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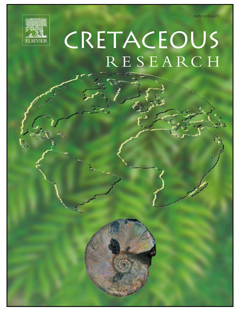

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A revised ammonoid biostratigraphy for the Aptian of NW Africa: Essaouira-Agadir Basin, Morocco.

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Abstract

A revised ammonoid biostratigraphy is presented for the Aptian of NW Africa, Essaouira-Agadir Basin (**EAB**), Morocco, based on detailed analysis of 5 key sections. A number of bio-events are documented and 26 genus and 43 species fully documented, forming the largest published Aptian ammonite collection made from NW Africa. The section at Tiskatine is documented as the type section, and 8 zones and subzones are defined, of which 5 are new. This work allows correlation of the Aptian of the **EAB** to the Standard Mediterranean Ammonite Scale (**SMAS**). Two main hiatuses are identified at the scale of the basin scale: a major one that includes most of the lower Aptian and the base of the upper Aptian and a second one encompass the top of the upper Aptian and the base of the lower Albian. The ammonite fauna displays a clear Tethyan palaeobiogeographic character affected by a fairly high degree of endemism at the genus and species level. The new genus and species *Elsaella tiskatinensis* is introduced.

Keywords: Ammonite, Biostratigraphy, Aptian, Essaouira-Agadir Basin, Morocco

1. Introduction

Aptian to lowermost Albian ammonite biostratigraphy across the northwest African Atlantic margin remains poorly documented compared to counterparts of the Mediterranean Tethys; such as in Spain (Moreno Bedmar et al., 2008, 2009, 2010, 2012a, 2014), France (Delanoy, 1995a; Cecca et al., 1999; Ropolo et al., 1999; Kennedy et al., 2000; Ropolo et al., 2000a-c; Dauphin, 2002; Dutour, 2005; Ropolo et al. 2006; Ropolo et al., 2008a-b; Frau et al., 2015), Tunisia (Lehmann et al., 2009; Chihaoui et al., 2010; Latil, 2011), and Iran (Raisossadat, 2004, 2006; Bulot in Vincent et al., 2010; Seyed-Emami and Wilmsen, 2016); or on the opposite side of the Central Atlantic Margin (CAM), e.g. Mexico (Barragán-Manzo and Méndez-Franco, 2005; Moreno Bedmar et al., 2012b, 2013, 2015, Barragán et al., 2016).

The Aptian Stage contains some globally significant events, recording a time of high sea-level during the mid-Cretaceous greenhouse period (Larson and Erba, 1999; Leckie et al., 2002). It also records some of the most wide-spread and best studied oceanic anoxic events (Schlager and Jenkyns, 1976; Scholle and Arthur, 1980; Arthur et al., 1990; Bralower et. al, 1994; Weissert et al., 1998; Föllmi et al., 2006; Föllmi, 2012).

In this study we present a new high-resolution dataset from NW Morocco, discussed within a broader regional/global context and with special reference to the standard ammonite zonal scheme of the Mediterranean Tethys (Reboulet et al., 2011, 2014). In Morocco, the Aptian successions of the west-central part of the Essaouira-Agadir Basin (**EAB**) is part of one of the most complete and best-constrained successions of the Lower Cretaceous in NW Africa. The Aptian succession is characterized by ammonite-rich, shallow-marine (Bouzergoun Formation) to shelf deposits (Tamzergout and Oued Tidzi formations), that crop out in a corridor along the Moroccan coast between the cities of Agadir and Essaouira (Fig. 1). The aim of the present contribution is to improve the biostratigraphic frame of the Aptian and lowermost Albian of the **EAB** based on the detailed analysis of the bed by bed distribution of ammonoids at five key sections (Fig. 1).

Our results document the specific character of the ammonoid fauna of the **EAB** and discuss its similarities and differences with equivalent ammonite faunas of Mediterranean-Caucasian Subrealm of the Tethyan Realm. The results of this study develop a strong reference framework for the Aptian to earliest Albian for the northwest African Atlantic margin (figure 12).

2. Regional Setting and Stratigraphy

Lower Cretaceous strata crops out over an area 100 km wide and 150 km long, adjacent to the Moroccan Atlantic coast; the only continuous succession of Mesozoic fill of the Central Atlantic Margin (CAM) (Fig. 1). Following Permo-Triassic rifting that separated Africa and North America (Le Roy and Piqué, 2001), extensive Jurassic carbonate platforms developed all along the NW Africa (Jansa and Wiedmann, 1982). Later deposition shared this inherited regional physiography, but also record distinct sub-basins with variable subsidence, evolving throughout the Early Cretaceous (Rey et al., 1988; Davison, 2005; Wenke et al., 2011).

During this time, the **EAB**, the focus of this study, was limited to the north by the Meseta and the Jebilet, to the south by the Souss Basin and to the east by the Massif Ancien de Marrakech. The general physiography formed a large gulf-like embayment opening out to the west into the Atlantic Ocean (Behrens et al., 1978). Present day exposure of the Mesozoic basin fill and adjacent basement terrains reflects the Cretaceous to Cenozoic inversion and uplift linked to the Atlasic/Alpine orogeny (Laville et al., 2004) and associated salt tectonics (Tari and Jabour, 2013).

This study focuses on the outcrops in the west-central part of the **EAB**, located between the prominent Cretaceous Essaouira and Chichaoua escarpment to the north and the broad Cap Ghir anticline to the south (Fig. 1). Strata are mainly flat lying, only exhibiting folding with steep flanks close to fault zones and associated with salt diapirs (Hafid et al., 2000, 2006). The maximum thickness of the entire Cretaceous post-rift succession is estimated to be 1300 m (Behrens et al., 1982) (Zem Zem section). The Lower Cretaceous reaches approximately 800 m in thickness but varies dramatically, thinning toward salt diapirs, suggesting Cretaceous syn-sedimentary activity (Hafid et al., 2000; Le Roy and Pique, 2001; Zühlke et al., 2004).

The Early Cretaceous represents a time of major change from the predominately carbonate-dominated system in the Middle- to Late Jurassic to a mixed carbonate-siliciclastic or purely siliciclastic systems in the Cretaceous, following drowning of the Jurassic carbonate platform. Cretaceous deposits in the **EAB** are dominated by shelfal mudstone successions with discrete intervals of coarse clastic sediment delivery in the late Valanginian, late early Hauterivian and late Barremian to earliest Aptian (Ambroggi, 1963; Behrens et al., 1978).

During the Aptian the paleogeography of the **EAB** was dominated by an open marine shelf. Arid climatic conditions are indicated by low nannofossil productivity (Herrle, 2002; Peybernes et al., 2013) and clay mineral composition (Daoudi and Deconinck, 1994). The **EAB** is thought to have been located away from the main upwelling zone, which existed during Aptian and early Albian times around the Mazagan Plateau to the north (Herrle, 2002). A cooling climatic trend has been recognized from the late Aptian – early Albian, evidenced by southward migration of high-latitude/boreal nannofossil into mid- and low-latitudes (Jeremiah, 1996, 2001; Herrle and Mutterlose, 2003; Rueckenheim et al., 2006). This trend was also observed in the **EAB** by Peybernes et al. (2013).

Overall the Aptian to Albian transition is a time of global eustatic sea-level rise (Hardenbol et al., 1998; Haq, 2014). In the **EAB** shallow-marine conditions were widespread during the early Aptian, with a transgression recognised in the late Aptian, the establishment of outer shelf conditions, and reoccurrence of the Atlas Gulf (Behrens et al., 1978).

Most of the formation names for the Lower Cretaceous were introduced by Duffaud et al. (1966), later revised by Rey et al. (1986a and b, 1988). The reference sections are mainly located along an E-W trending transect in the northern part of the **EAB** (Essaouira to Imi'n'Tanoute). There are no stratigraphic units at group level defined in the **EAB**. Previous sedimentological and stratigraphic work on the Lower Cretaceous in the areas was carried out by Ambroggi (1963), Duffaud et al. (1966), Wiedmann et al. (1978, 1982), Adams et al. (1980), Behrens et al. (1982) and Rey et al. (1986a and b, 1988). More recent studies have mainly focused on the ammonite biostratigraphy of the Berriasian to Hauterivian interval (Ettachfini, 1991, 2004; Wippich, 2001, 2003) and the integrated stratigraphy of the Barremian/Aptian interval (Witam et al., 1993; Witam, 1998; Nouidar and Chellai, 2001, 2002; Company et al., 2008; Peybernes et al., 2013).

2.1 Barremian to Albian lithostratigraphic framework

The first attempt to subdivide the lithostratigraphic succession of the **EAB** was made by Duffaud et al. (1966). For the Barremian to Albian interval, those authors introduced five lithostratigraphic units: the "Calcaires lumachéliques de Taboulaourt", the "Grès et marnes rouges du Bou Zergoun", the "Marno-calcaires de Tamzergout", the "Grès marneux du Lemgo" and the "Marnes de l'Oued Tidsi". This synoptic lithostratigraphic chart was introduced without formal description, a definition of boundaries or designation of reference sections.

Subsequent works by Rey et al. (1986a and b, 1988), Andreu (1989), Witam et al. (1993) and Witam (1998) led to refining the litho- and biostratigraphic framework of the **EAB**, but little attention was paid to the formal description and definition of the formations. Despite Witam's (1998) attempt to propose reference sections for the lithostratigraphic units introduced by Duffaud et al. (1966), a unified lithostratigraphic nomenclature for the **EAB** is still lacking. This drastically limits the value of the lithostratigraphic units for the correlation of the Barremian to Albian strata and also reflects the limited published work on regional stratigraphic relationships. Revising the lithostratigraphic framework of the **EAB** is beyond the scope of the present contribution and in this study we have utilised the existing scheme of Duffaud et al. (1966) that best applies to our observations in the west-central part of the basin (Fig. 2).

2.1.1 Bouzergoun Formation

The Bouzergoun Fm., composed of sandstones and red mudstones, was introduced by Duffaud et al. (1966). Rey et al. (1986a, 1988), describes them as margino-littoral deposits made of sands, varicoloured clays, dolomites and bioclastic-rich limestones with large cross-stratification; and topped by a major disconformity.

There is no agreement in the literature about the age of the Bouzergoun Fm. Rey et al. (1986a) proposed a late Barremian age, based on the occurrence of early Barremian ammonites in the underlying Taboulouart Fm. and early Aptian ammonites in the overlying Tamzergout Fm. This was amended by Nouidar and Chellaï (2001) who assigned the upper part of the Bouzergoun Fm. (red beds) to the lower Aptian, based on the occurrence of *Salpingoporella? dinarica* Radoičić. However, it is unclear if the occurrence is derived from new data obtained by the authors or from a misinterpretation of Canérot et al. (1986), who never reported these dasyclad algae from the **EAB**. In any case, the occurrence of *Salpingoporella? dinarica* does not allow discrimination between the Barremian and Aptian stages.

Analysis of outcrops for this new study identify the Bouzergoun Fm. as being composed of a thick succession of shelfal muds with minor sandstones at the base, truncated by coarsening and thickening-upward shallow-marine and deltaic sand-rich deposits and fluvial deposits. In places, erosional channel and valley features are in-filled by coarse clastic material and greenish to red-coloured mudstones with interbedded sandstones. The uppermost part of the formation is made of sandstones, sandy limestones and mudstone interbeds bearing marine fauna and often oyster-rich beds to the top (Fig. 2). The unit reaches a maximum thickness of 84 metres at Assaka.

Ammonites collected from Assaka identify a condensed horizon that marks the boundary between the Taboulouart and the Bouzergoun formations, of early late Barremian age (early to middle part of the *Gerhardtia sartousiana* Zone) (see also discussion in Company et al., 2008). In most sections studied the occurrence of *Procheloniceras dechauxi* (Kilan and Reboul, 1915) firmly establish an earliest Aptian age (see discussion below) for the uppermost beds of the Bouzergoun

Fm. (see discussion below). At Tiskatine, the top of the formation is marked by two beds of siltstones that contain a rich early late Aptian ammonite fauna (lower part of the *Colombiceras tobleri* Zone) (see discussion below). This indicates that the top of the Bouzergoun Fm. is diachronous and ranges in age from earliest to early late Aptian (base of the *Deshayesites forbesi* to lower part of the *Colombiceras tobleri* zones).

2.1.2 Tamzergout Fm.

The Tamzergout Fm. was defined by Duffaud et al. (1966) as a succession of marls and limestones. The vertical and lateral extension of this unit has been variously interpreted by subsequent authors (see discussion in Witam, 1998, p. 153-154).

The formation is mainly made up of fossiliferous alternating blue-grey marls and grey limestones that correspond to shallow-marine to shelfal deposits (Fig. 2). Rey et al. (1986a) restricted its age to the early Aptian (= Bedoulian in regional French stratigraphy) and limited its occurrence to the west and central part of the **EAB**. Rey et al. (1986a) also introduced the Tadhart Fm. of late Aptian age (= Gargasian in regional French stratigraphy), sitting between the Tamzergout and subsequent Oued Tidzi Fm. In this study we propose a different age range for the Tamzergout Formation (see below), from the early to latest Aptian. We therefore consider the Tadhart Fm. a time-equivalent unit for parts of the upper Tamzergout Fm. that is restricted to the eastern and more proximal parts of the basin. In the western and central part of the basin it cannot be discriminated from the Tamzergout Fm. In the studied area, the top of the Tamzergout Fm. is marked by a regional unconformity that was previously reported from Agadir (discontinuity **D4** of Peybernes et al. 2013). The formation reaches a maximum thickness of 33 metres at Tiskatine.

In most sections studied, the lower part of the formation contains the base of the *Deshayesites forbesi* Zone (lowermost Aptian). *Procheloniceras dechauxi* is abundant, but first appears in the underlying Bouzergoun Fm. At Tiskatine, the first limestone bed of the Tamzergout

Fm. is marked by the First Occurrence (**FO**) of "*Epicheloniceras*" *marocanus* (Roch, 1930) that indicates the base of the upper part of the *Colombiceras tobleri* Zone (see discussion below). The assigned ages further highlight the diachronicity of the top Bouzergoun and base Tamzergout Formation. The upper part of the formation is usually rich in small pyritic ammonites that indicate a latest Aptian age (*Elsaella tiskatinensis* Zone, see definition and discussion below).

2.1.4 Lemgo Formation

The Lemgo Fm. was introduced by Duffaud et al. (1966) and subsequently reinterpreted by Rey et al. (1986b) to include a complex of green marls, yellow sandy marls and sandy dolomites at the top. It is named after the Jbel Lemgo ridge, to the east of Imi'n'Tanoute.

Based on our field observations and microfacies analysis in the Mramer section, the Lemgo Fm. is composed of argillaceous sandstones and bioclastic-rich sandy limestones. Regional correlations suggest that the Lemgo Fm. represents the proximal equivalent of the upper Tamzergout Formation and is not present in the western central part of the basin (see discussion below).

Rey et al. (1988) assigned the formation to the uppermost Aptian (= Clansayesian in regional French stratigraphy) based on the occurrence of ammonite assemblages that characterized the *Nolaniceras nolani* and *Hypacanthoplites jacobi* zones. Material collected in this study of what is exposed of the Lemgo Fm. at the Mramer section indicates a latest Aptian to earliest Albian age (*Acanthohoplites ashiltaensis* to *Mellegueiceras chihaouiae* zones, see discussion below).

2.1.4 Oued Tidzi Formation

Described by Duffaud et al. (1966) as marls, it was redefined by Rey et al. (1988) as a complex of green marls bearing small pyritic ammonites, intercalated with marly limestones and sandy dolomites.

The unit is easily recognized in the west-central part of the **EAB** where it reaches a maximum thickness of 340 m and forms extensive recessive slopes in the landscape. Our field observations and microfacies analysis, focused on the lower part of this formation, show a clear change from blue marls and limestones of the Tamzergout Fm. to a complex of green marls with minor bioclastic-rich sandstone interbeds (Fig. 2). The early Albian age of the basal sandstones is established by the occurrence of the diagnostic ammonite genus *Douvilleiceras*.

2.2 Previous Work on Aptian biostratigraphy

Pioneering work reporting and describing ammonites in the **EAB** was undertaken by Kilian and Gentil (1906), Roch (1930) and Ambroggi (1963). The work of Ambroggi (1963) has to be highlighted, as it established the first regional biostratigraphic framework for the Lower Cretaceous. The ammonite biostratigraphy of the Berriasian - Barremian interval was subsequently refined by Ettachfini (1991, 2004), Wippich (2001, 2003) and Company et al. (2008). Yet, despite the good accessibility of sections and abundance of ammonites, no recent studies have focused on the detailed ammonite palaeontology and biostratigraphy of the Aptian – Albian interval.

Following the work of Roch (1930) and Ambroggi (1963), extensive faunal lists of Aptian and Albian ammonites were published by Bergner et al. (1982), Rey et al. (1986a and b, 1988), Witam et al. (1993) and Witam (1998). Unfortunately, the precise stratigraphic position of the material within the formations was not documented and only a very limited number of specimens were illustrated in the literature. As a consequence, the available previously published data sets do not fulfil the standards of modern biostratigraphic studies and it is difficult to reinterpret them in the light of our own results.

Most recently a detailed biostratigraphic framework based on bed by bed collections from a transect along the Agadir segment of the **EAB** was published by Peybernes et al. (2013). A fairly high degree of endemism was suggested by the introduction of many new species and genus names that are unfortunately not formally described or illustrated. The authors chose not to introduce new biostratigraphic units, but pointed out the necessity for a local ammonite zonal scheme. The published zonation is an attempt to apply the upper lower Aptian to lower Albian ammonite zonal scheme of northern Tethys (Reboulet et al., 2011) to the **EAB**. This interval is described as being strongly affected by condensation and temporal hiatuses. According to these authors, the co-occurrence of *Cheloniceras sp.* and *Deshayesites sp.* indicates an early Aptian age for the base of the Tamzergout Fm. (tentatively assigned the *Deshayesites deshayesi* Zone). Condensation and merging of unconformities across the lower/upper Aptian boundary is supported by the mixing of *Dufrenoyia furcata* and *Epicheloniceras martini* zones assemblages. The upper Aptian *Epicheloniceras martini*, *Parahoplites melchioris*, *Acanthohoplites nolani* and *Hypacanthoplites jacobi*, zones are identified on the basis of characteristic ammonites assemblages, even so it is highlighted that the extension of the *P. melchioris* Zone is uncertain, as the index fossil is absent and indicative taxa are scarce. The lower Albian *Leymeriella tardefurcata* Zone and *Douvilleiceras mammillatum* Superzone are recognized throughout most of the basin even though the index species are absent. It should be noted that a bed by bed distribution of ammonites is only documented in the Addar section and the authors do not provide photographic plates to substantiate the ammonite systematics used in their contribution.

3. Studied Sections

The present publication is focused on five Aptian-Albian sections (Fig. 1). Locations were chosen to reinvestigate previously studied sections for reference and further to add new sections for better spatial constraints and coverage of the western, central and the northern part of the basin.

3.1. Tiskatine (Fig. 3) - Lat.: 30.821463° Long.: -9.702555° (Tiskatine 1) and Lat.: 30.810477° Long.: -9.739966° (Tiskatine 2).

The lower part of the succession (beds **TK 159 to 206,** Fig. 3) is best exposed 6.5 Km to the east of the village of Assaka (Tiskatine 1), northwest of Adrar (mountain) Tiskatine. The upper beds (**TK 206 to 249**) are better exposed 3 Km to the east of Assaka (Tiskatine 2). The two sections were correlated using the marker bed **TK 206**. Section Tiskatine 1 starts in the river bed south of the road from Assaka to Tazzougart and continues to the north. At Tiskatine 2 the beds crop out on both sides of the road. Tiskatine 1 was previously studied by Roch (1930) and Ambroggi (1963).

3.1 m of the upper part of the Bouzergoun Fm. are exposed at Tiskatine. The first bed (**TK 157**) is a well-consolidated oyster-rich, ammonite-barren, sandy limestone topped by an iron-rich crust. It is followed by yellow sandstones interbedded with yellow to green mudrock partings (beds **TK 158-162**). The sandstones are fine-grained and show low angle cross-bedding and laterally extensive undulating surfaces. They are often topped by iron-enriched crusts, yielding phosphatic, glauconitic pebbles and fossils. The fossil content comprises ammonites, belemnites, echinoids, gastropods, and rare solitary coral fragments. The top surface of bed **TK 16**1 is marked by a belemnite accumulation that suggests transport and winnowing by currents (type 4 condensation accumulates of Doyle and Macdonald, 1993). The deposits represent a deepening-upward shallow marine succession. Wave-influenced shoreface sedimentation dominates at the base (bed **TK 157**) with a subsequent transition into lower shoreface to offshore sedimentation (bed **TK 158-162**). The contact with the overlying Tamzergout Fm. is marked by well-developed marls in bed **TK 163**. The contact is abrupt and marks the change to shelfal conditions below storm wave base.

The alternating blue-grey marls and grey limestones of the Tamzergout Formation develop from bed **TK 163** to bed **TK 247**. The marls are laminated, forming decimetre to metre thick beds. Limestones are 10 to 20 centimetres thick and appear massive. Contact between alternating beds are mostly sharp and planar. In the middle part of the succession some limestones beds have detrital component (**TK 180, 182, 192** and **194**) and two prominent fine-grained sandstone beds (**TK 184** and **TK 186**) are recognised. The sandstones are topped by ferruginous crusts. From bed **TK 197** to bed **TK 246** the succession is characterized by a fairly monotonous alternation of marls and limestones. **TK 206** is a prominent extremely fossiliferous marker bed, with a well-developed iron-crust on the top. Above, the marls are rich in pyritic nodules and ammonites, and some minor detrital input was observed toward the top of the Tamzergout Fm. that ends at a distinct glauconitic horizon (bed **TK 247**) rich in phosphate nodules. The total thickness of the Tamzergout Fm. is 33.15 metres. Sedimentation of the Tamzergout Fm. is mainly through suspension fall out. Sandstone beds **TK 184** and **TK 186** are interpreted as gravity flow deposits.

The base of the Oued Tidzi Fm. is marked by a fossil-rich sandstone bed **TK 248** that contains reworked phosphatic pebbles and glauconitic fossils (including ammonites). It is capped by a well-developed iron crust directly overlain by distinctive green to yellow marls of the Oued Tidzi Fm. Bed **TK 248** is interpreted as a shelf gravity flow.

Ammonite abundance and diversity vary throughout the succession. This discontinuous palaeontological record may partially reflect collection failure, despite an intensive search of the barren intervals. Based on our present knowledge, the following sequence of bio-events is recognised as regionally significant following comparison with the other sections studied:

- Bio-event 1: sudden mass occurrence of *Procheloniceras* in bed **TK 159**, followed by the first observed occurrence of *Deshayesites* in bed **TK 160**;
- Bio-event 2: peak of diversity in bed **TK 161a** dominated by *Colombiceras* and *Epicheloniceras*;

- Bio-event 3: first apparition datum of the endemic species "*Epicheloniceras*" *marocanus* at the top of bed **TK 162**, followed by its acme in bed **TK 166**;
- Bio-event 4: lowest occurrence of *Acanthohoplites* in bed **TK 184**;
- Bio-event 5: peak of abundance of *Pseudoaustraliceras* in beds **TK 192** and **TK 194**;
- Bio-event 6: sudden mass occurrence of *Elsaella* gen. nov. in bed **TK 206**;
- Bio-event 7: radiation of the Acanthohoplitidae (*Nodosohoplites*, *Protacanthoplites* and "*Hypacanthoplites*") from bed **TK 206** to bed **TK 221**;
- Bio-event 8: lowest occurrence of *Douvilleiceras* in bed **TK 248**.

Tiskatine is the only studied section where the complete succession of events was recognized and documented. It has, therefore, been selected as the reference section for the ammonite biostratigraphy of the west central part of the **EAB**.

3.2. Tamanar (Fig. 4) - Lat.: 31.057403° Long.: -9.601503°

This outcrop is 10 Km northeast of Tamanar and the section is also known as Ida Ou Shak named after the nearby village. It can be reached via an unmade track that leaves National road 1 approximately 8 Km north of Tamanar. This section has not been previously described in literature.

Fine-grained laminated sandstones with interbedded calcareous mudstones make up the lower 8 metres (beds **TM 49** to **58**) of the studied section and comprise the uppermost part of the Bouzergoun Fm. Oysters and other large bivalves are abundant throughout. The lower part of the logged section is affected by soft sediment deformation. The first occurrence of ammonites is recognised on top of the slumped interval. The deposits of the Bouzergoun Fm. here are interpreted as lower shoreface to offshore shelf transition.

The base of the Tamzergout formation is marked by the change to limestones and interbedded marls, both containing abundant open-marine fauna (e.g. ammonites and belemnites).

The formation encompasses beds **TM 59** to **TM 80**. Compared to the interval exposed at Tiskatine, the limestones here have a stronger siliciclastic detrital component. The succession is fairly monotonous, but a few beds have notable features. From bottom to top, these are:

- Bed **TM 69** contains very abundant ammonites (dominantly *Procheloniceras dechauxi*) associated with a high ferruginous content;
- Bed **TM 70a** is a slumped complex marked the only occurrence of upper lower Aptian ammonites (*Cheloniceras*) identified in this study;
- Bed **TM 71** contains a phosphatic, glauconitic and ferruginous fossil assemblage rich in ammonites, belemnites, bivalves, and brachiopods.
- Bed **TM 73** contains belemnites and bivalves and is marked by a well-developed and prominent iron crust.
- Bed **TM 76** is rich in ammonites and marks an increase in diversity of the ammonite fauna
- Bed **TM 80** yields abundant pyritic ammonites.

The sandstone of bed 81 is interpreted to define the base of the Oued Tidzi Formation, displaying a similar depositional environment to Tiskatine.

The Tamzergout Formation has a total thickness of 19.20 metres. At this location it is interpreted to be mixed shelfal pelagic marls, with changes in siliciclastic sediment influx transported by wave and current supported gravity flows, forming the sandy limestones.

Compared to the succession of bio-events recognized at Tiskatine, several points should be outlined:

- Bio-event 1 is marked by a less sudden appearance of *Procheloniceras* in bed **TM 55**;
- Bio-event 2 is not well expressed due to poor outcrop conditions but merely lies at the top of bed **TM 71**;

- Bio-event 3 is marked by the spot occurrence of "*Epicheloniceras*" *marocanus* in bed **TM 72**;
- Bio-event 4 and 5 are not recorded;
- Bio-event 6 and 7 are identified in beds **TM 76** to **TM 80** with a slightly different expression due to condensation combine with temporal hiatus.

3.3. Zem Zem (Fig 5) **-** Lat.: 31.241846° Long.: -9.372052°

Located about 17 Km to the south-southeast of Meskala, this outcrop can be reached via an unmade road leaving the main road between Bizdad and Ait Daoud, approximately 2 Km south-southeast of Bizdad. Nearby sections have been studied by Roch (1930), Butt (1982), Rey et al. (1986a, 1988) and Witam (1998).

The Bouzergoun Fm. reaches a thickness of 12 metres at Zem Zem (up to bed **ZZ 60**).The upper part is composed of sandy rudstones, sandstones and minor wackestones with marls interbedded. Fauna is dominated by brachiopods, oysters, ammonites and echinoderms, pointing towards open-marine conditions. Horizon **ZZ 59** is a prominent ferruginous surface just below the topmost bed of the formation, containing abundant fossils with phosphatic preservation. Deposition overall took place in a shoreface to carbonate-rich subtidal environment with higher energy index, on a shallow shelf.

The Tamzergout Fm. is interpreted to extend from bed **ZZ 61** to **ZZ 68** and is dominated by marls with two prominent limestone beds (**ZZ 61** and **ZZ 65**) and a sandstone bed topped by an iron crust (**ZZ 67**). The thickness of the Tamzergout Fm. is approximately 20 metres, and the presence of laterally extensive marls with limestone interbeds containing open marine fauna and reduced siliciclastic input suggests a low-energy shelf environment, similar to that at Tiskatine.

The base of the Oued Tidzi Fm. is defined as a prominent sandstone horizon, and continues to the top of the measured section, with a minimum thickness of 10 metres.

At Zem Zem, the palaeontological record shows that bio-event 1 (mass occurrence of *Procheloniceras*) is well expressed and almost directly overlain by the sudden appearance of *Elsaella* gen. nov., followed by the radiation of the Acanthohoplitidae (bio-events 6 and 7). Bio-event 2 is suspected in the condensed horizon at the top of the Bouzergoun Fm. (spot occurrence of *Epicheloniceras* with reworked *Deshayesites* at the top of bed **ZZ 60**). Bio-events 3, 4 and 5 are not recorded and outline the existence of a major temporal hiatus at the base of the Tamzergout Fm.

3.4. Oued Tlit (Fig. 6) - Lat.: 31.194306° Long.: -9.665616°

The section is located 4 Km southeast of Smimou, on the northern flank of the Djebel Amsittene anticline, north of the road between Smimou and Imi'n'Tlit. This locality has previously been studied by Roch (1930), Rey et al. (1986a, 1988) and Witam (1998).

The top of the Bouzergoun Formation comprises the lowermost 2.10 metres. It is composed of fine to medium-grained non-amalgamated sandstones interbedded with mudstones. The sandstones exhibit hummocky cross-stratification and are often affected by in-situ soft-sediment deformation. The upper part is formed by a very prominent set of oyster rudstones. The depositional environment is interpreted as shoreface to subtidal.

Ammonites occur immediately above the set of oyster rudstones and the remaining 11.70 m are interpreted to as part of the Tamzergout Formation. It comprises alternating marls and micritic limestones. A well-expressed hardground surface marked by iron crust and glauconite, associated with belemnite accumulation and phosphatic ammonites, occurs at the top of bed **OT 11**. The upper part of the Tamzergout Fm. has not been investigated in this study.

The succession of bio-event 1 (sudden appearance of *Procheloniceras*) and bio-event 2 (peak abundance of *Epicheloniceras* and *Colombiceras*) are recognized in the lower part of the Tamzergout Fm. Our findings also question the identification of the *Dufrenoyia* and *Epicheloniceras* illustrated by Witam (1998) from this section (see discussion below).

3.5. Mramer (Fig. 7) **-** Lat.: 31.657033° Long.: -9.164205° (Mramer 1) and Lat.: 31.666118° Long.: -9.153251° (Mramer 2).

Mramer represents the northernmost section studied in the **EAB**. It is located approximately 60 Km to the ENE of Essaouira and 12 Km NE of Tafetachte. The Mramer section is a composite section, both locations cropping out in a river bed. Mramer 1 is located about 1.5 Km to the northeast of the market in Mramer and location Mramer 2 is at the base of a steep slope south of the market. This outcrop was mentioned by Roch (1930) but not reported in detail.

The upper 3.50 metres of the Bouzergoun Fm. are exposed at this locality. Strata are dominated by sandstones and siltstones. The fauna is rich in oyster fragments, and further includes scarce ammonites; towards the top echinoderm fragments are common. The medium to fine-grained sandstones exhibit in-situ soft sediment deformation structures and common bioturbation, they are dominated by low-angle cross lamination, interpreted to have been deposited under shoreface conditions.

The following interval (beds **MR 9a** to **9f**) comprises part of the Tamzergout Fm., here composed of sandy limestones and marls interbedded. The limestones contain belemnites, bivalves, and echinoderms and exhibit prominent iron crusts at the tops. The exposed part of the Tamzergout Fm. records a return to shelfal, open water, and lower-energy depositional environments. This interval is capped by a zone of poor exposure that is 17.5m thick and likely composed of limestones and interbedded marls with increasing abundance of ammonites.

It is overlain by the Lemgo Fm., the proximal equivalent to the upper Tamzergout Fm. The base of the Lemgo Fm. is not exposed in the study area. It is composed of yellow argillaceous sandstones and sandy limestones obtaining a minimum thickness of 4.50 metres. Fossil-rich sandy limestones at the base (beds **MR 9x** to **9z**) are laterally continuous. Beds **MR 10** to **MR 17** comprise very fine to fine-grained sandstones interbedded with floatstones. Sandstones exhibit large-scale, higher energy dune bed forms and often rework the interbedded limestones. Limestones have well-developed iron crusts and are rich in fossils containing brachiopods, ammonites, gastropods, and belemnites. These fossils often occur in phosphatic and glauconitic preservation, pointing to a reoccurrence of anoxia.

This mixed siliciclastic-carbonate succession is interpreted to represent shelfal carbonates being reworked by sandstones deposited during intermittent, wave-influenced sedimentation. Abundance of ammonites and cosmopolitan taxa imply an open –marine connection but reoccurrence of anoxia and absence of indicative, open-marine fauna is pointing towards a periodic development of restricted environment. Overall, this represents a shallowing-up succession with a higher energy index than other time-equivalent sections studied in the sections of the central and western part of the basin. The Lemgo Fm. is overlain by marls and minor sandy limestones of the Oued Tidzi Fm. that starts at bed **MR 20** and marks the return into lower-energy shelfal sedimentation.

At Mramer, the Lemgo Fm. records the local expression of bio-events 6 to 8. The ammonite succession is characterized by the radiation of the Acanthohoplitidae from bed **MR 10m** to **MR 15**, followed the lowest occurrence of *Douvilleiceras* in bed **MR18**. Noteworthy is the occurrence of a well preserved and abundant fauna of *Mellegueiceras*, a genus that was so far only known from Central Tunisia (Latil, 2011).

4. Systematic Palaeontology

More than 1000 ammonite specimens were collected during two field sessions in 2015 and 2016. To our knowledge, the material collected represents the largest bed by bed collection made from the Bouzergoun and Tamzergout formations of the central and northern part of the **EAB**. The preservation of the material is variable and includes internal calcareous, phosphatic and pyritic moulds. Abundance varies considerably throughout the studied sections and high diversity is observed in specific horizons, some of which can be correlated at the scale of the **EAB**.

As already outlined in the faunal lists given by our predecessors (Roch, 1930; Ambroggi, 1963; Rey et al., 1986a), the ammonite assemblages are largely dominated by the Douvilleiceratidae Parona and Bonarelli, 1897 and Acanthohoplitidae Stoyanow, 1949. The Deshayesitidae Stoyanow, 1949, Desmoceratidae Zittel, 1895 and Ancyloceratidae Gill, 1871 are minor elements of the faunas. Aconeceratidae Spath, 1923, Phylloceratidae Zittel, 1884 and Tetragonitidae Hyatt, 1900 are even rarer.

Despite an extensive list of published work, the systematics of the Aptian Ammonoidea is still at a very preliminary stage due to the lack of modern taxonomic revision taking in consideration intraspecific variation and sexual dimorphism. This is especially true for the Douvilleiceratidae and Acanthohoplitidae, for which a plethora of typological species was introduced over the years (see lists in Klein and Bogdanova, 2013). Moreover, there is hardly any agreement among authors regarding the limits and content of *Colombiceras* Spath, 1923, *Acanthohoplites* Sinzow, 1908; *Protacanthoplites* Tovbina, 1970; *Nolaniceras* Casey, 1961; *Hypacanthoplites* Spath, 1923; *Procheloniceras* Spath, 1923; *Diadochoceras* Hyatt, 1900; *Nodosohoplites* Egoian, 1965 and *Epicheloniceras* Casey, 1954.

Finally, a large number of species are based on material that was collected from condensed beds. This is the case for many key taxa from South-eastern France (Seunes, 1887; Jacob, 1905) and Switzerland (Jacob and Tobler, 1906); and the great majority of the late Aptian faunas from western Caucasus (Egoian, 1965, 1969), northern Caucasus (Sinzow, 1906, 1913; Nikchitch, 1915), Dagestan (Anthula, 1900; Kazansky, 1914), Georgia (Kvantaliani, 1971, 1972), Turkmenistan (Glazunova, 1953; Tovbina, 1968, 1970, 1982) and Mangyschlak (Sinzow, 1908; Glazunova, 1953). Although the recent contribution of Bogdanova and Mikhailova (2016) clarifies the biostratigraphic distribution of the early late Aptian ammonites of the northern Caucasus and Transcaspia to some extent, the precise range of the latest Aptian faunas remain poorly understood.

The palaeontological study of the Aptian ammonite faunas from the **EAB** deserve extensive taxonomic descriptions that are beyond the scope of the present paper. Selected elements of the fauna that are crucial for the definition of the biostratigraphic scheme are illustrated (Figs. 8 to 11) and their taxonomic assignments are briefly discussed. In most cases, the identifications are based on direct comparison with the originals or plaster casts of the type material from SE France (Seunes, 1887; Jacob, 1905; Kilian and Reboul, 1915), Switzerland (Jacob and Tobler, 1906), Dagestan (Anthula, 1900) and Mexico (Burckhardt, 1925; Humphrey, 1949). A deliberate choice has been made to reduce synonymies to a limited number of key specimens. Emphasis has been taken on material from Morocco previously illustrated in the literature. Unless otherwise mentioned the suprageneric classification retained herein follows the nomenclature of Wright et al. (1996).

Order Ammonoidea Zittel, 1884
Suborder Ancyloceratina Wiedmann, 1966
Superfamily Douvilleiceratoidea Parona and Bonarelli, 1897
Family Douvilleiceratidae Parona and Bonarelli, 1897

Comment. For the reasons exposed by Bulot in Vincent et al. (2010, p. 184), Cheloniceratinae Spath, 1923 is herein considered as a junior subjective synonym of the subfamily Douvilleiceratinae.

Subfamily Douvilleiceratinae Parona and Bonarelli, 1897
Genus *Procheloniceras* Spath, 1923

Type species. Ammonites stobieckii d'Orbigny, 1850, p. 113.

Procheloniceras dechauxi (Kilian and Reboul, 1915)
Figure 8.7–12

Holotype. *Douvilleiceras Martinii* var. *Dechauxi* Kilian and Reboul, 1915, p. 56, pl. 1, fig. 7, 7b, pl. 7, fig. 2. The specimen is housed in the Université de Grenoble collections (catalogue number UJF-ID.1084).

Remarks. The genus *Procheloniceras* was reported on various occasions from the Tamzergout Fm. of the **EAB**. According to Roch (1930), *Procheloniceras pachystephanum* (Uhlig, 1883) is the most common species with *P. albrechtiaustriae* (Uhlig, 1883). Additionally, *P. stobieckii* (d'Orbigny, 1850) was reported by Rey et al. (1986a, 1988). None of the specimens quoted by those authors were illustrated. The well-preserved and abundant material collected at Tamanar and Zem Zem questions those identifications. Even though a full revision of the genus is needed, the recent contributions of Delanoy (1995, 1998) and Delanoy et al. (2008) has helped to clarify the systematics of *Procheloniceras*. Our material differs from *P. pachystephanum* and *P. albrechtiaustriae* by its smaller umbilicus, more depressed whorl section, and rigid and regular ornamentation. Most Moroccan specimens (Fig 8.7–10) match the holotype of *Procheloniceras dechauxi* well. The variability of the populations includes a slender morphology (Fig. 8.11–12) that superficially matches the lectotype of *P. stobieckii* illustrated by Conte (1981) and Ropolo et al. (2008a).

Genus *Epicheloniceras* Casey, 1954

Type species. *Douvilleiceras Tschernyschewi* Sinzow, 1906, by original designation.

Epicheloniceras gr. *subbuxtorfi – paucinodum* (Burckhardt, 1925)
Figure 9.1–8.

v 1930. *Douvilleiceras buxtorfi* Jacob and Tobler; Roch, p. 381, pl. 19, fig. 1a–d.

v 1930. *Douvilleiceras aequicostatum* Burckhardt; Roch, p. 381, pl. 20, fig. 1a–b.

1998. *Cheloniceras (Epicheloniceras)* gr. *martinioides* Casey; Witam, p. 356, pl. 7, fig. 2–6.

Remarks. Epicheloniceras is a fairly common element of the late Aptian ammonite faunas of the **EAB**. It is noteworthy that the large population from Tiskatine (bed **TK 161A**) can easily be distinguished from the *Epicheloniceras* of the *martini* (d'Orbigny, 1841) and *buxtorfi* (Jacob and Tobler, 1906) groups by the early loss of the ventral tubercles, simplified ornamentation and highly distinctive subrounded whorl section. The various morphotypes show close similarities with *Epicheloniceras paucinodum* (Burckhardt, 1925), *E. subbuxtorfi* (Burckhardt, 1925) and *E. aequicostatum* (Burckhardt, 1925). This affinity with the Mexican taxa was already recognised by Roch (1930, p. 381).

"*Epicheloniceras*" *marocanus* (Roch, 1930)

Figure 9.25–28.

v 1930. *Parahoplites* (?) *marocanus* Roch, p. 378, pl. 16, fig. 5–6.

Lectotype. *Parahoplites* (?) *marocanus* Roch, 1930, pl. 16, fig. 5 (UJF-ID.1601), herein designated.

Type locality. Tiskatine (= Djebel Tissakatine in Roch, 1930).

Description. Small–sized planulate ammonites (Dmax ≤ 50mm) with a moderately evolute coiling. Earliest ontogeny unknown. On the adult whorl, the whorl section is depressed, sub-rounded and becomes progressively compressed, sub-rectangular and is higher than it is wide. The venter is moderately flattened and becomes rounded near the aperture. The umbilical wall is rounded and tends to become steep in the adult. The suture line is unknown. Two ornamental stages on the adult whorl:

(*i*) alternation of tuberculate primary and one to two atuberculate secondary ribs. Small rounded tubercles occur on the upper part of the flank and divide into two branches. All ribs cross the venter but the adoral branches bear small thickenings on the ventrolateral margin;

(*ii*) abrupt change toward spaced, simple ribs with rare secondaries. Ribs are slightly flexuous or straight with a marked apertural bending on the upper part of the flank. All ribs cross the venter forming an elevated proverse bending.

Remarks. This micromorphic species is provisionally assigned to *Epicheloniceras*. Derivation from an *Epicheloniceras* stock is based on the similarity of its early ontogenetic stages with the juveniles of the *Epicheloniceras* of the *waageni* (Anthula, 1900) – *tschernyschewi* (Sinzow, 1906) group that occur in underlying level (see Fig. 9.29-32).

Family Deshayesitidoidea Stoyanow, 1949

Family Deshayesitidae Stoyanow, 1949

Genus *Deshayesites* Kazansky, 1914

Type species. *Ammonites Deshayesi* d'Orbigny, 1841, by original designation.

Deshayesites aff. *euglyphus* Casey, 1964 *in* Delanoy (1995)

Figure 8.1–6.

Microconchs

v 1995. *Deshayesites* aff. *euglyphus* Casey, Delanoy, p. 77, pl. 1, fig. 4, pl. 4, fig. 4.

v 1998. *Deshayesites* aff. *euglyphus* Casey, Delanoy, pl. 6, fig. 2, pl. 24, fig. 2 (= Delanoy, 1995, pl. 1 ,fig. 4, pl. 4, fig. 4).

1998. *Deshayesites* aff. *luppovi* Bogdanova, Witam, p. 357, pl. 8, fig. 2.

Macroconchs

v 1995. *Deshayesites* aff. *evolvens* Luppov, Delanoy, p. 77, pl. 3, fig. 1.

Remarks. The Moroccan material includes both microconchs and macroconchs. The microconch forms show an intermediate morphology between *Deshayesites luppovi* Bogdanova, 1983 and the coarser morphotypes of the *D. forbesi* Casey, 1961 group such as *D. euglyphus* Casey, 1964. They match well the specimens illustrated by Delanoy (1995) as *D.* aff. *euglyphus*. The larger macroconchs compares with specimens from South East France that were most often misidentified as *Deshayesites consobrinus* (d'Orbigny, 1841) (Ropolo et al., 2000a, p. 162-163, fig. 3.2 and 4; Ropolo et al.,2006, pl. 6, fig. 6). The Moroccan specimens are left in open nomenclature and their species assignment will be addressed in a forthcoming contribution once the ongoing revision of the material from South-eastern France is completed.

Superfamily Acanthohoplitoidea Stoyanow, 1949

Remark. Our ongoing revision of the Acanthohoplitidae supports the view that it has no phyletic link with the Parahoplitidae, even so both families derivate iteratively from the Douvilleiceratidae.

Family Acanthohoplitidae Stoyanow, 1949

Genus *Colombiceras* Spath, 1923

Type species. *Ammonites crassicostatus* d'Orbigny, 1841, by original designation.

Colombiceras tobleri (Jacob and Tobler, 1906)

Fig. 9.9-12

v 1930. *Parahoplites teffryanus* Karsten in Anthula; Roch, p. 377, pl. 16, fig. 7.

? 1998. *Colombiceras* aff. *tobleri* Jacob and Tobler; Witam, p. 362, pl. 10, fig. 5.

Remarks. Among the material from Morocco two morphologies can be distinguished. The most common is a compressed and finely ribbed morphotype with rectangular section and tabulate venter (Fig. 9.9–10). It somewhat bears a similarity to *Colombiceras crassicostatum* (d'Orbigny, 1841) and *Gargasiceras gargasense* (d'Orbigny, 1841) but the early ontogeny differs by having a distinct ribbing pattern where all the ribs appears single or by pairs on the umbilical margin and cross the venter without weakening. The other morphotype is a coarsely ribbed form that shows a rounded rectangular whorl section higher than wide, and a widely spaced alternation of primary and intercalatory ribs. It closely matches the lectotype of *Colombiceras discoidale* (Sinzow, 1908, pl. 5, fig. 17–18) at similar growth stages. In our opinion the slender and coarse morphotypes are conspecific and are linked by intermediate forms such as the specimen illustrated on Figure 9.9–11. Since the examination of a large number of specimens from South-eastern France has convinced us that *Colombiceras discoidale* represent a compressed morphotype of *C. tobler*i, the Moroccan specimens are considered to fall within the range of variation of the later species. It should be noted that the lectotype of *C. tobleri* notably differs from our material by its rounded section throughout ontogeny.

Genus *Acanthohoplites* Sinzow, 1908

Type species. *Parahoplites aschiltaensis* Anthula, 1900, by subsequent designation (Roman, 1938).

Remarks. Re-examination of Anthula's type material leaves no doubt that the lectotype designated by Dimitrova (1967, p. 185) is the microconch of the large specimen illustrated by Anthula (1900, pl. 10, fig. 4, pl. 11, fig. 1). Our material includes a series of individuals that match the macroconch well. Even though the large specimen illustrated on Figure 11.1-2 does not show the characteristic juvenile ornamental stage of *A. aschiltaensis*, complete material from other sections support its specific identification. The very large adult body chambers, which are characterized by a rigid adult ornamentation, and were collected from bed **MR 10t** and **11** at Mramer, are left in open nomenclature.

Genus *Protacanthoplites* Tovbina, 1970

Type species. Parahoplites abichi Anthula, 1900, by original designation.

Remarks. The genus has been variously interpreted since its introduction by Tovbina (1970) and some authors suggest that it could be a junior subjective synonym of *Acanthohoplites* (Wright et al., 1996, Bogdanova and Mikhailova, 2016). Comparison of the lectotypes of *A. aschiltaensis* and *P. abichi* shows that the two species are fairly close but the material at our disposal does not allow yet a definitive conclusion regarding synonymy. For the time being, we maintain the genus *Protacanthoplites* to accommodate the Moroccan specimens, that occur above the last occurrence *Acanthohoplites aschiltaensis*, and closely match *P. abichi* (Fig. 9.17–20), *P. bergeroni* (Seunes, 1987) and "*Protacanthoplites*" aff. *multinodosus* Tovbina, 1982 (Fig. 9.13–16).

Genus *Diadochoceras* Hyatt, 1900

Type species. *Ammonites nodosocostatus* d'Orbigny, 1841, by original designation.

Remarks. Specimens of *Diadochoceras* from the type locality of *D. nodosocostatum* are fairly numerous in the French historical collections (Obata, 1975), but our understanding of the genus is largely handicapped by the condensed character of faunas and the absence of a proper revision of the type species that is based on a single poorly preserved juvenile specimen (neotype designed by Guerin-Franiatte in Gauthier et al., 2006). Examination of the topotype material strongly suggest that the large number of new taxa introduced by Glazunova (1953), Mikhailova (1963), Egoian (1965, 1969) and Kvantaliani (1971, 1972) merely represent sexual dimorphism and intraspecific variation. This high variability is reflected by the Moroccan specimens and assignment to a *Diadochoceras nodosocostatum* group was preferred to identification of specific typologic taxa (Fig. 9.21-22).

Genus *Nodosohoplites* Egoian, 1965

Type species. *Nodosohoplites subplanatus* Egoian, 1965, by original designation.

Remarks. As pointed out by Klein and Bogdanova (2013), there is no agreement in the literature about the validity and content of *Nodosohoplites*. Wright et al. (1996) consider that the genus is a junior subjective synonym of *Diadochoceras*. Szives et al. (2007) suggest that some of the specimens that were placed in *Nodosohoplites* by Egoian (1965) are sexual dimorphs of *Diadochoceras*. Our material shows that the planulate forms with a reduced trituberculate ornamental stage similar to *Nodosohoplites subplanatus* and *N. multispinatus* (Anthula, 1900) appear at a slightly younger stratigraphical level than the first occurrence of *Diadochoceras* of the *nodosocostatum* group. Pending a global revision of *Diadochoceras* and *Nodosohoplites* based on abundant and stratigraphically well-documented populations we prefer to keep the two genera separate.

Genus *Elsaella* gen. nov.

Derivation of name. Dedicated to Elsa Schnebelen-Bulot for her participation to our field investigations in Morocco and continuous support to one of us (L.G.B.) during the preparation of this work.

Type species. *Elsaella tiskatinensis* sp. nov., by monotypy.

Diagnosis. Small–sized (D ≤ 45–50 mm), planulate ammonite with a moderately evolute coiling. Sub-rounded whorl section in the juvenile becomes sub-rectangular as growth increases. Venter is rounded throughout ontogeny. Umbilical wall is low to moderately steep at the adult stage. Two ornamental stage (*i*) irregular alternation of simple or bifurcate primary ribs and simple secondaries (D ≤ 15 mm); (*ii*) Uniform and dense ribs originates by pairs or bundles from periumbilical bullae. Bullae strengthen as growth increases and the ribs are more spaced on the outer part of the body chamber. All ribs cross the venter without interruption and slightly bend forward. Aperture is simple. Acanthohoplitid suture line.

Discussion. The genus *Immunitoceras* (type species: *I. immunitum* Stoyanow, 1949) compares superficially to *Elsaella*. The original description and the re-examination of the holotype leave no doubt that the primary ribs are bituberculated at the younger stages and do not compare with the equivalent ontogenetic stages of *Elsaella*. The only other acanthohoplid genus that can be compared with *Elsaella* gen. nov. is *Nolaniceras*. Differences between the type species of the two genera are discussed below.

Elsaella tiskatinensis sp. nov.

Fig. 10.1-16.

1998. *Nolaniceras nolani* Seunes, Witam, p. 361, pl. 9, fig. 7a-b, pl. 10, fig. 1-2 (sol).

1998. *Nolaniceras nolani* var. *planulata* Egoian, Witam, p. 361, pl. 10, fig. 3a-b (sol).

Holotype. (MANCH) LL.16123, (Fig. 10.1-2).

Paratypes. (MANCH) LL.16124 – LL.16131, (Fig. 10.3-16).

Type locality. Tiskatine, Essaouira-Agadir Basin, Morocco.

Type strata. Bed **TK206**, *Elsaella tiskatinensis* Zone (see definition below), upper Aptian.

Diagnosis. As for the genus.

Discussion. *Elsaella tiskatinensis* sp. nov. has been misidentified as *Nolaniceras nolani* in the Moroccan literature (Rey et al. 1986a, 1988, Witam 1998, Peybernes et al. 2013). In a recent revision, Bulot et al. (2014) have shown that *Nolaniceras nolani* differs from all other uppermost Aptian Acanthohoplitidae by its highly distinctive low and convex umbilical wall and most unusual ornamental style. Compared to *Elsaella tiskatinensis* sp. nov., *Nolaniceras nolani* can be distinguished by its compressed suboval whorl section throughout ontogeny, the absence of umbilical bullae and attenuation of the ribbing on the venter.

Remarks. The late upper Aptian Moroccan faunas also includes a coarser and larger forms of *Elsaella* that compare with *Acanthoceras bigoti* Seunes (1887) and *Acanthoceras migneni* Seunes (1887). These two species have been diversely interpreted in the literature and remain poorly understood since it seems that the originals from the Mignen collection are lost. The coarser forms of *Elsaella* that dominates the assemblages at Mramer and Zem Zem are provisionally referred as *Elsaella* sp. 1

and sp. 2. More work is needed to determine if these forms represent ecological morphotypes of *E. tiskatinensis* or new taxa.

Geographical and stratigraphical distribution. Since *E. tiskatinensis* is a very common ammonite in the lower part of the late upper Aptian of the **EAB**, it is selected herein as the index species of the *E. tiskatinensis* Zone. Outside Morocco, and despite an extensive survey of the literature, none of the specimens previously referred to *Nolaniceras nolani* in the literature can be assigned with certainty to our new species.

Genus *Hypacanthoplites* Spath, 1923

Type species. *Acanthoceras Milletianum* Var. *plesiotypica* Fritel, 1906, by original designation.

Remarks. Problems with the systematics of the genus *Hypacanthoplites* have been addressed at length by Bulot (2010). The genus was reported on many occasions in the Moroccan literature (Rey et al. 1986a, 1988, Witam 1998, Peybernes et al. 2013). Our new collection shows that hypacanthoplid-like ammonites occur at two different levels in the **EAB**.

The older fauna is preserved as small pyritic internal moulds that occur above the *Elsaella* beds at Tiskatine, Tamanar, and Zem Zem. Those forms are provisionally placed in "*Hypacanthoplites*" and left in open nomenclature as sp. 1, sp. 2 and sp. 3. They all show a very clear tabulate venter associated with a weakening of the ribs on the siphonal line. Even though there is a reinforcement of the ribs on both sides on the ventral shoulder; this feature is not as marked as in true *Hypacanthoplites*. The ornamental style of the very finely ribbed "*Hypacanthoplites*" sp. 1 (Fig. 11.15-25) suggests evolution from *Elsaella tiskatinensis*. To the difference "*Hypacanthoplites*" sp. 3 (Fig. 11.3-11) shows a very distinct bituberculate ontogenetic stage that somehow recalls the ornamentation of *Hypacanthoplites tuberculatus* Egoian, 1969 and *H. microtuberculatus* Egoian, 1969.

Higher up in the succession, a collection of specimens that match the type material of *Mellegueiceras chihaouiae* Latil, 2011 and "*Hypacanthoplites*" *paucicostatus* Breistroffer in Dubourdieu, 1953 was made. This fauna will be described in a separate paper and its early Albian age is established by the co-occurrence of the genus *Douvilleiceras*. It should be noted that the fragments identified by Witam (1998, pl. 9, fig. 4-6) as *Hypacanthoplites* gr. *jacobi* (Collet, 1907) are merely misidentified "*Hypacanthoplites*" *paucicostatus*.

5. Ammonite biostratigraphy and correlation to the Standard Mediterranean Ammonite Scale (SMAS)

As shown by the systematic notes, the ammonite faunas from the **EAB** have a distinct character that is most certainly linked to the palaeogeography of the basin. Although the successive assemblages are clearly of Tethyan affinity, none of the index species of the Standard Mediterranean Ammonite Scale (**SMAS**) of Reboulet et al. (2011, 2014) were found in the course of our study. As a consequence, we have chosen to introduce a regional biostratigraphic scale based on the main bio-events recognized at the basin scale (Fig. 12). When possible correlations with the **SMAS** are proposed, the precision of these correlations is handicapped by the fact, that for the upper part of Aptian Stage, the biostratigraphic subdivision of the **SMAS** is largely based on assemblage zones and subzones originally defined in the former Soviet Union (Bogdanova and Tovbina, 1995) for which detailed successions are still poorly documented.

Lower Aptian – *Procheloniceras dechauxi* Zone, new this paper

Index species. *Procheloniceras dechauxi* (Kilian and Reboul, 1915)

Reference section. Tiskatine – bed **TK 159** to **TK 160b**.

Definition. The base of the zone is defined by the first occurrence of the index–species that largely dominates the assemblage in all studied sections. The diversity is low but some beds are rich in *Deshayesites* aff. *euglyphus* Casey in Delanoy (1995). It should be noted that *P. dechauxi* and *D.* aff. *euglyphus* are most often mutually exclusive. *Audouliceras* sp. ind., *Pseudohaploceras* cf. *matheroni* (d'Orbigny, 1841) and *Melchiorites melchioris* (Tietze, 1872) are minor elements of the fauna.

Correlations. Correlation with the **SMAS** is based on the occurrence of *P. dechauxi* and *D.* aff. *euglyphus*. These two taxa are known to occur in the lower part of the *Deshayesites forbesi* Zone in South East France (Delanoy, 1995, 1998; Pictet, 2012).

Upper Aptian – *Colombiceras tobleri* Zone, Eristavi (1960) emended.

Index species. *Colombiceras tobleri* (Jacob and Tobler, 1906)
Reference section. Tiskatine – bed **TK 161a** to **TK 183c**.

Definition. Since its first introduction, the *Colombiceras tobleri* Zone was variously interpreted in the literature (see discussion in Bogdanova and Mikhailova, 2016). As herein understood, the zone is defined by the first occurrence of its index–species. Two subzones can be distinguished in the **EAB**.

Colombiceras tobleri Subzone, new, this paper

Index species. As for the zone.
Reference section. Tiskatine – bed **TK 161a** to **TK 163**.

Definition. The base of the subzone is defined by the first occurrence of the index–species. The diversity of the fauna is fairly high. Together with the index species, the various *Epicheloniceras* of the s*ubbuxtorfi – paucinodum* group are the most common elements of the faunal assemblage. Desmoceratids are unusually common compared to the rest of the succession. *Pseudohaploceras angladei* Dutour, 2005 non (Sayn, 1891), *Zuercherella zuercheri* (Jacob and Tobler, 1906), *Melchiorites* aff. *emerici* (Raspail, 1831) and *Caseyella* sp. ind. were identified. The heteromorph taxa "*Ammonitoceras*" *lahuseni* (Sinzow, 1906) and ? *Pseudoaustraliceras* sp. are minor elements of the fauna. A single phylloceratid tentatively assigned to *Phylloceras* sp. was collected.

"*Epicheloniceras*" *marocanus* Subzone, new, this paper

Index species. "*Epicheloniceras*" *marocanus* (Roch, 1930)
Reference section. Tiskatine – bed **TK 164** to **TK 183c**.

Definition. The base of the subzone is defined by the first occurrence of the index–species. The diversity of the fauna is very low. The lower part of the subzone is marked the acme of "*Epicheloniceras*" *marocanus* and its upper part correspond to a barren interval. The last occurrence of *C. tobleri* is to be noted at the base of the subzone. In the barren interval, spot occurrence of *Epicheloniceras* of the *waageni* (Anthula, 1900) – *tschernyschewi* (Sinzow, 1906) group was identified.

Correlations. Because of the highly endemic character of the fauna, a precise correlation with the **SMAS** is hard to establish. A provisional correlation between the base of the *C. tobleri* Zone of Morocco and the base of the *E. gracile* Subzone (*E. martini* Zone) can be proposed on the basis of the evolution of the genus *Colombiceras* in SE France (Bulot in Dauphin 2002), Caucasus and Transcaspia (Bogdanova and Mikhailova, 2016). Due to the somehow “primitive” character of the

Moroccan *C. tobleri* a slightly older position in the *E. martini* Zone cannot be excluded. Ongoing study of the large collection of *Epicheloniceras* should allow more precise correlation in the future.

Upper Aptian – *Acanthohoplites aschiltaensis* Zone, Mordvilko (1960) emended.

Index species. *Acanthohoplites aschiltaensis* (Anthula, 1900). First

Reference section. Tiskatine – bed **TK 184** to **TK 205**.

Definition. Since its introduction, the *Acanthohoplites aschiltaensis* Zone has had a number of interpretations in the literature (see discussion in Bogdanova and Mikhailova, 2016). As herein understood the zone is defined by the first occurrence of the index–species. The diversity is very low but a distinctive horizon rich in *Pseudoaustraliceras* of the *ramososeptatum* (Anthula, 1900) group (Fig. 9.23 – 24) was identified in the middle part of the zone. The geographical extension of this bio-event at the scale of the basin remains unknown. In the marginal areas of the **EAB**, the occurrence of large *Epicheloniceras* that do not match any species of the literature is also to be noted. The precise range and affinities of those specimens are still to be documented.

Correlations. The precise range of *A. aschiltaensis* has never been precisely calibrated with the **SMAS** zones. Data from South-eastern France suggests that the lowest occurrence of the *Acanthohoplites* of the *aschiltaensis* group occurs in the uppermost part of the *E. martini* Zone close to its boundary with the *P. melchioris* Zone (Bulot in Dauphin, 2002; Frau and Bulot, unpublished data). According to Russian literature, *A. aschiltaensis* is a common element of the *P. melchioris* Zone (Bogdanova and Mikhailova, 2016, with references).

Upper Aptian – *Elsaella tiskatinensis* Zone, new this paper

Index species. *Elsaella tiskatinensis* gen. nov. sp. nov.

Reference section. Tiskatine – bed **TK 206** to **TK 247**.

Definition. The zone is defined by the first occurrence of the genus *Elsaella*. Two subzones can be distinguished.

Elsaella tiskatinensis Subzone, new this paper

Index species. As for the zone.

Reference section. Tiskatine – bed **TK 206** to **TK 220**.

Definition. The first occurrence of the genus *Elsaella* marks the base of the subzone. In all studied sections the fauna is marked by the evolutive radiation of the Acanthohoplitidae. The various morphologies of *Elsaella* dominate in the lower part of the subzone. In the upper part of the subzone a fairly diverse assemblage of Acanthohoplitidae develops and includes *Diadochoceras* of the *nodosocostatum* group, *Nodosohoplites* of the *subplanatus* group, and various species of P*rotacanthoplites*. *Epicheloniceras clansayense* (Jacob, 1905) is a secondary element of the fauna in the marginal parts of the **EAB**.

"*Hypacanthoplites*" spp. Subzone, new this paper

Index species. Hypacanthoplitids with a tabulate venter ("*Hypacanthoplites*" sp. 1, "*H.*" sp. 2 and "*H.*" sp. 3).

Reference section. Tiskatine – bed **TK 221** to **TK 247**.

Definition. The fauna is dominated by "*Hypacanthoplites*" sp. 1, "*H.*" sp. 2 and "*H.*" sp. 3 but also contains relict elements from the underlying subzone such as *Protacanthoplites abichi* and *Nodosohoplites gr. subplanatus*. Other noteworthy taxa are *Pseudosilesites seranoniformis* Egoian, 1969 (Fig.11.12-14), *Puzosiella minuta* Egoian, 1969 and *Melchiorites* ? *problematicus* (Fallot and Termier, 1923).

Correlations. The detailed range of the ammonite faunas of the *A. nolani* Zone of the **SMAS** is still not documented. Nevertheless, it seems reasonable to consider that the first occurrence of *Diadochoceras* in the lower part of the *E. tiskatinensis* Zone suggests a correlation with a level close to the base *D. nodosocostatum* Subzone. Co-occurrence of primitive "*Hypacanthoplites*" spp. and *Pseudosilesites seranoniformis* in the upper part of the *A. nolani* Zone was reported from North-eastern Spain by Robert et al. (2001). This suggests that the base of the *Hypacanthoplites* spp. Subzone is likely older than the base of the *H. jacobi* Zone even so correlation with a slightly younger level cannot be excluded.

In agreement with Latil (2011), the base of the Lower Albian (*M. chihaouiae* Zone) is marked by the co-occurrence of first representatives of the genus *Douvilleiceras* (Fig. 9.33) with *Mellegueiceras chihaouiae*. This boundary is clearly documented at Tiskatine and Mramer. At Mramer, the index species of the overlying lower Albian "*Hypacanthoplites*" *paucicostatus* Zone was also identified.

It should be noted that the beds that contain the first Lower Albian faunas with *Douvilleiceras* (see details below) directly overlie the "*Hypacanthoplites*" spp. Subzone. As a consequence we suspect a hiatus that would embrace the uppermost part of the *H. jacobi* Zone and lower part of the *L. tardefurcata* Zone.

6. Conclusions

High-resolution bed by bed sampling of five sections in the west-central **Essaouira Agadir Basin (EAB)** has yielded the largest Aptian published ammonite collection in NW Africa. The results provide new information on the age range of previously defined formations, and a type section with fully documented collections correlated against type species. In addition, new species have been identified and the collections provide new insights into the regional endemism of species in this part of NW Africa.

The main conclusions from the study are:

- A diverse Aptian and early Albian ammonite fauna is documented, comprising 26 different genera and 43 species.
- The global palaeobiogeographic character of the fauna is Tethyan, however a high degree of endemism is recognised at the genus and species level.
- A new genus and species *Elsaella tiskatinensis* is described.
- New material also allows re-examination of *Parahoplites marocanus,* provisionally included in the genus *Epicheloniceras*.
- Based on the ammonite distribution a regional biostratigraphic scale is introduced for the Aptian of the **EAB.** 8 zones and subzones are recognised, 5 of which are new.
- The section at Tiskatine [Lat.: 30.821463° Long.: -9.702555° (Tiskatine 1) and Lat.: 30.810477° Long.: -9.739966° (Tiskatine 2)] is selected as the type section for the Aptian in the west-central part of the **EAB**. Key taxa are documented, illustrated with collection references. A correlation based on first occurrence of common taxa with the **Standard Mediterranean Ammonite Scale (SMAS)** is proposed when possible.
- Two basin-scale regional hiatuses are identified. The lower one encompasses the time equivalent of the middle part of the *D. forbesi* Zone to lower part of the *E. martini* Zone of

the **SMAS**. The upper one includes the *H. jacobi* Zone and the lowermost part of the *L. tardefurcata* Zone equivalent.

- The age of the Tamzergout Fm. has been clearly defined, ranging from the local and newly introduced *D. dechauxi* to the *E. tiskatinensis* zones
- The top Bouzergoun / base Tamzergout Fm. is identified as being diachronous, ranging in age from the early to late Aptian (*D. dechauxi* to *C. tobleri* zones)
- The improved age dating of the Lemgo Fm. (based on collection from the Mramer section) indicates a range from middle upper Aptian *A. ashiltaensis* Zone to the lowermost Albian "*H.*" *paucicostatus* Zone
- An early Albian age for the base of the Oued Tidzi Fm. is established by the lowest occurrence of the genus *Douvilleiceras*

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Captions ammonite figures

Figure 1. Digital elevation model with sub-crop of geological maps, showing Lower Cretaceous outcrops of the Essaouira Agadir Basin, studied sections and key locations.

Figure 2. Generalised lithostratigraphy of the upper Bouzergoun to lower Oued Tidzi formations, and depositional environments in the west-central part of the EAB.

Figure 3. Tiskatine section. Ammonoid distribution and biostratigraphic interpretation.

Figure 4. Tamanar section. Ammonoid distribution and biostratigraphic interpretation.

Figure 5. Zem Zem section. Ammonoid distribution and biostratigraphic interpretation.

Figure 6. Oued Tlit section. Ammonoid distribution and biostratigraphic interpretation.

Figure 7. Mramer section. Ammonoid distribution and biostratigraphic interpretation.

Figure 8. (1–6) *Deshayesites* aff. *euglyphus* (Casey, 1964) *in* Delanoy (1995) – (1–2) and (5–6) from bed **TK 160** ((MANCH) LL.16103 and (MANCH) LL.16105), (3–4) from bed **TR 70** (MANCH) LL.16104; (7–12) *Procheloniceras dechauxi* (Kilian and Reboul, 1915) from bed **TR 69** ((MANCH) LL.16106 – (MANCH) LL.16108). All specimens coated with ammonium chloride prior to photography. Scale bar is 10mm.

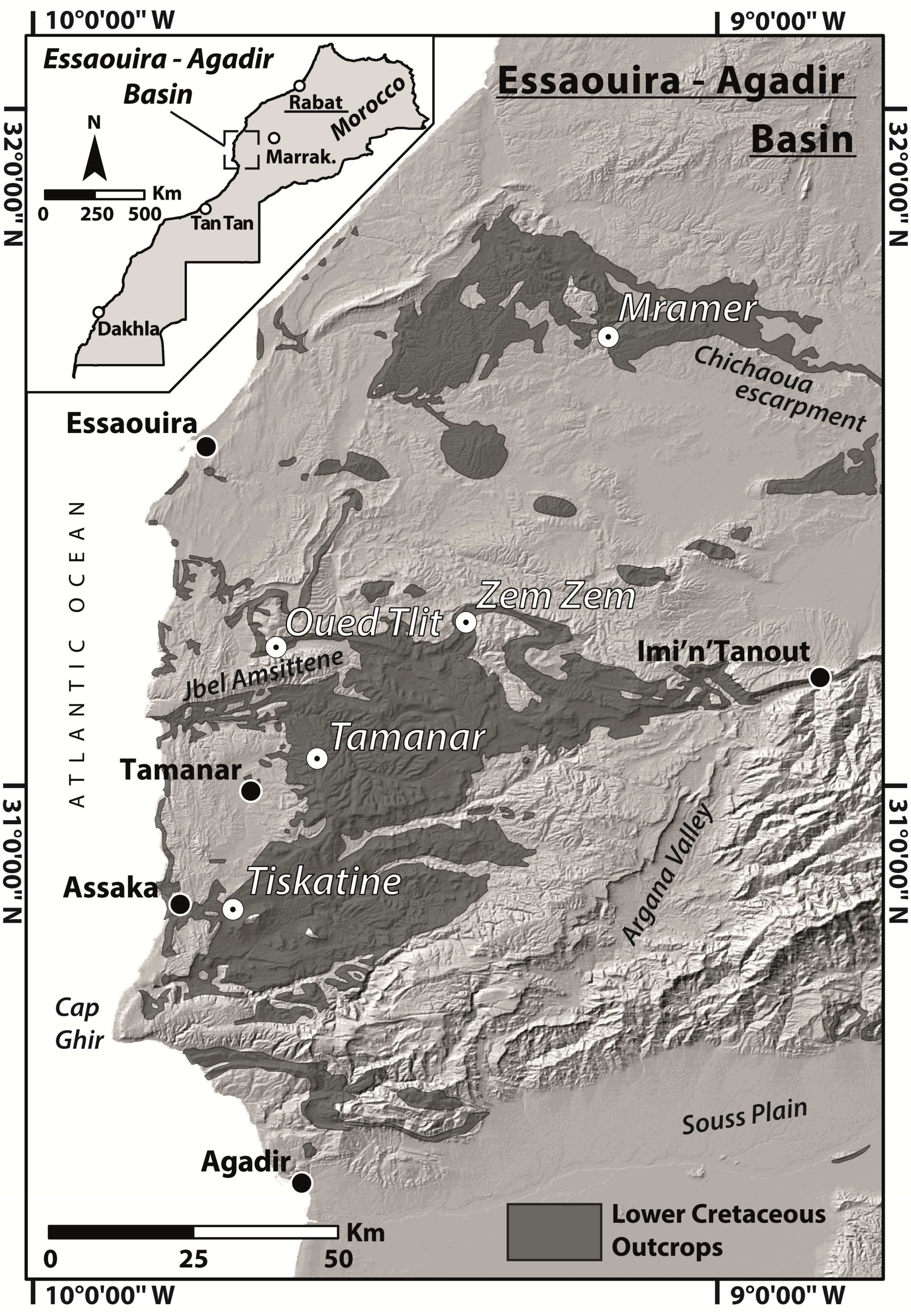
Figure 9. (1–8) *Epicheloniceras* gr. *subbuxtorfi – paucinodum* (Burckardt, 1925) from bed **TK 161A** ((MANCH) LL.16109 – (MANCH) LL.16111); (9–12) *Colombiceras tobleri* (Jacob and Tobler, 1906) from bed **TK 161A** ((MANCH) LL.16112 and (MANCH) LL.16113); (13–16) "*Protacanthoplites*" aff. *multinodosus* (Tovbina, 1982) from bed **TK 206** ((MANCH) LL.16114); (17–20) *Protacanthoplites abichi* (Anthula, 1900) from **TK 212/213** ((MANCH) LL.16115); (21–22) *Diadochoceras* gr. *nodosocostatum* (d'Orbigny, 1841) from bed **TK 206**((MANCH) LL.16116); (23–24) *Pseudoaustraliceras* gr. *ramososeptatum* (Anthula, 1900) from **TK 196** ((MANCH) LL.16117); (25–28)

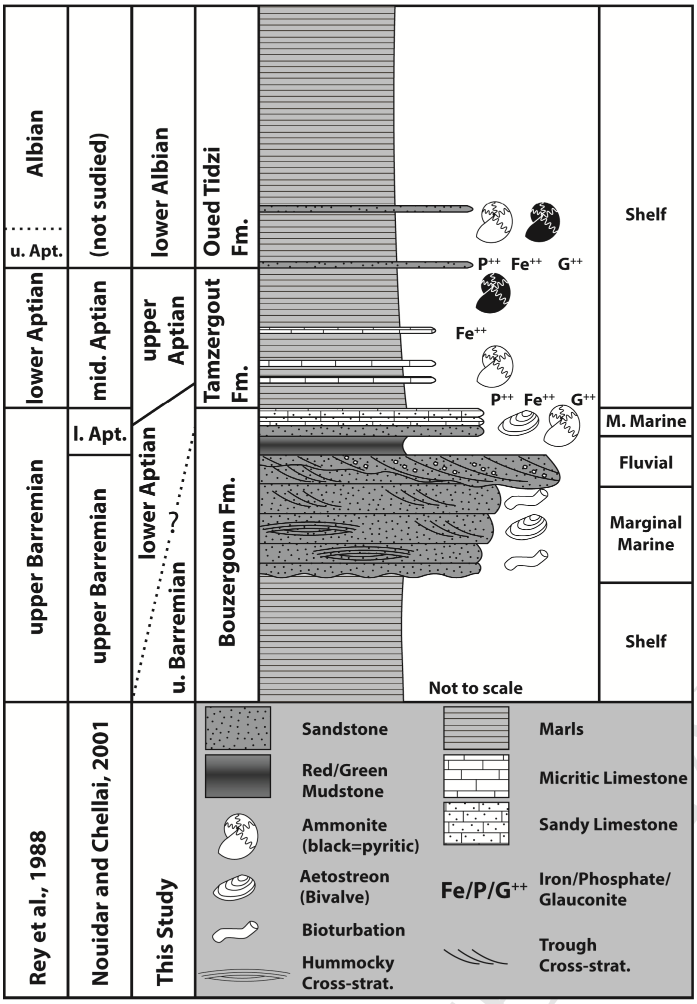
"*Epicheloniceras*" *marocanus* (Roch, 1930) from bed **TK 166** ((MANCH) LL.16118 and (MANCH) LL.16119); (29–32) *Epicheloniceras* sp. juv. 1 gr. *waageni* (Anthula, 1900) – *tschernyschewi* (Sinzow, 1906) from bed **TK 163** (MANCH) LL.16120 and (MANCH) LL.16121); (33) *Douvilleiceras* cf. *leightonense* (Casey, 1962) from bed **TK 248** ((MANCH) LL.16122). All specimens coated with ammonium chloride prior to photography. Scale bar is 10mm.

Figure 10. *Elsaella tiskatinensis* gen. and sp. nov. from bed **TK 206** – (1–2) holotype ((MANCH) LL.16123), (3–16) paratypes (MANCH) LL.16124 – (MANCH) LL.16131). All specimens coated with ammonium chloride prior to photography. Scale bar is 10mm.

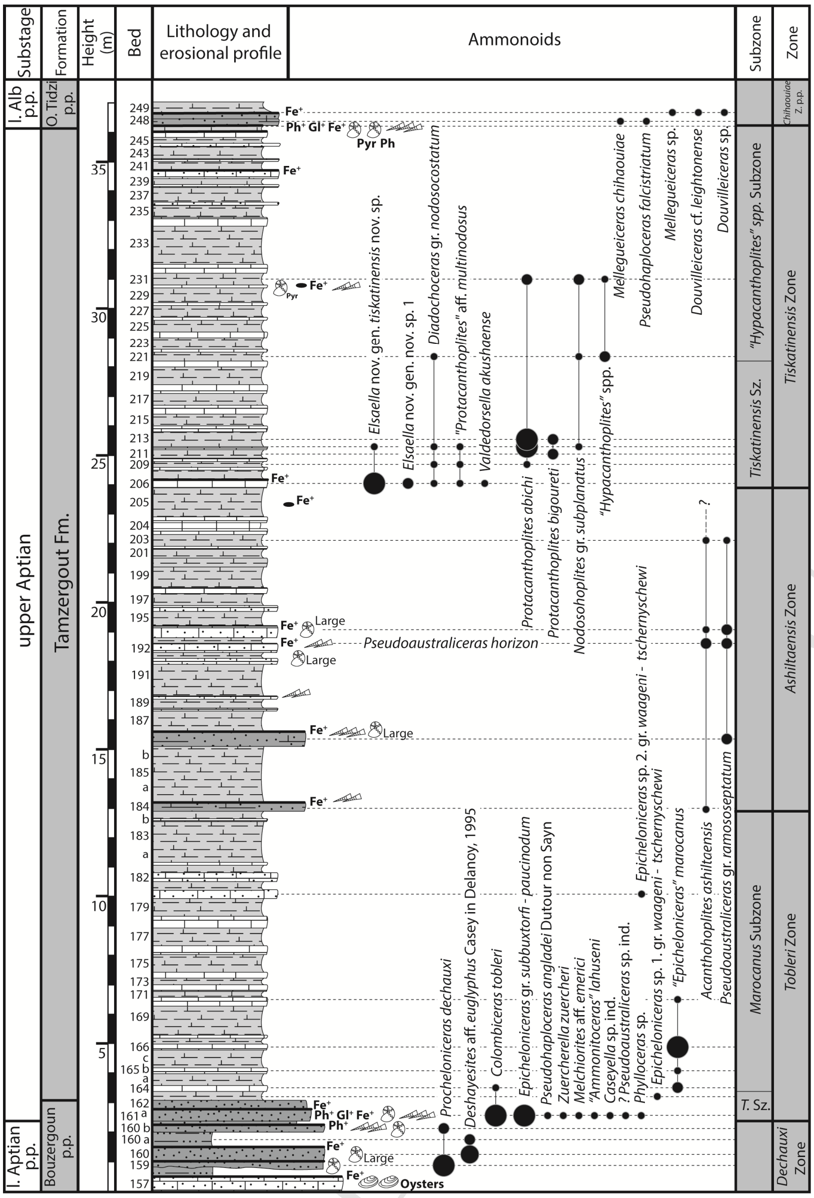
Figure 11. (1–2) *Acanthohoplites aschiltaensis* (Anthula, 1900) from bed **TK 192** ((MANCH) LL.16132); (3–11) "*Hypacanthoplites*" sp. 3 – (3–8) are from bed **ZZ 68** ((MANCH) LL.16133 and (MANCH) LL.16134), (9–11) from bed **TM 80** ((MANCH) LL.16135); (12–14); *Pseudosilesites seranoniformis* (Egoian, 1969) from bed **TM 80** ((MANCH) LL.16136); (15–25) "*Hypacanthoplites*" sp. 1 from bed **TM 80** ((MANCH) LL.16137 – (MANCH) LL.16140). All specimens coated with ammonium chloride prior to photography. Scale bar is 10mm.

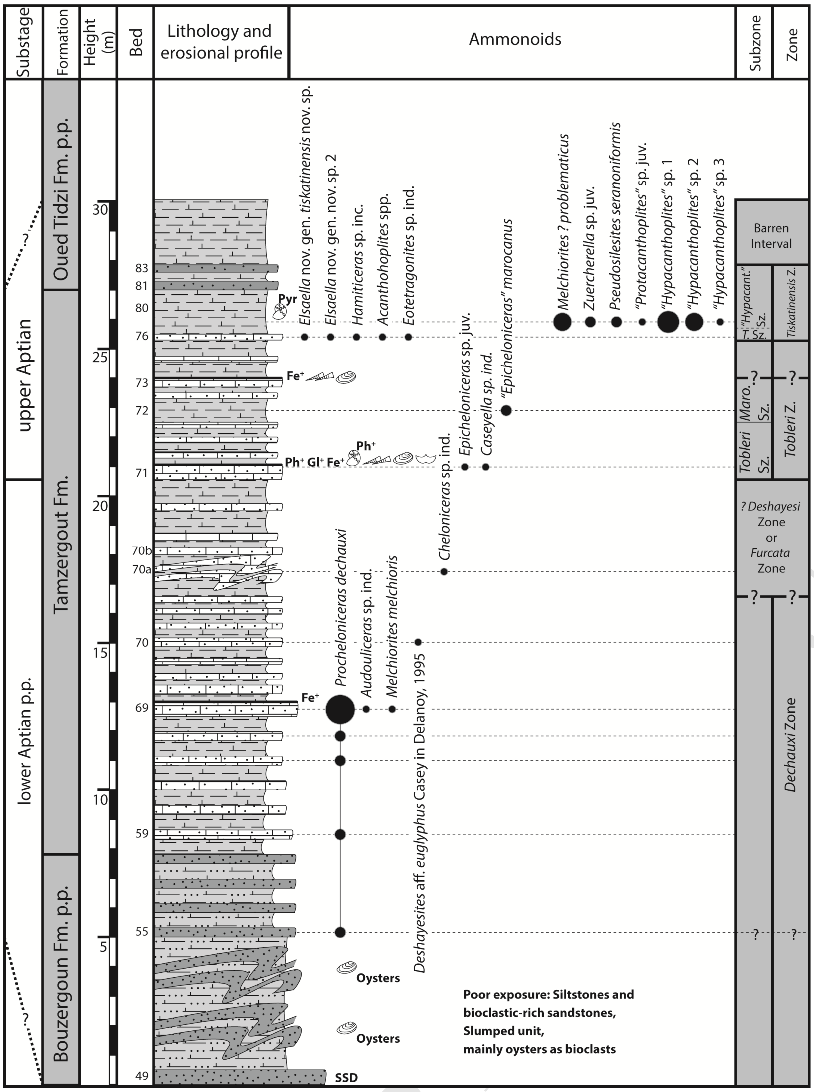
Figure 12. Chart showing correlation between the **EAB** and **SMAS** ammonite scales (**SMAS** zones and subzones after Reboulet et al. 2011, 2014).


10°0'00" W
9°0'00" W
Essaouira - Agadir Basin
Rabat
Morocco
Marrak.
Km
0 250 500
Tan Tan
Dakhla
N
Essaouira - Agadir Basin
32°0'0.00" N
32°0'0.00" N
Mramer
Chichaoua escarpment
Essaouira
ATLANTIC OCEAN
Zem Zem
Oued Tlit
Jbel Amsittene
Imi'n'Tanout
Tamanar
Tamanar
31°0'0.00" N
31°0'0.00" N
Argana Valley
Assaka
Tiskatine
Cap Ghir
Souss Plain
Agadir
Km
0 25 50
Lower Cretaceous Outcrops
10°0'00" W
9°0'00" W

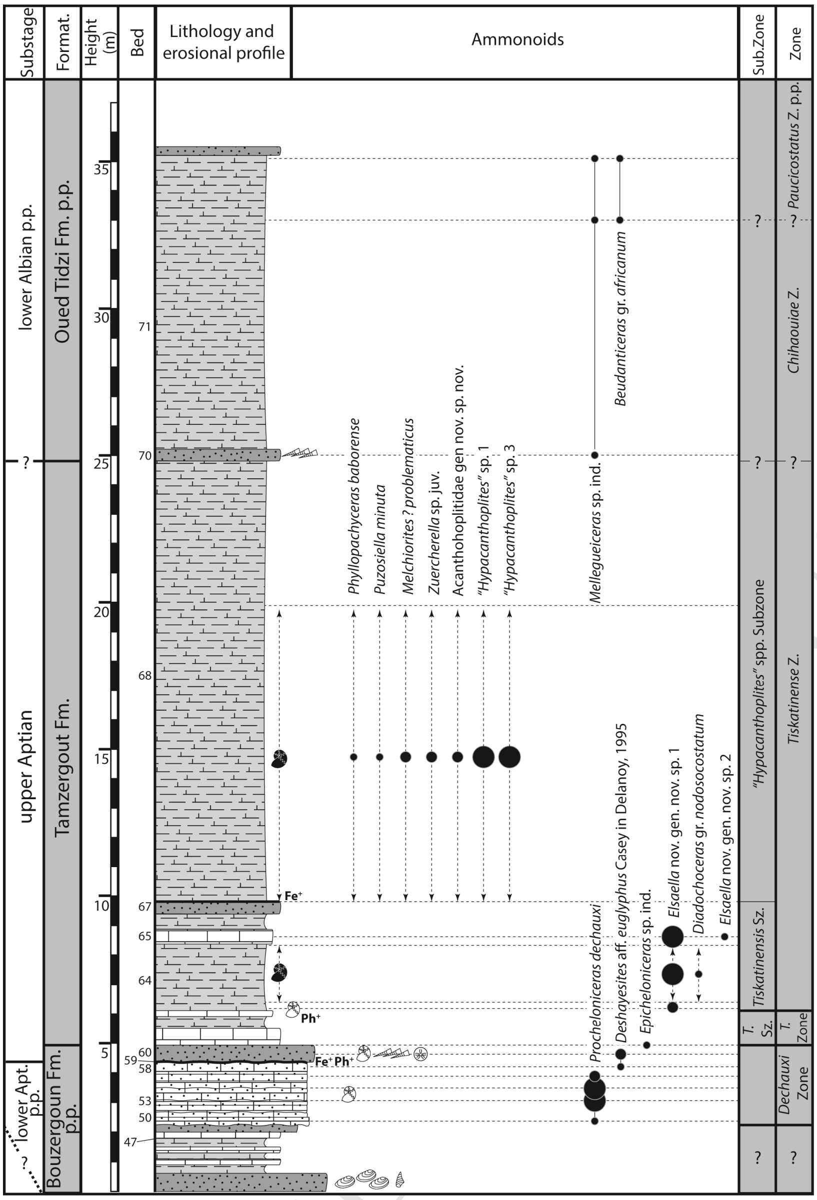


Albian
u. Apt.
lower Aptian
upper Barremian
(not sudied)
mid. Aptian
l. Apt.
upper Barremian
lower Albian
upper Aptian
lower Aptian
u. Barremian
Oued Tidzi Fm.
Tamzergout Fm.
Bouzergoun Fm.
P++ Fe++ G++
Fe++
P++ Fe++ G++
Not to scale
Shelf
M. Marine
Fluvial
Marginal Marine
Shelf
Rey et al., 1988
Nouidar and Chellai, 2001
This Study
Sandstone
Red/Green Mudstone
Ammonite (black=pyritic)
Aetostreon (Bivalve)
Bioturbation
Hummocky Cross-strat.
Marls
Micritic Limestone
Sandy Limestone
Fe/P/G++
Iron/Phosphate/ Glauconite
Trough Cross-strat.

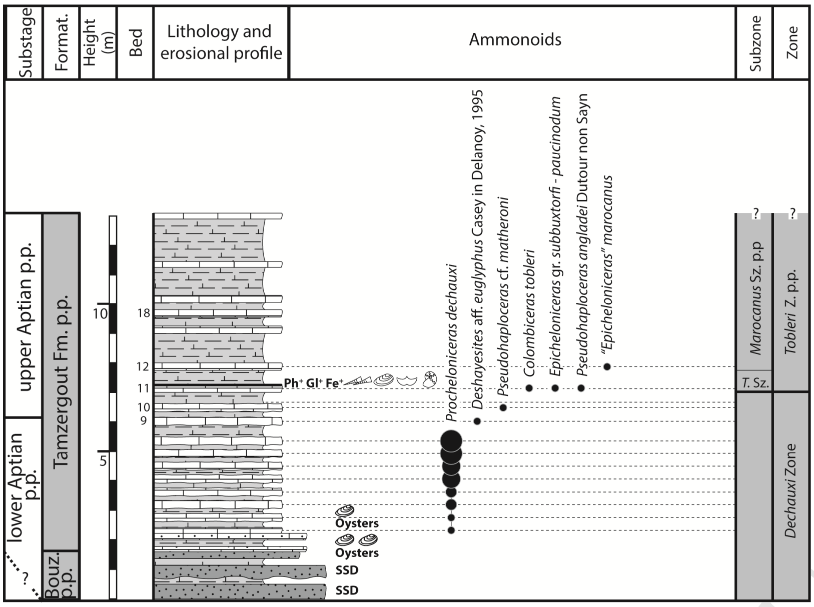

Substage
Formation
Height (m)
Bed
Lithology and erosional profile
Ammonoids
Subzone
Zone
l. Alb p.p.
O. Tidzi p.p.
upper Aptian
Tamzergout Fm.
l. Aptian p.p.
Bouzergoun p.p.
Chihaouiae Z. p.p.
"Hypacanthoplites" spp. Subzone
Tiskatinensis Zone
Tiskatinensis Sz.
Ashiltaensis Zone
Marocanus Subzone
Tobleri Zone
T. Sz.
Dechauxi Zone
Pseudoaustraliceras horizon
Fe+
Ph+ Gl+ Fe+
Pyr Ph
Large
Oysters
Elsaella nov. gen. tiskatinensis nov. sp.
Elsaella nov. gen. nov. sp. 1
Diadochoceras gr. nodosocostatum
"Protacanthoplites" aff. multinodosus
Valdedorsella akushaense
Protacanthoplites abichi
Protacanthoplites bigoureti
Nodosohoplites gr. subplanatus
"Hypacanthoplites" spp.
Mellegueiceras chihaouiae
Pseudohaploceras falcistriatum
Mellegueiceras sp.
Douvilleiceras cf. leightonense
Douvilleiceras sp.
Procheloniceras dechauxi
Deshayesites aff. euglyphus Casey in Delanoy, 1995
Colombiceras tobleri
Epicheloniceras gr. subbuxtorfi - paucinodum
Pseudohaploceras angladei Dutour non Sayn
Zuercherella zuercheri
Melchiorites aff. emerici
"Ammonitoceras" lahuseni
Caseyella sp. ind.
? Pseudoaustraliceras sp. ind.
Phylloceras sp.
Epicheloniceras sp. 1. gr. waageni - tschernyschewi
Epicheloniceras sp. 2. gr. waageni - tschernyschewi
"Epicheloniceras" marocanus
Acanthohoplites ashiltaensis
Pseudoaustraliceras gr. ramososeptatum



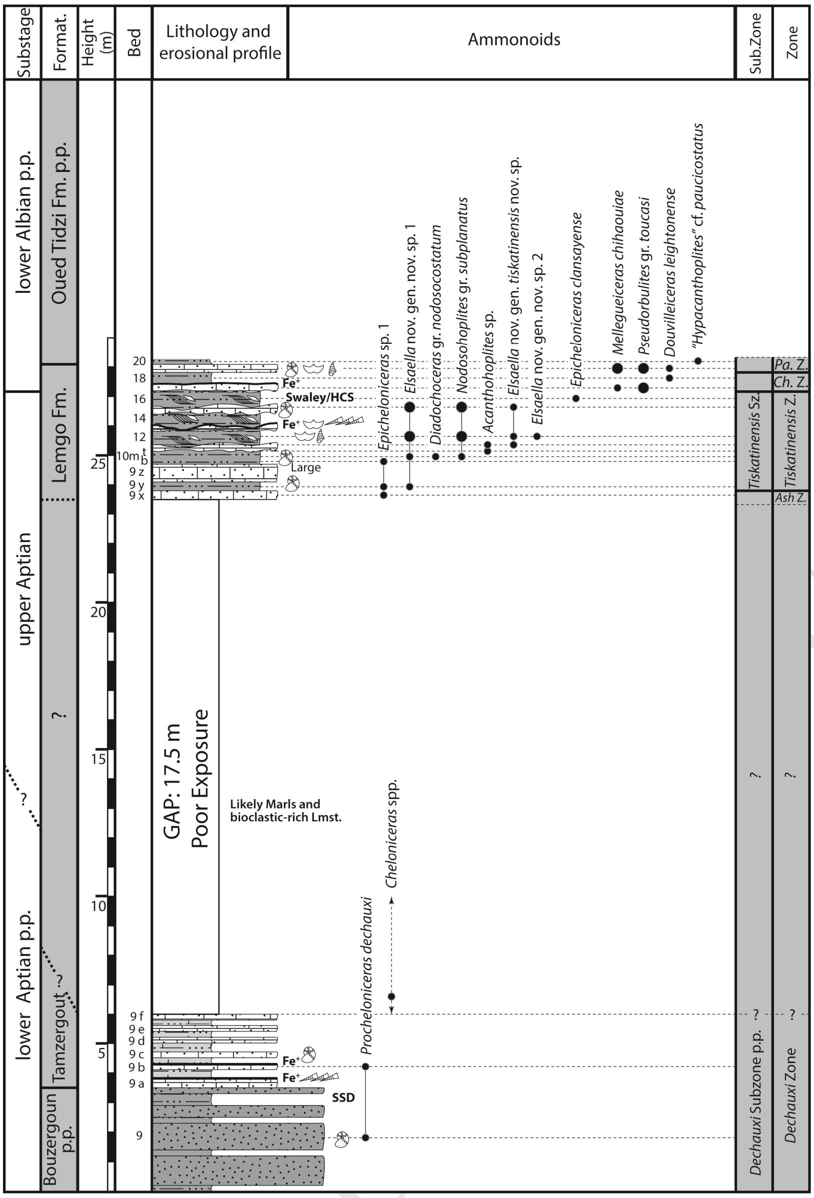
Substage
Formation
Height (m)
Bed
Lithology and erosional profile
Ammonoids
Subzone
Zone
upper Aptian
lower Aptian p.p.
Oued Tidzi Fm. p.p.
Tamzergout Fm.
Bouzergoun Fm. p.p.
Elsaella nov. gen. tiskatinensis nov. sp.
Elsaella nov. gen. nov. sp. 2
Hamiticeras sp. inc.
Acanthohoplites spp.
Eotetragonites sp. ind.
Epicheloniceras sp. juv.
Caseyella sp. ind.
"Epicheloniceras" marocanus
Cheloniceras sp. ind.
Melchiorites ? problematicus
Zuercherella sp. juv.
Pseudosilesites seranoniformis
"Protacanthoplites" sp. juv.
"Hypacanthoplites" sp. 1
"Hypacanthoplites" sp. 2
"Hypacanthoplites" sp. 3
Procheloniceras dechauxi
Audouliceras sp. ind.
Melchiorites melchioris
Deshayesites aff. euglyphus Casey in Delanoy, 1995
Barren Interval
Tiskatinensis Z.
Tobleri Z.
Tobleri Sz.
Maro. Sz.
? Deshayesi Zone or Furcata Zone
Dechauxi Zone
Pyr
Fe+
Ph+ Gl+ Fe+
Ph+
Oysters
Oysters
SSD
Poor exposure: Siltstones and bioclastic-rich sandstones, Slumped unit, mainly oysters as bioclasts



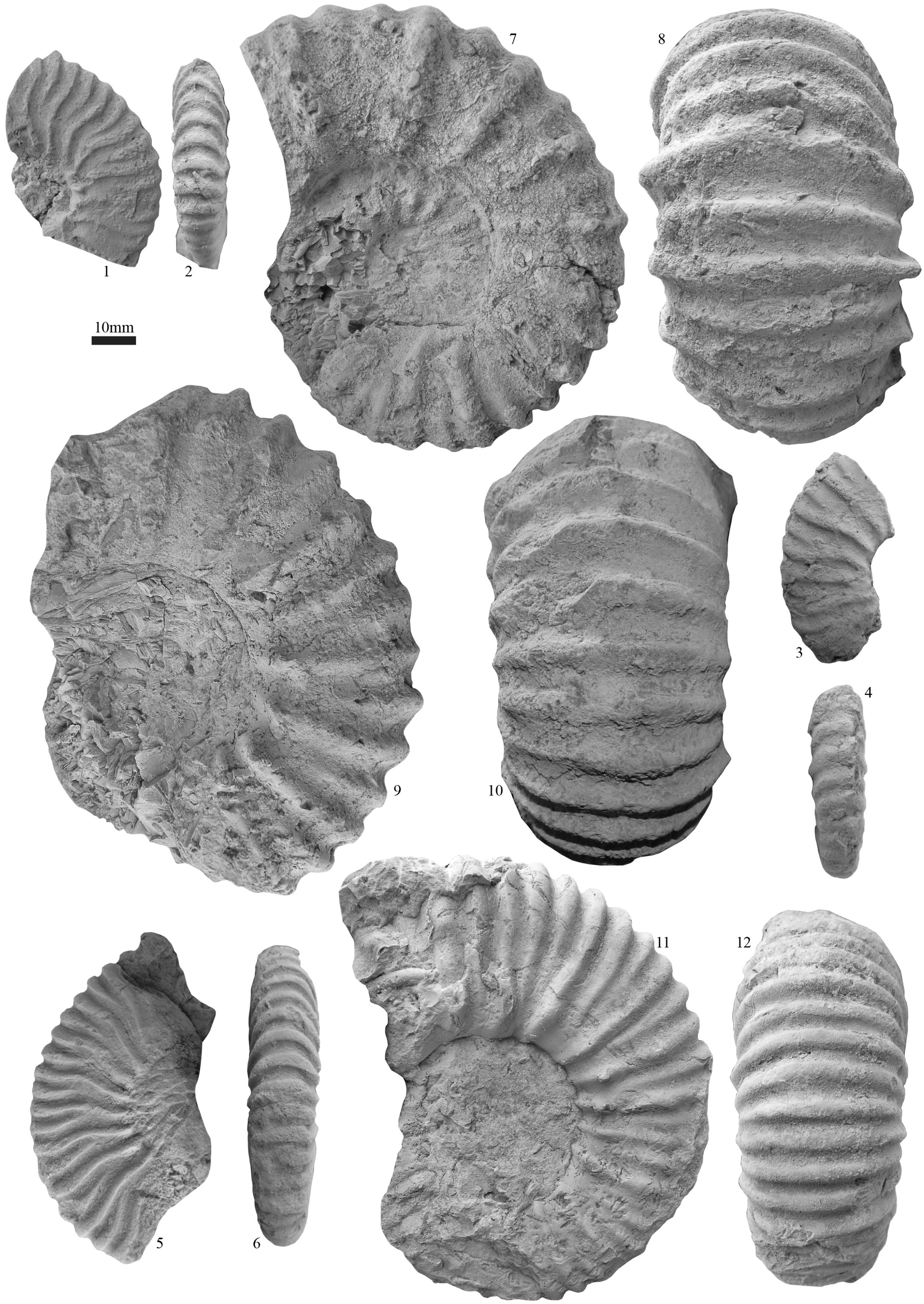
Substage
Format.
Height (m)
Bed
Lithology and erosional profile
Ammonoids
Sub.Zone
Zone
lower Albian p.p.
upper Aptian
lower Apt. p.p.
Oued Tidzi Fm. p.p.
Tamzergout Fm.
Bouzergoun Fm. p.p.
Phyllopachyceras baborense
Puzosiella minuta
Melchiorites ? problematicus
Zuercherella sp. juv.
Acanthohoplitidae gen nov. sp. nov.
"Hypacanthoplites" sp. 1
"Hypacanthoplites" sp. 3
Mellegueiceras sp. ind.
Beudanticeras gr. africanum
Procheloniceras dechauxi
Deshayesites aff. euglyphus Casey in Delanoy, 1995
Epicheloniceras sp. ind.
Elsaella nov. gen. nov. sp. 1
Diadochoceras gr. nodosocostatum
Elsaella nov. gen. nov. sp. 2
Fe⁺
Ph⁺
Fe⁺ Ph⁺
"Hypacanthoplites" spp. Subzone
Tiskatinensis Sz.
T. Sz.
Paucicostatus Z. p.p.
Chihaouiae Z.
Tiskatinense Z.
T. Zone
Dechauxi Zone



Substage
Format.
Height (m)
Bed
Lithology and erosional profile
Ammonoids
Subzone
Zone
upper Aptian p.p.
lower Aptian p.p.
Tamzergout Fm. p.p.
Bouz. p.p.
10
5
18
12
11
10
9
Ph⁺ Gl⁺ Fe⁺
Oysters
Oysters
SSD
SSD
Procheloniceras dechauxi
Deshayesites aff. euglyphus Casey in Delanoy, 1995
Pseudohaploceras cf. matheroni
Colombiceras tobleri
Epicheloniceras gr. subbuxtorfi - paucinodum
Pseudohaploceras angladei Dutour non Sayn
"Epicheloniceras" marocanus
Marocanus Sz. p.p
T. Sz.
Tobleri Z. p.p.
Dechauxi Zone



Substage
Format.
Height (m)
Bed
Lithology and erosional profile
Ammonoids
Sub.Zone
Zone
lower Albian p.p.
upper Aptian
lower Aptian p.p.
Oued Tidzi Fm. p.p.
Lemgo Fm.
Tamzergout
Bouzergoun p.p.
GAP: 17.5 m Poor Exposure
Likely Marls and bioclastic-rich Lmst.
Swaley/HCS
Large
SSD
Fe+
Epicheloniceras sp. 1
Elsaella nov. gen. nov. sp. 1
Diadochoceras gr. nodosocostatum
Nodosohoplites gr. subplanatus
Acanthohoplites sp.
Elsaella nov. gen. tiskatinensis nov. sp.
Elsaella nov. gen. nov. sp. 2
Epicheloniceras clansayense
Mellegueiceras chihaouiae
Pseudorbulites gr. toucasi
Douvilleiceras leightonense
"Hypacanthoplites" cf. paucicostatus
Procheloniceras dechauxi
Cheloniceras spp.
Tiskatinensis Sz.
Tiskatinensis Z.
Pa. Z.
Ch. Z.
Ash Z.
Dechauxi Subzone p.p.
Dechauxi Zone



1
2
10mm
7
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10
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12
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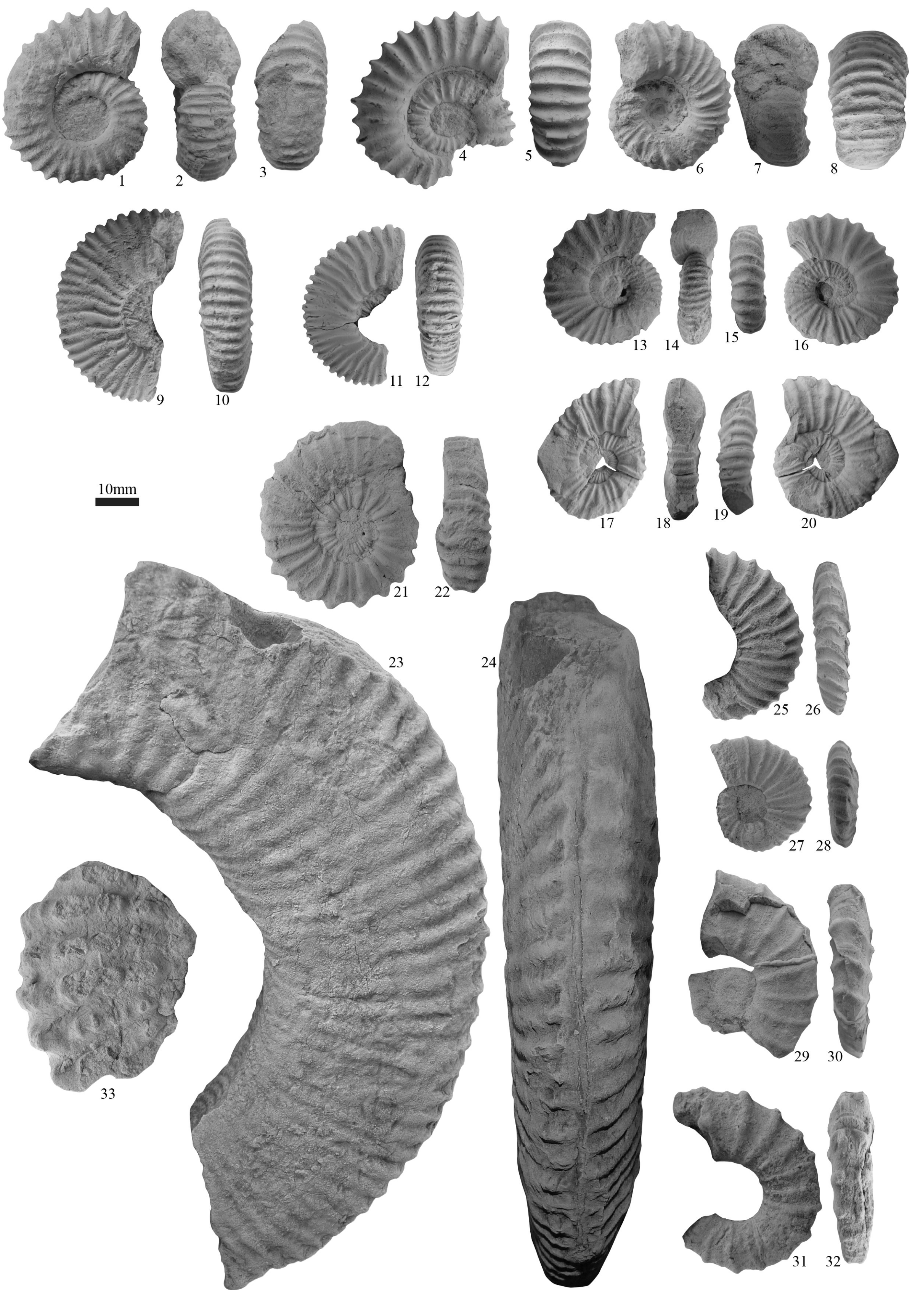
6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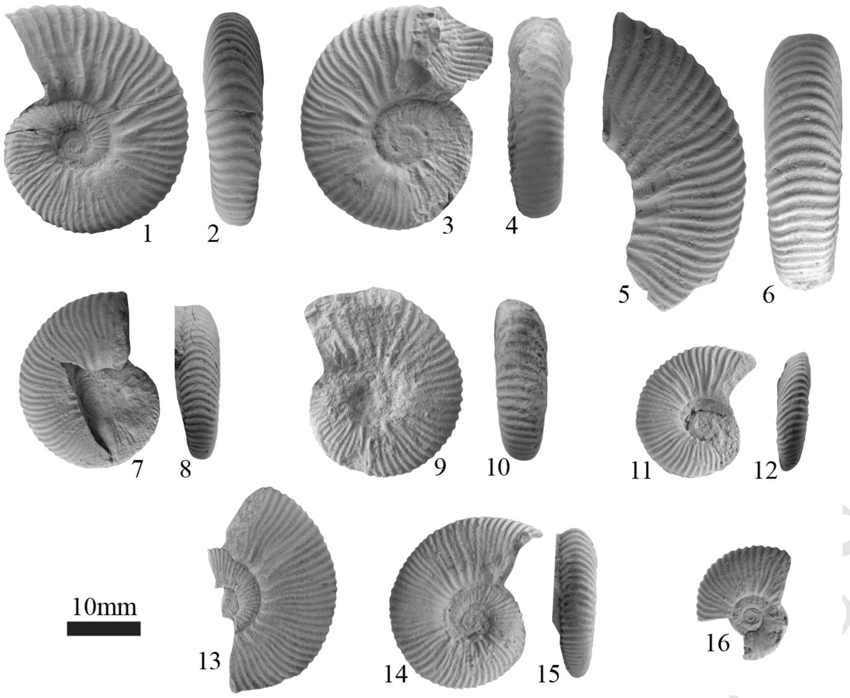
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10mm
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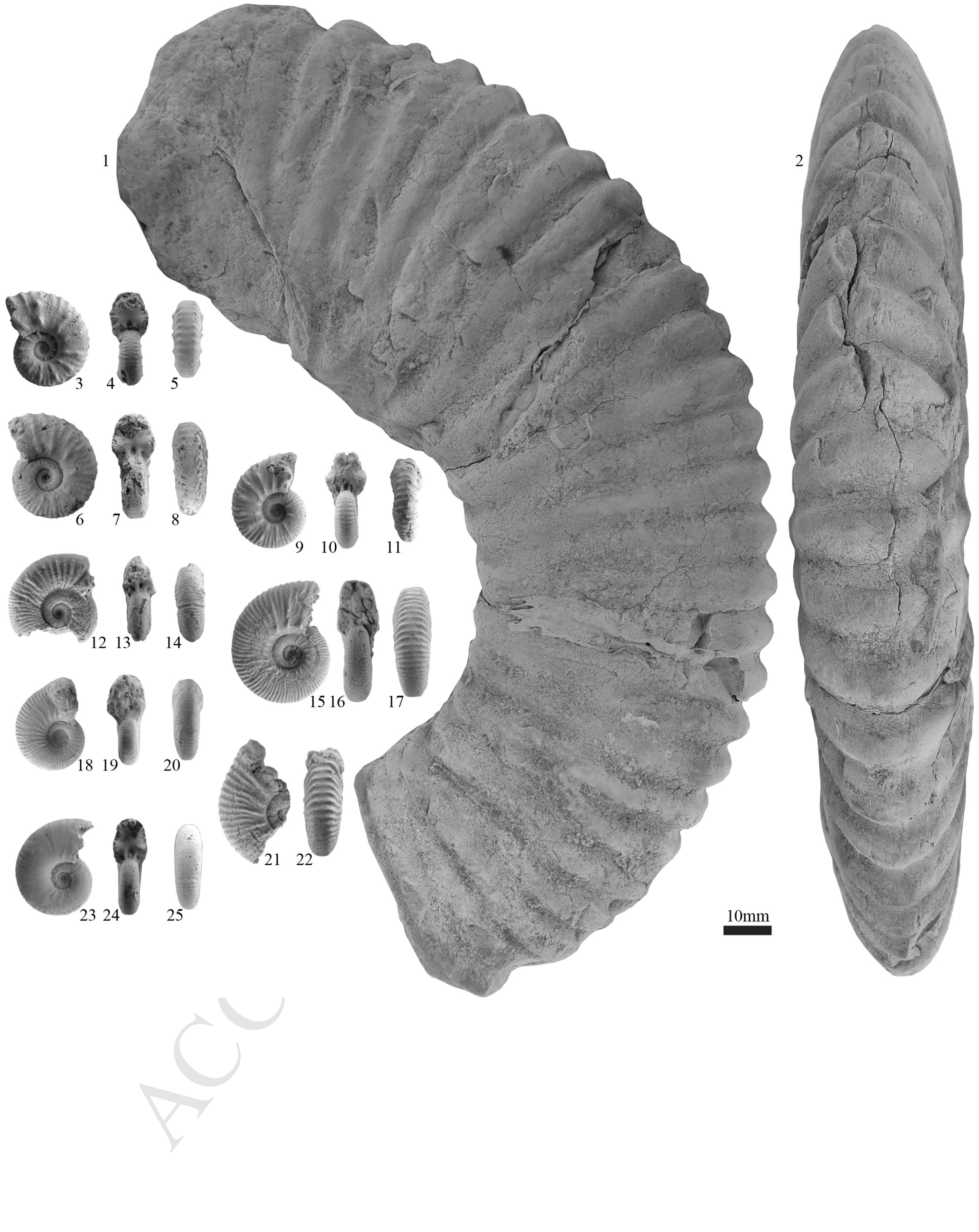
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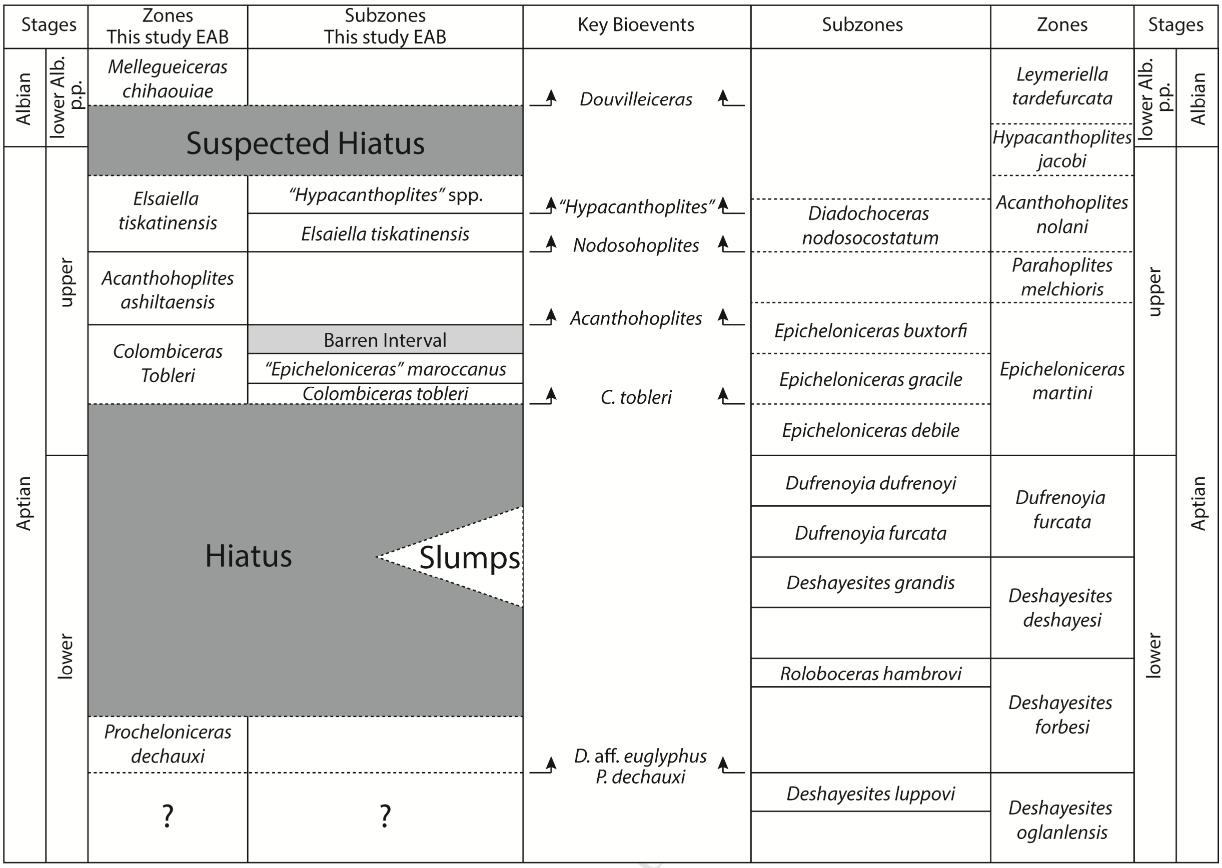
10mm


Stages
Zones
This study EAB
Subzones
This study EAB
Key Bioevents
Subzones
Zones
Stages
Albian
lower Alb. p.p.
Mellegueiceras chihaouiae
Suspected Hiatus
Douvilleiceras
Leymeriella tardefurcata
Hypacanthoplites jacobi
Aptian
upper
Elsaiella tiskatinensis
"Hypacanthoplites" spp.
Elsaiella tiskatinensis
"Hypacanthoplites"
Nodosohoplites
Diadochoceras nodosocostatum
Acanthohoplites nolani
Acanthohoplites ashiltaensis
Parahoplites melchioris
Acanthohoplites
Colombiceras Tobleri
Barren Interval
"Epicheloniceras" maroccanus
Colombiceras tobleri
C. tobleri
Epicheloniceras buxtorfi
Epicheloniceras gracile
Epicheloniceras debile
Epicheloniceras martini
lower
Hiatus
Slumps
Dufrenoyia dufrenoyi
Dufrenoyia furcata
Dufrenoyia furcata
Deshayesites grandis
Deshayesites deshayesi
Roloboceras hambrovi
Deshayesites forbesi
Procheloniceras dechauxi
D. aff. euglyphus
P. dechauxi
Deshayesites luppovi
Deshayesites oglanlensis
?
?