to grainstones, coral frame- and rudist bafflestones (Fig. 6, Table 2). The southwestern part of the Djebel Serdj cephalopod occurrence (occurrence 3a in Fig. 6) contains *P. maximus* and *P.* cf. *nutfieldiensis*, whereas *P.* cf. *nutfieldiensis*, *Riedelites* sp. and *Neohibolites* sp. have been recorded in the northeastern part (Fig. 6, occurrence 3b). The interval with cephalopod occurrence 3 is the termination of the Aptian shallowing-upwards sequence in this area. It can be attributed to the inner ramp, more precisely the lagoonal facies (Table 2 and Fig. 6).

5. Conclusions on facies and palaeobiogeography

Cretaceous cephalopod palaeobiogeography was largely affected by transgression-regression cyclicity, subsequent opening and closure of marine gateways and, perhaps to a lesser extent, by other factors such as temperature (Wiedmann, 1988; Rawson, 1993; Bengtson and Kakabadze, 1999). Generally, rising sea level eliminated geographical barriers and enabled wider distribution, whereas a high sea level hindered migration through a reduction in shallow-water connections and led to the development of specialized associations in isolated areas of shallow water (e.g. Wiedmann, 1988).

5.1. Lower Aptian

Ammonites, particularly biostratigraphic markers, are not only scarce in the lower Aptian in the OAE 1a interval in this area, but also throughout much of the Mediterranean Tethyan region (Landra et al., 2000; Bernaus et al., 2003). Exceptions to this occur in the Aralar Mountain area of the Basque-Cantabrian basin (García-Mondéjar et al., 2009), a rapidly subsiding region on the Biscay spreading margin. In the Lombardy basin in northern Italy, Landra et al. (2000) assumed an evolutionary stasis in the majority of the ammonite groups, especially the Deshayesitidae which are rare in distal facies (upper and middle shelf). The dearth of ammonites in this interval in Italy agrees with our sections on the central Tunisian Platform (e.g. Chaabani and Razgallah, 2006; Fig. 1). In the sections in northern Italy, deshayesitids are missing, but lytoceratids and heteromorphs occur (Landra et al., 2000). These are both groups with a supposed pelagic mode of life (Westermann, 1996). Our Tunisian fauna largely lacks these pelagic forms, apart from the association of fairly common *Pseudohaploceras* with the otherwise sparse lower Aptian ammonite fauna. This further supports our microfacies interpretation of these sediments as outer ramp deposits (Fig. 6). Aguado et al. (1999) found a similar assemblage in some levels of the OAE interval on a distal carbonate ramp in southeastern Spain. This peculiar fauna accompanied the nannoconid crisis in Spain and possibly reflects a lowered fertility in the deep photic zone, as indicated by lower numbers of nannoconid phytoplankton (Erba, 2004).

Our material is statistically not significant, but the quantitatively poor ammonite fauna is probably not related to low oxygen conditions, albeit ammonites are generally nectonic organisms that react sensitively to oxygenation (e.g. Batt, 1993). Coiled ammonites often occur in deposits which were clearly euxinic in nature with no bottom dwellers, and the absence of heteromorphs in those successions might indicate a low-oxygen bottom or near bottom living environment (e.g. Bréhérét, 1997). Although ammonites are rare throughout the Aptian in our area, there is a continuous record of benthic and planktonic foraminifera in the sections, even throughout the OAE 1a, indicating rather well-oxygenated conditions for the bottom water as well as for the higher part of the water column (Heldt et al., 2008). Additonally benthic macrofossils occur, such as brachiopods and echinoids, indicate well-oxygenated conditions for many horizons.

The lower Aptian distribution pattern shows affinities to the faunas of central and western Tethys as well as to the Atlantic province (*Riedelites* sp.). *Heminautilus sanctaecrucis* might indicate an affinity to the Boreal cephalopod fauna, a Tethys-Boreal faunal exchange would have been possible through the Anglo-Paris Basin and in the Proto-Atlantic northward (Rawson, 1992).

5.2. Upper Aptian

A late Aptian global warming episode is indicated by the migration of Tethyan faunas toward the Boreal realm, a positive $\delta^{13}C$ excursion and a negative $\delta^{18}O$ excursion in deep-sea carbonates, as well as an expanded northern limit of 'reef' growth in the Pacific realm (Takashima et al., 2007). This could explain why representatives of the ammonite family Parahoplitidae are characteristic elements of upper Aptian cephalopod faunas both in the Mediterranean area as well as in Boreal high latitudes (e.g. Kemper, 1982, 1995; Martínez et al., 1994; Delamette et al., 1997; Raisossadat, 2006). In particular, the dominance of *Parahoplites* in the upper Aptian Tunisian Platform sections represents a part of its conspicuously wide distribution in the late Aptian and is probably temperature controlled. *Parahoplites* is well-known from Central and Western Europe (e.g. Casey, 1965; Kemper, 1971) and the wider area around the Caspian Sea (e.g. Sinzow, 1909; Rouchadzé, 1938; Raisossadat, 2006), where this group is assumed to have originated (Kemper, 1982). Only a few accounts interpret their distribution in relation to palaeoenvironment and facies. Kemper and co-authors, especially, noted the characteristics of the genus *Parahoplites* in the Lower Saxony Basin in northern Germany (Gaida et al., 1978; Kemper, 1982, 1995). Large-size *Parahoplites* (particularly *P. nutfieldiensis*, *P. maximus*, *P. irregularis*) are restricted to a proximal position on the shelf, and to marginal clay- and siltstone facies, as observed in northern Germany, southern England as well as in the Caucasus mountains and Mangyshlak (Kemper, 1982, 1995). Kemper (1982) suggested that occurrences of these large-size ammonites in northern Germany were allochthonous rather than autochthonous, the ammonites having undergone post-mortem transport from deep to shallow water deposits induced by upwelling. He assumed a provenence in a deep depression off the coastline or on the slope of the Rhenish Massif High. Today there is, however, no evidence for such a habitat in northern Germany during the late Aptian and this is also missing for the English occurrences (Rawson, 1992). It is noteworthy that in the moderately deep shelf areas of northern Germany species of *Parahoplites* are small (*P. multicostatus*, *P. melchioris* and *P. schmidti*) and less frequent in occurrence compared to the marginal facies (Gaida et al., 1978; Kemper, 1982, 1995).

Our record of *Parahoplites* from a lagoonal environment in north central Tunisia (Fig. 6) fits in with those from marginal facies recorded in other parts of the world, discussed above. The palaeoenvironmental position is close to coral and rudist patches, but distant from deep water, indicating that shallow water settings were at least a significant part of the habitat of the large-size *Parahoplites*. The idea of Kemper (1982, 1995) of an allochthonous origin of large *Parahoplites* in northern Germany disagrees with our data from Tunisia, which suggest that this group of ammonites actually lived in shallow water habitats.

The interval with particularly large-sized ammonites of the genus *Parahoplites* (Fig. 3) is also characterized by a belemnite migration event from the Tethys into the Boreal region observed for northern Germany (Mutterlose, 1998; note divergent stratigraphy in Takashima et al., 2007). The otherwise strictly Tethyan *Duvalia grasiana* invaded for a second time during the Aptian for the largest part of the *Parahoplites nutfieldiensis* Zone; a temperature-control of this invasion has been suggested (Mutterlose, 1988). This belemnite event could be linked to the event-like occurrence of large-size *Parahoplites* recognizable in many areas of the world during that time interval. A shallow water preference of large-size *Parahoplites,* as suggested in the present paper, fits well to a high temperature environment.

The upper Aptian Tunisian cephalopod fauna shows palaeobiogeographic affinities with those of the west and central Tethys. Affinities with South America faunas are particularly indicated by *Riedelites* sp., resulting in a more cosmopolitan picture compared to that of the lower Aptian.

6. Systematic palaeontology

Specimens are preserved mainly as internal mould, a few specimens are crushed impressions in the laminated carbonates around OAE 1a. Belemnites are the rarest cephalopods in the study area. Since only one longitudinal section of *Neohibolites* sp. (GSUB C4049) was collected, belemnites are not included in the systematic part.

Order: Nautilida Agassiz, 1847
Family: Cymatoceratidae Spath, 1927

Genus: *Heminautilus* Spath, 1927

Type species. Nautilus saxbii Morris, 1848, by original designation.

Heminautilus sanctaecrucis Conte, 1980
Fig. 7M

1980 *Heminautilus sanctaecrucis* Conte, p. 138, pl. 1, figs. 1, 2, 4a.
?1985a *Heminautilus* cf. *sanctaecrucis* Conte, 1980; Conte, p. 30, pl. 1, fig. 6, text-fig. 4–1 to 4–5.

Material. One specimen, GSUB C4035, from the lower member of the Hamada Formation (lower Aptian), from slightly bituminous bioclastic to peloidal limestones (packstone), about 10 m below the base of the OAE 1a interval of locality 1 at Djebel Serdj (Table 1, Fig. 2).

Discussion. The tricarinate venter as well as the typical elongated lower branch of the lateral lobe with a flat angle assigns the specimen to *Heminautilus sanctaecrucis* and allows distinction from *Heminautilus lallierianus* (d'Orbigny, 1841), *Heminautilus saxbii* (Morris, 1848) and *Heminautilus tejeriensis* Martínez and Grauges, 2006 (see Martínez and Grauges, 2006). Conte (1980) gives the range of his species as middle Barremian to lowermost Aptian (base of Bedoulian). Conte (1985a) referred to *H*. cf. *sanctaecrucis* as lower Bedoulian, *Pseudocrioceras coquandi* Zone of the lower Aptian. The specimens from Djebel Serdj in Tunisia are the first record outside France.

Genus: *Cymatoceras* Spath, 1927

Type species. Nautilus pseudoelegans d'Orbigny, 1840, by original designation.

Cymatoceras neckerianum (Pictet, 1847)
Fig. 7D
1847 *Nautilus neckerianum* Pictet, p. 16, pl. 1, fig. 9
1980 *Cymatoceras neckerianum* (Pictet, 1847); Calzada and Viader, p. 163; text-fig. 1 (and synonymy)

1983 *Cymatoceras neckerianum* (Pictet, 1847); Weidich, Schwerd and Immel, p. 564, pl. 2, fig. 5 (and synonymy)

Material. Eight specimens, GSUB C4054 and C4055, from a slightly more prominent bioclastic to peloidal limestone ledge (wacke- and packstone) at locality 1 at Djebel Serdj (Table 1, Fig. 2). This corresponds to the lower part of the Serdj Formation of the upper Aptian, almost 120 m above its base.

Discussion. Our material does not add to the debate of Weidich et al. (1983) on the distinction between *C. neckerianum* and *C. neocomiensis* (d'Orbigny, 1840). Perviquière (1903, 1907) mentioned nautiloids belonging to *Cymatoceras neocomiensis* or *C. neckerianum* (of modern nomenclature) already from Djebel Serdj, but the present specimens are the first documented records from Tunisia. The geographical distribution of *C. neckerianum* includes England, Mozambique, France, Rumania, Spain, and Kazhakhstan (Calzada and Viader, 1980; Förster, 1975; Neagu, 1965; Sinzow, 1909; Weidich et al., 1983). The oldest record published yet is from the upper lower Aptian of Spain (Calzada and Viader, 1980), who considered that it ranged from the upper "Bedoulian" to the lower "Gargasian". Unequivocal upper Aptian records are known from England, Mozambique and France, but the species has been recorded as occurring in the lower Albian (Förster, 1975; Neagu, 1965; Weidich et al., 1983).

Subclass: Ammonoidea Zittel, 1884
Order: Ammonoitida Zittel, 1884
Suborder: Ammonitina Hyatt, 1889
Superfamily: Desmocerataceae Zittel, 1895
Family: Desmoceratidae Zittel, 1895
Subfamily: Puzosiinae Spath, 1922
Genus: *Pseudohaploceras* Hyatt, 1900

Type species. Ammonites liptoviensis Zeuschner, 1856, by original designation.

Pseudohaploceras ex gr. *liptoviense* (Zeuschner, 1856)
Fig. 7L
Synonymy. A synonymy is given by González-Arreola et al. (1996), see also Delanoy (1997).

Material. One specimen, GSUB C4034, from the lower member of the Hamada Formation, from slightly bituminous bioclastic to peloidal limestones (packstone), about 10 m below the base of the OAE 1a interval of locality 1 at Djebel Serdj (Table 1, Fig. 2).

Discussion. Since the venter is missing, it remains unclear if the venter of our material is widely rounded as in *P. liptoviense*. Memmi (1981) mentioned *P. liptoviense* from a Djebel Nehal in Tunisia. This species also occurs in Barremian to Aptian strata and is known from the Czech Republik, north-west Germany, Austria, Tunisia, Mexico (González-Arreola et al., 1996).

Pseudohaploceras matheroni (d'Orbigny, 1841)
Fig. 7E

Synonymy. A synonymy is given by Aly, 2006, see also García et al., 2007.

Material. One specimen, GSUB C4044, from bioclastic limestone (wacke- and packstone) in the upper OAE 1a interval in the lower part of the Hamada Formation of locality 1 at Djebel Serdj (Table 1, Fig. 2). Two specimens (GSUB C4045, C4046), possibly representing this species, in a laminated bioclastic wacke- and packstone from a slightly higher level in the upper OAE 1a interval at locality 2 at Djebel Serdj (Table 1 and Figs. 2 and 4D); there are further unregistered specimens from the same level.

Discussion. The straight constrictions, wide umbilicus and faint ribs of the same strength point to *P. matheroni* and clearly separate GSUB C4044 from *Pseudohaploceras douvillei* (Fallot, 1920), which has more falcoid constrictions and a narrower umbilicus, and from *Pseudohaploceras liptoviense*, with ribs of variable thickness and constrictions, as well as ribbing that is usually more strongly curved (compare pl. 4 in González-Arreola et al., 1996). Memmi (1981) mentioned *P. matheroni* from Djebel Nehal, Tunisia. Outside Tunisia *Pseudohaploceras matheroni* is known from upper Barremian to lower Aptian strata of France, Spain, Bulgaria, Georgia (Vašícek and Summesberger 2004), Poland (Marek et al., 1989), Romania (Avram et al., 1990), Azerbaidjan (Ali-Zade et al., 1988), and Sinai, Egypt (Hamama and Gabir, 2001; Aly, 2006).

Subfamily: Beudanticeratinae Breistroffer, 1953

Genus: *Zuercherella* Casey, 1954

Type species. Desmoceras zuercheri Jacob and Tobler, 1906, by original designation.

Zuercherella sp.
Fig. 7F, G and Fig. 9

Material. One specimen, GSUB C4040, from the upper Aptian Serdj Formation of locality 5 at Djebel Slata (Table 1, Fig. 4A).

Discussion. Of species of the genus *Zuercherella*, our specimen is most similar to *Z. etayosernai* Bogdanova and Hoedemaeker, 2004 from the Aptian of Colombia in lacking ribs as the one unique feature. The present medium-sized shell (whorl height of around 40 mm) is smooth except for shallow constrictions on the outer half of the flank. The adult suture line of our specimen is moderately complex (Fig. 9), with the A/U saddle about the same size and simplicity as the A lobe and the E/A of the same height as the A/U and similar to that of other species referred to this genus today (e.g. Rouchadzé, 1933, text-fig. 7; Renz, 1982, text-fig. 10d). However, the adult suture line of *Z. etayosernai* is unknown, as are also the differences from those of other species. Pervinquière (1907, p. 137, pl. 5, fig. 26a–c) referred to an ammonite from the Aptian–Albian boundary interval of Djebel Tella (Oust) in Tunisia as *Desmoceras* (*Uhligella*) cf. *Zürcheri* Jacob. This is a nucleus with a maximum diameter of 16 mm, no constrictions and a whorl section that is about as broad as high, with the greatest breadth around mid-flank. The genus is known from Europe, northern and eastern Africa, central Asia, Mexico, and Columbia and ranges from the upper Barremian to the upper Aptian (Wright, 1996; Bogdanova and Hoedemaeker, 2004).

Superfamily: Deshayesitaceae Stoyanow, 1949
Family: Deshayesitidae Stoyanow, 1949
Subfamily: Deshayesitinae Stoyanow, 1949

Genus *Deshayesites* Kasansky, 1914

Type species. Deshayesites deshayesi Leymerie in d'Orbigny, 1841, by original designation.

Deshayesites latilobatus (Sinzow, 1909)
Fig. 7H

1881 *Hoplites deshayesi* (Leymerie), Neumayr and Uhlig, pl. 45, figs. 1, 1a-b.
1997 *Deshayesites latilobatus* (Sinzow, 1909); Immel, Seyed-Emami and Afshar-Harb, p. 186; pl. 6, fig. 3 (and synonymy).
1999 *Deshayesites latilobatus* (Sinzow, 1909); Bogdanova and Prozorovsky, pl. 6, fig. a, b.
1999 *Deshayesites latilobatus* (Sinzow, 1909); Avram, p. 444, text-figs. 4d-f.
2007a *Deshayesites latilobatus* (Sinzow, 1909); Moreno, p. 60; pl. 1, figs. 1–3, 26; text-fig. 5.
2007b *Deshayesites latilobatus* (Sinzow, 1909); Moreno, text-fig. 4b.

Material. One specimen, GSUB C4038, from the lower member of the Hamada Formation at Djebel Serdj (locality 2, see Table 1, Figs. 2 and 4C), with brachiopod- and echinoid-rich marlstone-limestone couplets. These silty bioclastic wacke- and packstones are found about 20 m below the base of the OAE 1a interval.

Discussion. Although the present material is worn the ribbing is strong enough to be still discernible. This very large *Deshayesites* specimen (diameter more than 230 mm) fits well to the specimens of similar size figured from Germany (Neumayr and Uhlig, 1881) and England (Casey, 1980). It shares the feature of fairly distant primary ribs compared to the secondary ribs with *D. fittoni* Casey, 1961, which is a much smaller species (see Casey, 1964). *D. latilobatus* is so far known from Russia, southern England, northern Germany, and northeastern Iran. The present specimen is the first record from Tunisia; the biostratigraphy of this lower Aptian form is best known for England (*Deshayesites deshayesi* Zone, *Cheloniceras parinodum* Subzone, see Casey, 1980).

Deshayesites sp.
Fig. 7K

Material. One specimen, GSUB C4033, from the lower member of the Hamada Formation, from the slightly bituminous bioclastic to peloidal limestones (packstone) of the lower Aptian, about 10 m below the base of the OAE 1a interval of locality 1 at Djebel Serdj in north central Tunisia (Table 1, Fig. 2).

Discussion. Although the specimen is slightly worn, the blunt and low ribs are an original feature. This ribbing, in combination with the moderately evolute coiling and the origin of the secondary ribs comparatively high on the flank, does not fit to any species known from the late evolutionary history of this genus. It is reminiscent of species of the *deshayesi* Zone, such as *D. geniculatus* Casey. The evolute coiling and lack of ventrolateral tubercles rule out *Paradeshayesites* and *Dufrenoyia*. *Deshayesites* is a lower Aptian genus, for a discussion on the biostratigraphical significance see Section 3.2.

Genus *Dufrenoyia* Kilian and Reboul, 1915

Type species. Ammonites furcatus J. de C. Sowerby, in Fitton, 1836, by subsequent designation of Kilian and Reboul, 1915.

Dufrenoyia sp.
Fig. 7A

Material. One specimen, a cast of an external mould, GSUB C4031, from the lower member of the Hamada Formation, from the

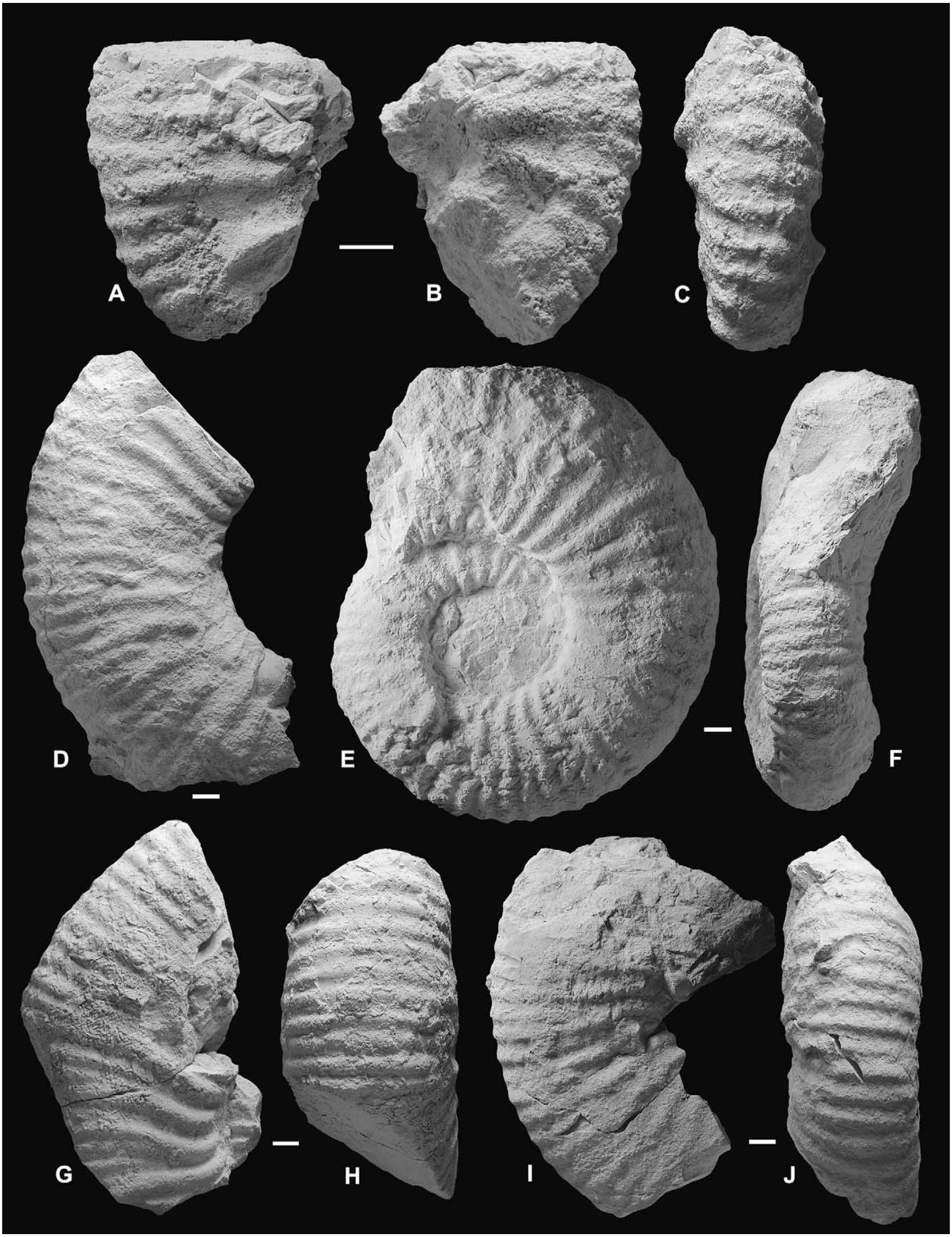

Fig. 8. Ammonites from the upper Aptian of northern Tunisia. A–C, *Riedelites* sp., GSUB C4051. D, *Parahoplites* cf. *nutfieldiensis* (J. Sowerby, 1815), GSUB C4048. E, F, *Parahoplites laticostatus* (Sinzow, 1908), GSUB C4047. G, H, *Parahoplites maximus* (Sinzow, 1908), GSUB C4042. I, J, *Parahoplites* cf. *nutfieldiensis* (J. Sowerby, 1815), GSUB C4053. Scale bar 10 mm.

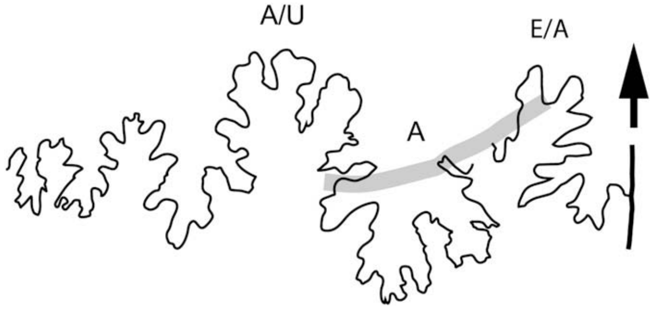

Fig. 9. Suture of a *Zuercherella* sp. at wh 48 mm. The grey shaded area indicates the position of constriction on the specimen. GSUB C4040, figured as Fig. 7F, G.

slightly bituminous bioclastic to peloidal limestone (packstone) of the lower Aptian, about 10 m below the base of the OAE 1a interval at locality 1 at Djebel Serdj (Table 1, Fig. 2).

Discussion. The combination of distinct ventrolateral tubercles, ribbing pattern and coiling indicates *Dufrenoyia*. Similar *Dufrenoyia* with ribs clearly broader than the interspaces that flatten and widen to the venter are found in *Dufrenoyia durangensis* Humphrey, 1949; the holotype in particular also shows a similar fairly evolute coiling. This species is described from Mexico where it is limited to the *Dufrenoyia justinae* Zone, which can be correlated with the European *Dufrenoyia furcata* Zone (Barrágan-Manzo and Méndez-Franco, 2005). For a discussion on the stratigraphical meaning of *Dufrenoyia* sp. in our section, a genus that is believed to characterize the upper lower Aptian (e.g. Bogdanova and Michailova, 2004; Ropolo et al., 2006), see Section 3.2.

Subfamily: Acanthohoplitinae Stoyanow, 1949

Genus *Riedelites* Etayo-Serna, 1979

Type species. Riedelites esthersernae Etayo-Serna, 1979, by original designation.

Riedelites sp.
Fig. 8A–C

Material. One specimen, GSUB C4051, from a bioclastic peloidal limestone (wacke- and packstone) in the upper Serdj Formation at its type locality (locality 1, Table 1 and Fig. 2).

Discussion. The distinct ornament of prominent and distant ribs crossing the venter and particularly the large smooth areas on the inner flank between primary ribs, recall the type of *Parahoplites inconstans* (Riedel, 1938, pl. 6, figs. 8–10), a member of the genus *Riedelites* (Sharikadze et al. 2004). Our specimen also agrees in its secondaries, which mostly do not arise before the upper third of the flank, but it is too fragmentary for a specific assignment. We agree with Sharikadze et al. (2004) that the addition of umbilical tubercle-like thickenings to the original diagnosis by Etayo-Serna (1979) is necessary. These are present in GSUB C4051, but there can be more than just one intercalated rib between the primary ribs, as can be seen in the type of *R. inconstans*. Previously, *Riedelites* has been described from Colombia only, suggesting an early late Aptian age (Sharikadze et al., 2004).

Subfamily: Parahoplitinae Spath, 1922

Genus *Parahoplites* Anthula, 1899

Type species. Parahoplites melchioris Anthula, 1899, by original designation.

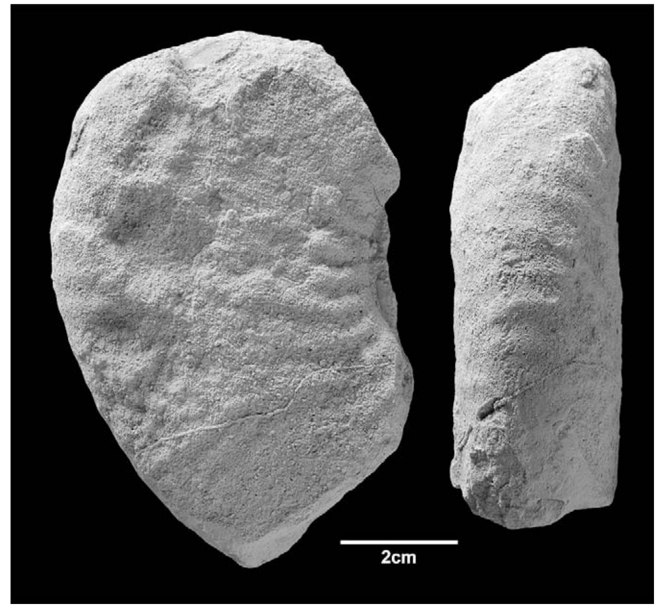

Fig. 10. *Parahoplites* sp. 1, GSUB C4082, from the upper Aptian of Djebel Slata, northern Tunisia.

Parahoplites maximus (Sinzow, 1908)
Fig. 8G, H

A synonymy is given by Raisossadat (2006).

Material. One specimen, GSUB C4042, from an upper Aptian bioclastic to peloidal limestone (wacke- and packstone) of the upper Serdj Formation of locality 4 at Djebel Serdj (Table 1, Fig. 2).

Discussion. The whorl section in GSUB C4042 corresponds to that of the lectotype (Sinzow, 1908) in that it is oval, with slightly convex flanks, and the greatest breadth on the lower third of the flank, close to the umbilical rim (WB/WH about 0.76), and with a venter that is rounded and moderately broad. The lectotype, as well as the specimens from England and northern Germany (Kemper, 1982), appear to have slightly less flexuous ribs than the present specimen. The species is known from Caucasus (Daghestan), Mangyshlak (Kazakhstan), England, Germany, Iran (Raisossadat, 2006), Colombia (Sharikadze et al., 2004), and herein from Tunisia. It is also mentioned from Spain (Martínez et al., 1994). In southern England it occurs in the upper Aptian *P. nutfieldiensis* Zone (*Tropaeum subarcticum* Subzone) according to Casey (1965). According to Kemper (1982) it occurs in the upper Gargasian, *P. nutfieldiensis* Zone of north-west Germany. In Colombia its stratigraphic occurrence is given as middle Aptian.

Parahoplites laticostatus (Sinzow, 1908)
Fig. 8E, F

1908 Acanthohoplites laticostatus Sinzow, p. 482; pl. 5, figs. 9–13.
1938 Parahoplitoides cerrosensis Anderson, p. 168; pl. 33, fig. 1.
1953 Acanthoplites laticostatus Sinzow, 1908; Glazunova, p. 41; pl. 7, figs. 2a-c; text-fig. 16.

Material. One specimen, GSUB C4047, from nodular bioclastic to peloidal limestones (wacke- and packstone) in the lowermost Serdj Formation of the upper Aptian, above the prominent cliff that marks the base the Serdj Formation at Djebel Serdj (compare Fig. 3; locality 3, see Table 1 and Fig. 2).

Discussion. In its sinuous, fairly distant and coarse ribs bending forward at about mid-flank, the Tunisian specimen corresponds well with the material figured by Sinzow (1908). *Parahoplites laticostatus* (Sinzow, 1908) from the Caucasus Mountains is most similar to *Parahoplitoides cerrosensis* of Anderson, 1938, from California, as already noted by Anderson (1938). *Parahoplitoides* is regarded as a synonym of *Deshayesites* by Wright (1996), but *Parahoplitoides cerrosensis* clearly belongs to *Parahoplites*. The minor differences between *P. laticostatus* and *P. cerrosensis*, namely a more rounded whorl section and slightly more sinuous ribs in the former, are considered as intraspecific variation herein. In California, *P. laticostatus* occurs approximately in the middle of the Horsetown Group, *Argonaut* Zone of Anderson (1938), corresponding to the upper Aptian (“Lower Gargasian”, Anderson, 1938: table 2). It also occurs in the Caucasus, Mangyshlak (Kazakhstan), and California (Sinzow, 1908; Glazunova, 1953; Anderson, 1938).

Parahoplites cf. *nutfieldiensis* (J. Sowerby, 1815)
Fig. 7I, J, 10D, I, J

A synonymy is given by Sharikadze et al. (2004).

Material. Five specimens, GSUB C4041, C4043, C4048, C4053, C4081, from the lower part of the Serdj Formation, from bioclastic to peloidal limestones (wacke- and packstone) about 120 section metres above the base of this formation, and from a silty peloidal limestones interval (wacke- to packstone) with common bivalves and gastropods at the top of our section (Fig. 2). These records are from localities 1 and 2 (Table 1, Figs. 2 and 4B). It is also recorded from locality 5 at Djebel Slata (Tab. 1 and Figs. 2 and 4A).

Discussion. *Parahoplites nutfieldiensis* is characterized by a dense and fairly strong ribbing, including the primary ribs, and a high oval whorl section, as recognizable in most of the present specimens. Our specimens from Djebel Slata show an oval whorl section (GSUB C4041 and C4081), recalling the only slightly compressed whorl section of the otherwise very similar *Parahoplites melchioris* Anthula, 1899 (Anthula, 1899, pl. 8, fig. 5b). One of the specimens from Djebel Serdj (GSUB C4043) shows a tendency to smoothness after about 200 mm diameter and indicates a fairly evolute coiling. Although the lectotype of *P. nutfieldiensis* is also rather evolute (Casey, 1965, pl. 67, fig. 5a), a more mature syntype of Sowerby (1815; Casey, 1965, pl. 68, fig. 2) tends to be more involute than GSUB C4043. The type material and other specimens of *P. melchioris* (Anthula, 1899, pl. 8, figs. 4a, 5a; Sinzow, 1908, pl. 2, fig. 1) are more evolute than *P. nutfieldiensis*; however, large-size adults of *P. melchioris* are unknown. *Parahoplites* is an upper Aptian genus (Wright, 1996); *P. nutfieldiensis* occurs in the eponymous zone of the upper Aptian in southern England (e.g. J. Sowerby, 1815), northern Germany (Kemper, 1971, 1976), France (Conte, 1985b), and possibly Chile (Perez et al., 1990) and Colombia (Sharikadze et al., 2004).

Parahoplites sp. 1
Fig. 10

cf. 1908 *Parahoplites campichei* Pictet and Renevier, 1908; Sinzow, p. 460; pl. 1, figs. 5, 6 only.
cf. 1967 *Parahoplites campichei* Pictet and Renevier, 1908; Wachendorf, Bettenstaedt and Ernst, p. 289; pl. 36, fig. 3.

Material. One specimen, GSUB C4082, from the upper Aptian Serdj Formation of locality 5 at Djebel Slata (Table 1, Fig. 4A).

Discussion. The weak ribbing is an original feature of GSUB C4082, as indicated by the preservation of details of the suture, the venter even shows the frilling of sutural elements. The specimen from Tunisia shares a unique combination of features with specimens described from the upper Aptian of Kazakhstan by Sinzow (1908, pl. 1, figs. 5, 6 only) and from Mozambique by Wachendorf et al. (1967 pl. 36, fig. 3), both referred to *Parahoplites campichei*. These features in common comprise dense, low ribs, strong umbilical bullae, and an unusually strongly compressed whorl section with a small, arched venter. The Tunisian specimen differs from those from Kazakhstan and Mozambique in a somewhat denser ribbing. There are a few other similar ammonites described, including *P. vectensis* Casey (Casey, 1964, p. 413), but these are similar only in having a compressed whorl section as well as low ribs.

Suborder: Ancyloceratina Wiedmann, 1966
Superfamily: Ancylocerataceae Gill, 1871
Family: Ancyloceratidae Gill, 1871

Genus *Toxoceratoides* Spath, 1924

Type species. Toxoceratoides royerianum d’Orbigny, 1842, by original designation.

Toxoceratoides sp.
Fig. 7B

Material. One specimen, GSUB C4032, from bioclastic limestones (wacke- and packstone) in the upper OAE 1a interval in the lower part of the Hamada Formation of locality 1 at Djebel Serdj; a specimen referred to as ?*Toxoceratoides* is from the same locality (Table 1, Fig. 2).

Discussion. The inital part of the left flank of fragment GSUB C4032 barely shows a damaged umbilical tubercle. That this is part of the typical double row of tubercles in *Toxoceratoides* is clear from the external mould of the inner whorls, which shows this feature. GSUB C4037 presumably belongs to the same taxon, but since it is a body chamber it does not show the dignostic double row of tubercles. *Toxoceratoides* is of widespread geographical occurrence in the upper Barremian–upper lower Aptian of Europe, western Asia, eastern Africa, Zululand, California, Patagonia, and Antarctica (Wright, 1996).

Family: Anisoceratidae Hyatt, 1900

Genus *Ancyloceras* d’Orbigny, 1842
Type species. Ancyloceras matheronianum d’Orbigny, 1842, p. 30, fig. 5, by subsequent designation of Haug, 1889, p. 212.

? *Ancyloceras*
Fig. 7C

Material. One specimen, GSUB C4036, from the lower member of the Hamada Formation, from bituminous bioclastic limestones (wacke- and packstone) of the lower OAE 1a interval of the lower Aptian of locality 1 at Djebel Serdj (Table 1, Fig. 2).

Discussion. GSUB C4036 shows a very irregular pattern of straight ribs that vary between very strong and very weak, a feature reminiscent of the initial spiral of lower Aptian *Ancyloceras* (e.g. Förster and Weier, 1983, pl. 1). *Ancyloceras* is widely distributed throughout Europe, Georgia, Azerbaijan, Russia, Turkmenistan, south-east Africa, Japan, California, Colombia (Kakabadze and Hoedemaeker, 2004; Wright, 1996), Turkey (Türkünal, 1962), and Venezuela (Renz, 1982) and occurs from the lower Barremian to the lower Aptian.

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