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Ammonite stratigraphy and the belemnite genus *Hibolithes* in the higher Serdj Formation (Aptian–Albian boundary interval) in north central Tunisia

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Abstract: The identifications of some ammonite findings from the Aptian–Albian boundary interval of the type locality of the Serdj Formation at Djebel Serdj in north central Tunisia are revised and their biostratigraphic value is discussed. From this stratigraphic section, a single belemnite finding is described that has been previously identified as *Neohibolites*. A newly prepared thin section of the guard shows the internal structure of rostrum and phragmoconus, including some septa, and allows an assignment as *Hibolithes* cf. *obtusirostris* (Pavlow in Pavlow & Lamplugh 1891). It represents the youngest record of this genus from the Tethys where the youngest record of *Hibolithes* was hitherto early Barremian. The new evidence is also of palaeobiogeographic interest, since *Hibolithes* is originally a genus of the Tethys, which migrated early into the Boreal and from there later on again into the Tethys.

Kurzfassung: Die Bestimmung einiger Ammonitenfunde aus dem Grenzbereich Aptium/Albium der Typlokalität für die Serdj-Formation am Djebel Serdj in nord-zentral Tunesien werden revidiert und ihre biostratigraphische Aussage diskutiert. Aus diesem stratigraphischen Abschnitt wird ein bislang als *Neohibolites* bestimmter einzelner Belemnitenfund beschrieben. Ein neu angefertigter Dünnschliff zeigt den internen Aufbau von Rostrum und Phragmokon, inklusive einiger Septen, und ermöglicht die Bestimmung als *Hibolithes* cf. *obtusirostris* (Pavlow in Pavlow & Lamplugh 1891). Der Fund ist der jüngste dieser Gattung aus der Tethys, aus der *Hibolithes* bislang nur bis in das frühe Barremium bekannt war. Der neue Nachweis ist auch paläobiogeographisch interessant, da *Hibolithes* ursprünglich eine Gattung der Tethys ist, die früh in das Boreale migrierte und später zurück in die Tethys einwanderte.

Keywords: biostratigraphy, Lower Cretaceous, Aptian–Albian boundary interval, ammonites, belemnites, *Hibolithes*, Tunisia

Schlüsselwörter: Biostratigraphie, Unterkreide, Aptium/Albium-Grenzbereich, Ammoniten, Belemniten, *Hibolithes*, Tunesien

1. Introduction

During the last fifteen years, Aptian (Lower Cretaceous) carbonate deposits of the Serdj Formation at its type locality Djebel Serdj, north central Tunisia (Figs. 1 and 2) were studied by Tunisian, French and German geologists in detail with regard to lithology, lithostratigraphy, biostratigraphy (mainly ammonites), chemostratigraphy (including isotopic stratigraphy), and microfacies (Heldt et al. 2008, 2010; Lehmann

et al. 2009; Ben Chaabane et al. 2019). These data were used for international correlation of these Tunisian successions (Weiß 2012; Núñez-Useche et al. 2014) and allow to reconstruct the palaeoenvironmental evolution of a south-Tethyan carbonate platform margin and to investigate its response to global climate change. The unusually 600 metres thick deposits consist of limestones, marlstones and siltstones, suggesting an accumulation in mid- and inner-ramp positions. The hermatypic platform biota in these deposits induce a

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Fig. 1: Main study area at Djebel Serdj as part of the Serdj-Bargou anticline in north central Tunisia, with villages and the sampling locality of the described ammonites and belemnites.

stable oligotrophic water regime. Stable isotopes show a mid-late Aptian warming phase corresponding to siliciclastic limestones and siltstones, resulting rather from higher precipitation rates and intensified weathering, presumably of the southeasterly situated Kairouan Island and the southerly Kasserine Island, than from a drowning episode (Heldt et al. 2010).

2. Geologic setting

During Cretaceous times, Tunisia formed part of the North-African epicontinental border, and the southern part of the Tethys, respectively. Trans- and regression cycles can be combined in the Lower Cretaceous into four megasequences (Burlot et al. 1983: 263), the third of them comprises the time interval from the late early Aptian (“Gargasian”) to the middle Albian. Dominated by the Kairouan and Kasserine islands in central Tunisia, this time interval is characterised by the following facies distribution (comp. Castany 1953: Pl. III, VI and Burlot et al. 1983: Fig. 1): (1) sandstones and shallow marine carbonates as well as dolomites alternating with evaporites are found in south central and southern Atlas Tunisia (Orbata and Kebar formations; Trabelsi 2012) and the Chott regions (Berrani Formation; Hfaiedh et al. 2013); (2) extensive shallow marine carbonate deposits interfinger-

ing with shales and sandstones (Hamada, Serdj, Hameima and Fahdene formations; Chihaoui et al. 2010; Latil 2011; Ben Fadhel et al. 2014), and lagoonal facies with coral-rudist reefal buildings dominantly in the salt dome zone (Serdj Formation; Lehmann et al. 2009; Heldt et al. 2010; Ben Chaabane et al. 2019) of northern Atlas Tunisia are recorded from 36° N (including the Serdj-Guitoun-Bargou ranges; Fig. 1) to about 34.15° N (Zaghib-Turki 2003); (3) open marine/pelagic organic-rich shales intercalated with thin limestones containing planktic faunas (Fahdene and Bahloul formations; Soua 2016) are represented in northern Tunisia.

The Barremian Hamada Formation, as well as the Aptian–lower Albian Serdj Formation (informally subdivided as Lower Serdj and Upper Serdj by Ben Chaabane et al. 2019) crop out as a well exposed succession south of the town of Sidi Hamada (GPS Post Office: 35.96065°N, 9.54625°E) in the Serdj Mountain, which is the type locality for both formations (Fig. 2).

3. Ammonites and biostratigraphy

The Aptian ammonite fauna in north central Tunisia contains deshaysitids, pseudohaploceratids and hypacanthoplites, and is, therefore, typical for the shelf environmental regions of the Tethys. This hemipelagic fauna shows affinities to faunas from the western and central Tethys as well as the Boreal region that was indistinctly defined compared to other stages of the Cretaceous (Lehmann et al. 2015). Ammonites with a supposed pelagic mode of life that occur in more distal Tethyan environments, such as lytoceratids, phylloceratids and heteromorphs, are a minor component, if present at all. In the late Aptian, large acanthohoplites are found in inner ramp and lagoonal facies. Ammonites of this group are rare in the uppermost strata of Djebel Serdj (Heldt et al. 2010: 710); their poor preservation and importance in respect to the Aptian–Albian boundary interval are reasons why some identification were quite often debated. Latil (2011) and later partly Ben Chaabane et al. (2019, with Latil as a co-author) re-assigned some of the ammonites described originally by Lehmann et al. (2009) with partly contradictory results (Table 1). Furthermore, ammonite taxonomy is also difficult since parahoplite ammonites (sensu lato) generally tend to be homoeomorphic and morphological differences are slight compared to other Cretaceous stages. Consequently, the identifications are briefly discussed in the following for the biostratigraphical dating of the belemnite specimen. The abbreviation GSUB refers to Geosciences Collection of the University of Bremen, Germany, and indicates the repository of specimens.

3.1 Discussion of *Mellegueiceras*

Mellegueiceras Latil (2011) is a hypacanthohoplite ammonite that is an allegedly endemic genus from Tunisia that was recently also reported from Morocco (Luber et al. 2017, 2019). Since this genus is critical for the stratigraphical in-

Fig. 2: Central part of Djebel Serdj, with the section trail from the town of Sidi Hamada to the top of the mountain range with the finding location of the belemnite (red point). The red line marks the Aptian–Albian boundary interval.

terpretation of the Aptian–Albian boundary interval in Tunisia, it is discussed here. *Mellegueiceras* was separated from *Hypacanthoplites* Spath, 1923 by “its irregular ribbing and the lack of tuberculation” according to Latil (2011: 371). Klein & Bogdanova (2013: 208) question if *Mellegueiceras* should be regarded as a separate genus without discussing this issue any further.

The type species of *Mellegueiceras*, *M. ouenzaensis*, shows a somewhat irregular ribbing on the inner whorls only and this feature is not more irregularly developed compared to some *Hypacanthoplites* species referred to as *Hypacanthoplites*. This is true for *Hypacanthoplites elegans* for example, with its neotype that is showing an irregularity between the bullae and a high variability in the number and height of onset of secondary ribs in between primary ribs. However, *H. elegans* is much more finely ornamented compared to the type species of *Hypacanthoplites*, *Hypacanthoplites milletianus* (d’Orbigny, 1841), and it remains unclear if species showing stronger ribbing or even strongly tuberculated inner whorls like *H. plesiotypicus* (Fritel 1906) can be reasonably placed in the same genus. Therefore, it possibly makes sense to accommodate *H. elegans* in *Mellegueiceras*.

The thickened ribs at the umbilical margin of the inner whorls in *Mellegueiceras* are very close to be called bullae and this is not clearly separating it from *Hypacanthoplites*. *M. ouenzaensis* can be separated from *Hypacanthoplites* though, by the inner whorls that are well-rounded and thus contrast the angular cross section seen in at least many well-known European species of *Hypacanthoplites*. Other species of *Mellegueiceras*, *M. hameimaense* and *M. minutum* (both first described by Latil 2011), also show angular inner whorls

and thus these features do not serve to distinguish both genera properly. “*Mellegueiceras*” *chihaouiae* appears to be quite different in cross section as well as ornament and rather resembles *Hypacanthoplites* than the type species of *Mellegueiceras* and the other species attributed to this genus. As an indication of uncertainty, we added quotation marks to the genus name herein.

A separation of *Mellegueiceras* from *Parahoplites* Anthula, 1900 is based on “ribs that are never bent forward on the venter, persistent irregular ribbing and wider umbilicus” following Latil (2011: 371). The first feature mentioned is not a criterion for exclusion and thus less advantageous for a distinction. It is believed to be a key feature to distinguish *Parahoplites* from acanthohoplids, but maybe this feature that is based on *Parahoplites melchioris* Anthula, 1900, is not strong enough to define *Parahoplites* in the current sense. Regarding to the second feature several *Parahoplites* species show an irregular ribbing (e.g. *Parahoplites daveyi* Casey, 1965 and *Parahoplites irregularis* Casey, 1965) and thus the irregularity of ribbing is not critical either. At last, a tendency to a more evolute coiling is developing within the *Parahoplites*, *Acanthohoplites*, *Hypacanthoplites* lineages during the late Aptian–early Albian and thus it does not constitute a unique feature as well.

This discussion shows that the definition of *Mellegueiceras*, *Hypacanthoplites* and *Parahoplites* is currently unsatisfying and that a new genus concept is needed. Furthermore, the affiliation of some species currently attributed to *Hypacanthoplites* and *Parahoplites* needs to be reviewed.

In the following the revised identifications of ammonites from the uppermost section at Djebel Serdj (section metres 810 to 835) given in Table 1 are discussed.

Table 1: Ammonite identifications from the uppermost interval bearing ammonites at the Djebel Serdj section, above section meter 812 of the composite section by Lehmann et al. (2009; Fig. 3). Note that Heldt et al. (2010) mentioned *Neodeshayesites nicholsoni* (this was erroneously published since it is based on an outdated field identification of GSUB C4051), *Parahoplites maximus* (based on GSUB C4042, following Lehmann et al. 2009) and *P. cf. nufieldiensis* (general citation, not referring to any inventory numbers).

Section meter [m] (Lehmann et al. 2009; Fig. 3)	Inventory number	Identification by Lehmann et al. (2009) [figure number therein and commentary]	Identification by Latil (2011), [commentary]	Identification by Klein & Bogdanova (2013), [commentary]	Identification by Ben Chaabane et al. (2019), [commentary]	Revised identification present paper
834	C4051	<i>Riedelites</i> sp. [Fig. 8A–C]	Possibly <i>Mellegueiceras chihauiaie</i> [p. 371, 372]	Possibly <i>Mellegueiceras chihauiaie</i> [p. 209]	<i>Mellegueiceras chihauiaie</i> [Fig. 5 and 12]	<i>Acanthohoplites?</i> sp.
825	C4053	<i>Parahoplites</i> cf. <i>nufieldiensis</i> [Fig. 8I, J]	not revised [p. 371 and 372: only C4043 is “tentatively referred to” <i>Mellegueiceras chihauiaie</i> among the ammonites that were originally identified as <i>Parahoplites</i> cf. <i>nufieldiensis</i> ; C4053 is from the lower Lower Serdj Formation: 420 m]	<i>Parahoplites nufieldiensis</i> [p. 219, erroneously not referred to as Fig. 8I, J, but 6I, J]	<i>Mellegueiceras chihauiaie</i> [Fig. 5 and 12]	“ <i>Mellegueiceras?</i> ” cf. <i>chihauiaie</i>
815	C4042	<i>Parahoplites maximus</i> [Fig. 8G, H]	<i>Mellegueiceras chihauiaie</i> [p. 371, 372]	<i>Mellegueiceras chihauiaie</i> [p. 209]	<i>Mellegueiceras chihauiaie</i> [Fig. 5 and 12]	“ <i>Mellegueiceras?</i> ” sp.
812	C4048	<i>Parahoplites</i> cf. <i>nufieldiensis</i> [Fig. 8D]	not revised [like for C4053, see above]	<i>Parahoplites nufieldiensis</i> [p. 219, erroneously not referred to as Fig. 8D, but 6D]	<i>Mellegueiceras chihauiaie</i> [Fig. 5 and 12]	“ <i>Mellegueiceras?</i> ” cf. <i>chihauiaie</i>

3.2 Section metre 812: GSUB C4048

Originally: *Parahoplites* cf. *nutfieldiensis*, **revised:** “*Mellegueiceras*”? cf. *chihaouiae* (Fig. 3H)

Latil (2011), Klein & Bogdanova (2013) and Ben Chabaane et al. (2019) suggested to attribute some of the specimens figured as *P.* cf. *nutfieldiensis* by Lehmann et al. (2009) to “*M.*” *chihaouiae*. After one of us (JL) was studying the type specimens of *P. nutfieldiensis* at the Natural History Museum (Lehmann et al. 2019: Supplementary Data Appendix B) we agree that the Tunisian specimen are not conspecific with *P. nutfieldiensis*. Based on the fairly open coiling and according to the ornament, it appears likely that they represent “*Mellegueiceras*”. GSUB C4048 (Lehmann et al. 2009: Fig. 8D) as well as C4053 (Figs. 3D, E; Lehmann et al. 2009: Fig. 8I, J) are very poorly preserved and thus it is not convenient to determine them on the species level. The same is true for C4043 (Figs. 3I, J; Lehmann et al. 2009: Fig. 7I, J) from a lower level in the section.

The specimen C4048 shows simple, strong ribs and secondary ribs that do not arise before mid-flank and that are as strong as the primary ribs on the inner half of the flank. There is usually one secondary rib in between two primary ribs. This rib pattern contrasts the type material of *P. nutfieldiensis* from the Lower Greensand Group, but some new material at hand (Mark Bayliss collection, to be transferred to the Natural History Museum, London) from the same strata demonstrates a considerable variability. The coiling of C4048 appears to be more evolute than in *P. nutfieldiensis* and generally in *Parahoplites* and agrees with the re-identification given above.

A stratigraphic position as lowermost Albian and not upper Aptian (Latil 2011) is confirmed by data from Morocco where “*Mellegueiceras*” *chihaouiae* is associated with *Douvilleiceras* (Luber et al. 2017, 2019).

3.3 Section metre 815: GSUB C4042

Originally: *Parahoplites* cf. *maximus*, **revised:** “*Mellegueiceras*”? sp. (Figs. 3F, G)

This specimen is less distorted compared to the other specimens revised here. We orientate this fragment different from Lehmann et al. (2009) and the whorl section appears to be broadest around mid-flank and not near the umbilical rim. However, in our re-identification we disagree with the interpretation of Latil (2011), Ben Chabaane et al. (2019) and Klein & Bogdanova (2013) that GSUB C4042 represents “*Mellegueiceras*” *chihaouiae*. It is different from the “*M.*” *chihaouiae* macrococh of a similar size (Latil 2011: Pl. X and XI, 4), by a ribbing on the inner flank with ribs that are more distant and that are forming bullae on the very broad ribs. Near the umbilical edge the ribbing is generally reflecting backwards in GSUB C4042, leading to a rib style that is flexuous, as in the type of *P. maximus*, but even more distinct than in some of the specimens figured by Sinzow (1908: Pl. I, Fig. 3). In cross section, GSUB C4042 is much broader and less evenly rounded than “*M.*” *chihaouiae*. The particularly

strong umbilical bullae that are bending forward on the lowermost flank, and then very strongly forwards again, is also present in acanthohoplites. A similar ribbing pattern can be seen in some latest Aptian acanthohoplites, e.g. in mid-size specimen figured by Sinzow (1908: Pl. VIII, Figs. 8 and 11). They are referred to as *Nolaniceras* spp. by Klein & Bogdanova (2013), a view that is not followed by Bulot et al. (2014): according to these authors, *Nolaniceras* is strictly defined to the holotype of the type species. It is also true for the paratype of *Acanthohoplites aschiltaensis* Anthula (1900: Pl. XI, Fig. 1), but also in ?*Parahoplites tenuicostatus* (Sinzow 1908: Pl. VII, Fig. 2). The exact stratigraphic assignment of the latter species is unclear and thus it is unknown if this feature is of stratigraphic relevance (compare Szives et al. 2007: 72).

3.4 Section metre 825: GSUB C4053

Originally: *Parahoplites* cf. *nutfieldiensis*, **revised:** “*Mellegueiceras*”? cf. *chihaouiae* (Figs. 3D, E)

The ribs of specimen C4053 are all of equal strength, more delicate than in C4042 (Figs. 3F, G) described above and also finer than in C4043 (all referred to as *P.* cf. *nutfieldiensis* by Lehmann et al. 2009, but with C4053 from a much lower stratigraphic level). C4053 agrees with the other specimens identified earlier as *P.* cf. *nutfieldiensis* in showing one secondary rib in between two primary ribs only. The poor preservation permits only to assume that the secondary ribs arise probably as low as at mid-flank and that the cross segment is very well-rounded probably shows the greatest whorl breadth around mid-flank.

Except for the finer ribbing, the features of C4053 also distinguish it from the type material of *P. nutfieldiensis* (compare 3.2). We disagree with Klein & Bogdanova (2013) who assigned this specimen to *P. nutfieldiensis* (omitting the “cf.” by Lehmann et al. 2009), but agree with the re-identification of Latil (2011).

3.5 Section metre 834: GSUB C4051

Originally: *Riedelites* sp., **revised:** *Acanthohoplites*? sp. (Figs. 3A–C)

The worn and distorted fragment was originally assigned to *Riedelites* because it recalls the type of *Parahoplites inconstans* (Riedel 1938: Pl. 6, Figs. 8–10; now *Riedelites inconstans*; see Klein & Bogdanova 2013: 151), by its prominent and distant ribs and particularly “the large smooth areas on the inner flank between primary ribs”, and the secondary ribs that do not arise before a high position on the flank (Lehmann et al. 2009: 907). Despite these similarities with the type of Riedel (1938), as well as the other material referred to *Riedelites* (e.g. Etayo-Serna 1979; Sharikadze et al. 2004), we revise the initial identification here. The Tunisian specimen shows extremely strong umbilical bullae and even a more robust ribbing.

A similar morphology compared to GSUB C 4051 shows also *Parahoplites robustus* Sinzow, 1908, a species that is of

Fig. 3: Ammonite records from Djebel Serdj, northern Tunisia. (A–C) *Acanthohoplites*? sp., GSUB C4051. (D, E) “*Mellegueiceras*”? sp., GSUB C4053. (F, G) “*Mellegueiceras*”? sp., GSUB C4042. (H) “*Mellegueiceras*”? cf. *chihaouiae*, GSUB C4048. (I, J) “*Mellegueiceras*”? sp., GSUB C4043. Scale bar 10 mm.

unknown detailed stratigraphic occurrence, but the bullae are even more distant in the Tunisian specimen. In this aspect, it resembles *Mellegueiceras hameimaense* of Latil (2011) in which the bullae appear to be closer to each other. GSUB C 4051 is not conspecific with the material attributed to “*M.*” *chihaouiae* Latil (2011) as suggested by Latil (2011: 371, 372) as well as by Klein & Bogdanova (2013), because of its pronounced and particularly very distant umbilical bullae without any ribs in between – an ornament unlike that of juvenile representatives of “*M.*” *chihaouiae*. We place GSUB C 4051 into acanthohoplites because it is similar in showing distant umbilical bullae although representatives of these usually contrasts by secondary ribs that are also present in between the umbilical bullae and are mostly not smooth in between as seen the GSUB C4051.

3.6 Discussion of the geological age

Based on the revised ammonite record from section metres 812 to 834 we interpret that the dating of this part of the Djebel Serdj section by Lehmann et al. (2009) is probably slightly too old.

As already stated by Szives et al. (2007) the “stratigraphical distribution of *Parahoplites*, and also the co-occurrence with *Acanthohoplites* and *Hypacanthoplites* is problematic” and Owen (1996) states that the upper limit of *Parahoplites* falls together with the occurrence of *Hypacanthoplites* in the Late Aptian *Nolaniceras nolani* Zone that is debated though (Casey 1996). Szives et al. (2007) suggested that *Acanthohoplites*, *Hypacanthoplites* and *Parahoplites* are partly co-occurring in northern Iran interpreting Raisossadat (2006). This interpretation might be partly based on general statements of ammonite occurrence but no detailed ranges are given by Raisossadat (2006). Probably only *Acanthohoplites* and *Parahoplites* co-occur (cf. Raisossadat 2006: Fig. 2). The results of the most recent paper on this topic also did not find evidence for a co-occurrence of *Acanthohoplites*, *Hypacanthoplites* and *Parahoplites* (Lehmann et al. 2019). At least it is clear that acanthohoplites overlap with *Hypacanthoplites* and *Parahoplites* based on the record in Iran (Lehmann et al. 2019).

Out of this discussion the taxonomic re-interpretations of the individual ammonite record from section metres 812 to 834 by Klein & Bogdanova (2013) is problematic from a stratigraphic point of view. If GSUB C4048 (Fig. 3H) is interpreted an unequivocal representative of *P. nutfieldiensis*, as done by these authors, the index of the *P. nutfieldiensis* Zone of the middle upper Aptian would co-occur with latest Aptian or earliest Albian ammonites (“*M.*” *chihaouiae*).

The critical interval belongs to the T4 and Cu5 units of Ben Chaabane et al. (2019), attributed to the “*M.*” *chihaouiae* Zone sensu Latil (2011). This zone is not well-dated in Tunisia, further index ammonites are missing. An alleged condensation by “reworked phosphatised *Epicheloniceras*” (Latil 2011: 372), respectively “Reworked, phosphatised, juvenile *Epicheloniceras* sp.” (Ben Chaabane et al. 2019: 588) is actually based on a misidentification. These reported che-

loniceratids are actually douvilleiceratids, possibly of a hitherto new genus (pers. obs. by one of us: LGB). However, although it remains uncertain if it represents latest Aptian or earliest Albian sediments from the Tunisian record (compare Ben Chaabane et al. 2019: Fig. 17) the association of “*M.*” *chihaouiae* with *Douvilleiceras* in Morocco places it into the Albian (Luber et al. 2017). Nevertheless, our revised dating is in accordance with the interpretation of the T4 and Cu5 units as “Aptian–Albian transition” by Ben Chaabane et al. (2019) and places the uppermost faunal horizon of Lehmann et al. (2009) probably into the earliest Albian (comp. Figs. 4A and B).

4. The belemnite findings

4.1 Belemnites in the southwestern Tethys

Belemnites are generally rare findings in the northwest African Lower Cretaceous, except in some few layers. In the north-Tethyan regions from the Vocontian Basin in southeast France to the Betic Cordillera in southeast Spain, they are known to be common (see Janssen et al. 2012 with references herein). Contemporaneous beds in the western High Atlas of Morocco contain lots of belemnites, so that these beds can be characterised by belemnite assemblages similar to those of France and Spain (Mutterlose & Wiedenroth 2008). One of the first who investigated northwest African Lower Cretaceous belemnites and used them for biostratigraphy was Coquand (1862: 27, 28), characterising in the Algerian region of Constantine an “Étage néocomien caractérisé par les *Belemnites dilatatus* Blainv.” (corresponding to *Duvalia dilatata* of the Hauterivian), and an “Étage aptien caractérisé par le *Belemnites semi-caniculatus* Blainv.” (corresponding to *Mesohibolites semicanaliculatus* of the Aptian). South of Constantine, Peron (1889–90: 1) found “les *Belemnites latus*, *B. bipartitus*, etc. dans les marnes néocomien” in the Batna region (corresponding to *Duvalia lata* Blainville, and *Pseudobelus bipartitus* Blainville of the Valanginian–Hauterivian interval). Gentil (1902: 192, 193) found in the Tafna Basin of central Algeria “*Pseudobelus bipartitus* Blainv.” and “*Duvalia dilatata* d’Orb.” from the Hauterivian at Arlal, and “*Hibolites* sp.” and “*Duvalia Grasi* Duv. sp.” from the Barremian of the same location.

4.2 The Djebel Serdj belemnites

Pervinquier (1903: 41) described the section of the Djebel Serdj in detail giving lists of fossils for every lithological unit but without belemnites. In fossil-lists of the neighbouring Djebel Bargou and Djebel Guitoun (comp. Fig. 1), Pervinquier (1903: 45, 46) cited “*Belemnites (Hibolites) semicanaliculatus* Blainv.” which is now *Mesohibolites semicanaliculatus* (de Blainville 1827). Four years later, Pervinquier (1907: 403 ff.) described a lot of belemnites from the Tunisian Lower Cretaceous that belong to the genus *Duvalia* (5 species), *Pseudobelus* (1 species) and *Hibolites* (9 species).

Fig. 4: Correlation of the composite sections of (A) Ben Chaabane et al. (2019: Fig. 5), (B) Lehmann et al. (2009: Fig. 3), and (C) Google Earth map with the position of the belemnite finding. The red line between T4 and Cu5 marks the Aptian–Albian boundary interval, the red point the belemnite. Scale bar aside section A is equal to that in section B.

From the latter genus, only one species remains today in the genus concept of *Hibolites*, the other species are representatives of the genus *Mesohibolites* and *Neohibolites*. Castany (1951: 31) cited from the Djebel Serdj “*Belemnopsis semicanaliculatus* Blainv.”, which is nowadays *Mesohibolites semicanaliculatus* (de Blainville 1827), a form with great affinities to our finding. Since then, belemnites are recorded only as “belemnites” or “rostra” (e.g. Ben Fadhel et al. 2011) or even only as symbols aside a lithostratigraphic column (e.g. Latil 2011).

4.3 The GSUB C4049 belemnite

The belemnite GSUB C4049 from section metre 828 of the composite section of Lehmann et al. (2009; Fig. 3; GPS North 35.96674°, East 009.59452°) was neither figured nor described, but is the specimen referred to as *Neohibolites* sp. in their range chart, and also mentioned on their p. 901–903 and their Table 1. It was also mentioned by Heldt et al. (2010: Table 1) and comes from the uppermost part of the outcrop of the Serdj Formation at its type locality at Djebel Serdj (Fig. 4C) in north central Tunisia. Originally this stratigraphic interval was placed into the middle upper Aptian based on the ammonite records of *Parahoplites* cf. *nutfieldensis*, *Parahoplites maximus* and *Riedelites* in between section metres 810 to 835 (Lehmann et al. 2009: Fig. 2), are herein revised (Table 1). This stratigraphic interval (Figs. 4A and B) is now placed into the highest upper Aptian or lowermost Albian.

4.3.1 Description

Order Belemnitida Macgillivray, 1840
Suborder Pachybelemnopseina Riegraf, 1998
Family Mesohibolitidae Nerodenko, 1983
Genus *Hibolites* Denys de Montfort, 1808
Hibolites cf. *obtusirostris* (Pavlow in Pavlow & Lamplugh, 1891)
Figs. 5B, 6A–F

Comments to the species authorship: The Imperial Society of Naturalists of Moscow published their Bulletin quarterly. The article of the two authors about the Speeton Clay and their Russian equivalents appeared in four parts: introduction by both authors, geology of the Speeton Clay by Lamplugh, belemnites by Pavlow and ammonites by Pavlow. The first three parts appeared in the double-number 2 & 3 delivered in September 1891, the fourth part in December 1891. The cover for the whole volume was published in the first quarter of the next year, which is 1892. Therefore, the authorship has to be cited as “Pavlow 1891” or “Pavlow in Pavlow & Lamplugh, 1891”.

Description: The short but effective diagnosis of the species made by Pavlow (1891: 262–263, Pl. VII, Fig. 7) as well as the detailed new description of Swinnerton (1952: 61–62, Pl. XVI, Figs. 3–7) allowed an unreserved definition – the use of open nomenclature is due to the fact that no external

features are to be seen. A preparation of the rostrum was not possible because of the hardness of the limestone around it. So, most of the features for identifying are from a thin section. In the following, the rostral nomenclature is adopted from Spaeth (1971) (comp. Fig. 5A).

The belemnite finding is a slightly eroded rostrum with an elongated outline (Fig. 6A). The apical line is straight and central (Figs. 5B and 6B, C). A short peak is preserved (Fig. 6A), which lies centrally without forming a distinct mucro. The alveolar angle is 17 degrees, which coincides with data from Pavlow (1891: 262) and Spaeth (1989: 79). The protoconch is overgrown by calcite. This coarse-grained overgrowth is induced by a ventral furrow at the alveolar end (comp. Fig. 6G) which is a third of the orthorostrum. Therefore, the view has to be perpendicular to the dorsoventral plain, which means it is a lateral view. The minimal thickness D_{min} (blue line in Fig. 5B) shifts ontogenetically to the alveolus, whereas the maximal thickness D_{max} (red line in Fig. 5B) remains more or less at one point of the rostrum, the ratio D_{max}/D_{min} has a constant value of 1.5, comparable to some specimens from the Isle of Heligoland (according to unpublished data by one of us: CS). The reason for this D_{max} position is a reduced growth of the length in relation to thickness and breadth during ontogeny. Therefore, the apical part becomes more obtuse, shown in Fig. 5C by a striking bend in the graph. The Tunisian form is smaller compared to those from the Isle of Heligoland (Spaeth 1989) or the Speeton Clay (Swinnerton 1952), but the congruence of the blue-circle graph and the green-square graph shows that the Tunisian form is an adult specimen. Fig. 6B shows the thin section in incident light with dark background, so that mineral overgrowth is visible very well: besides the calcite of the ventral furrow, bright points of calcification are visible in the rostrum. Fig. 6C is the thin section seen in transmitted light. The calcitic rostrum of the guard shows only little diagenetic overgrowth because the accretion lines are visible excellently. In Fig. 6D, the area of the peak is enlarged to show an offspring, presumably the first chambers of a bryozoan colony. This means that the rostrum was exposed at the sea bottom for only short time before it was covered by carbonate mud. Fig. 6E shows the section of the rostrum after the sawing of the thin section. The plane of intersection cuts here the siphuncle, which was filled by carbonate mud. In spite of the coarse-grained calcitic filling of the phragmoconus, segmentation into eight chambers is still visible. Fig. 6F is a magnification of part of the phragmoconus with the siphuncle and the alveolar wall, which shows a slight undulation because of the roundness of the chambers (comp. Doguzhaeva & Melendez 2017: Fig. 9). For comparison with older Early Cretaceous *Hibolites* species, two sketches of the typical Hauterivian–Barremian *H. jaculoides* Swinnerton, 1937 are given in Figs. 6G and H. Fig. 6G is a ventral side with typical slender alveolar end and a ventral furrow, Fig. 6H is a lateral sight with a typical peeling of the alveolar end.

Fig. 5: (A) Sketch of a belemnite guard with the main features important for identification (redrawn from Spaeth 1971). (B) Thin section of the described belemnite with position of features and dimensions mentioned in the text (lateral section, comp. Fig. 6C). (C) Graphic description of the ontogenetic changes of the apical angle in relation to the apical length. Blue-circle graph comprises data from the Tunisian belemnite (specimen GSUB C4049), green-square graph from a specimen from the Isle of Heligoland (redrawn and completed from original material of Spaeth 1989).

Fig. 6: *Hibolithes* cf. *obtusirostris* (Pavlow in Pavlow & Lamplugh 1891) (specimen GSUB C4049 from Djebel Serdj, northern Tunisia (A–F) and sketches of *Hibolithes jaculoides* (G, H) for comparison. (A) Original sight of the belemnite finding, lateral section. (B) The thin section in incident light with dark background, lateral section. (C) Thin section seen in transmitted light, lateral section. (D) Area of the peak, enlarged to show an offspring (bryozoan?). (E) Section of the rostrum after the sawing of the thin section, lateral section. (F) Magnification of part of the phragmoconus with the siphuncle. (G) Sketch of *Hibolithes jaculoides*, showing the ventral side with typical slender alveolar end and a ventral furrow. (H) Sketch of *Hibolithes jaculoides* in lateral sight with a typical peeling of the alveolar end. The scale bar represents 10 mm and is valid for all rostra.

4.3.2 Discussion of taxonomy and palaeobiogeography

Though the outer diagnostic features of the belemnite cannot be seen, various measurements and internal features discussed in the previous chapter lead to the determination as *Hibolites* cf. *obtusirostris* (Pavlow in Pavlow & Lamplugh, 1891). The co-occurring *Mesohibolites semicanaliculatus* (de Blainville, 1827) (see chapter 4.2) is less elongate/more stout and less obtuse with a distinct mucro and a greater alveolar angle. Some neohibolitids with obtuse ends similar to the Tunisian specimen, e.g. *Neohibolites minimus obtusus* Stolley, 1911 (comp. Spaeth 1971: 62), are smaller, show a different apical angle graph and are of middle Albian age.

The stratigraphic position of latest Aptian–earliest Albian (see chapter 3.6) is very young and hitherto unknown for this genus for the Tethys; the youngest specimens of *Hibolites* are known from Tethyan occurrences of Early Barremian age (e.g. Janssen 1997; Janssen & Fözy 2003). In contrast to this, from Boreal localities (e.g. northern Germany) *Hibolites* is known from Aptian sediments, too (Stolley 1911; Mutterlose et al. 1983; Spaeth 1989 and references therein). Under palaeobiogeographic aspects, the originally Tethyan belemnite genus *Hibolites* was able to migrate early into the Boreal regions as well as re-migrated later on into Tethyan areas again (Stevens 1973; Mutterlose et al. 1983). This scenario was repeated by Upper Cretaceous belemnitellids, as they also immigrated occasionally into northern Tethyan margins (Christensen 1997).

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