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Famennian (Late Devonian) ammonoids from the Ouarourout section (Saoura Valley, Algeria)

Ammonoïdes du Famennien (Dévonien supérieur) de la coupe de Ouarourout (Vallée de la Saoura, Algérie)

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ABSTRACT

In North Africa, the ammonoids constitute an important part of the Devonian marine macro-invertebrates. New material has been recently collected in the 'Argiles de Marhouma' Formation from several sections located near Béni-Abbès in the Saoura Valley (Ougarta Mountains, Algerian Sahara). Red nodular limestones (i.e., 'griotte' facies) characterize this formation rich in ammonoids. The assemblages from the Ouarourout section are composed of Goniatitida and Clymeniida constituting 30 species and 19 genera belonging to 11 families, with *Cyrtoclymenia*, *Erfoudites*, *Kosmoclymenia*, *Planitornoceras*, *Platyclymenia*, and *Prionoceras*, as the most abundant genera. The taxonomic comparison and the biostratigraphic correlations are made by considering the assemblages recorded in the Anti-Atlas of Morocco, which are very close to those observed in Algeria. In the Ouarourout area, the 'Argiles de Marhouma' Formation contains middle and late Famennian ammonoid assemblages and three biostratigraphic intervals can be identified: *Planitornoceras*, *Platyclymenia* and *Medioclymenia*.

Keywords: Algeria, Devonian, Ammonoidea, systematics, biostratigraphy.

RESUME

En Afrique du Nord, les ammonoïdes constituent une part importante des macro-invertébrés marins

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du Dévonien. Du nouveau matériel a été récemment collecté au sein de la Formation des 'Argiles de Marhouma' dans plusieurs secteurs situés près de Béni-Abbès dans la vallée de la Saoura (Monts d'Ougarta, Sahara algérien). Des calcaires nodulaires rouges (faciès de type 'griotte') caractérisent cette formation riche en ammonoïdes. Les assemblages de la section de Ouarourout sont composés de Goniatitida et de Clymeniida constituant 30 espèces et 19 genres appartenant à 11 familles ; les genres les plus abondants sont *Cyrtoclymenia*, *Erfoudites*, *Kosmoclymenia*, *Planitornoceras*, *Platyclymenia* et *Prionoceras*. Les comparaisons taxonomiques et les corrélations biostratigraphiques sont établies en considérant les faunes décrites au Maroc, qui sont très proches de celles observées en Algérie. Dans les environs de Ouarourout, la Formation des 'Argiles de Marhouma' contient des assemblages d'ammonoïdes datant du Famennien moyen et supérieur, et trois intervalles biostratigraphiques peuvent être identifiés : *Planitornoceras*, *Platyclymenia* et *Medioclymenia*.
Mots clés: Algérie, Dévonien, Ammonoidea, systématique, biostratigraphie.

1. Introduction

Ammonoids (Mollusca, Cephalopoda) appeared in the Early Devonian and rapidly became abundant and diverse in marine habitats (House, 1985; Becker and House, 1994; Klug et al., 2008; Klug et al., 2015a, b). They diversified in the context of the 'Devonian Nekton Revolution' characterized by the development of many active swimming marine organisms and important morphological innovations (Klug et al., 2010). In addition to their classical biostratigraphic ability and application, the knowledge of Devonian ammonoids can provide important insights regarding the understanding of this ecosystem revolution and the early diversification patterns in general (Klug et al., 2010). The Famennian (Late Devonian) corresponds to an important time interval for the ammonoid evolution: it is characterized by particularly high levels of taxonomic richness and morphological disparity and marked by the appearance of the order Clymeniida. Through the Famennian, the ammonoids also suffered several global extinction and were particularly impacted by the Kellwasser (Frasnian/Famennian boundary) and Hangenberg (Devonian/Carboniferous) crises (House, 1970, 1985, 1989; Becker, 1993b; Becker and House, 1994; see reviews of Korn and Klug, 2012; Korn et al., 2015c).

The North Gondwana platform is considered to be one of the best regions to study the Devonian ammonoids. In the Anti-Atlas of Morocco, the middle and late Famennian ammonoids are particularly well documented, thanks to the numerous articles which have been published over the last 25 years (Korn 1994, 1999, 2004; Becker 1995, 2000, 2002; Becker and House 2000; Becker et al. 2002; Korn and Klug 2002; Korn et al. 2000, 2014, 2015a, 2015b, 2016a, 2016b; Ebbighausen and

Korn 2007; Klug et al. 2016). However, they remain scarcely known in Algeria (Fig. 1; see reviews of Korn and Klug, 2015; and Korn and De Baets, 2015).

FIGURE 1 AROUND HERE

In Algeria (north Gondwana), Late Devonian deposits were first recognized in the Saoura Valley (Ougarta Mountains) by Haug (1903) based on ammonoids. Gautier (1906) realized the first comprehensive study regarding the geology of this area, and Alimen et al. (1952) refined it and described several important sections. More details were also given by Menchikoff (1930) who listed rich ammonoid assemblages in the Famennian succession of the Saoura Valley. The richness in ammonoids enabled Petter (1959, 1960) to discriminate the rough standard zonation established by Wedekind (1908, 1926) in Germany and subsequently modified by several authors (see the review of Korn and Klug, 2015). Göddertz (1987) published a monographic study describing ammonoids from the Saoura Valley (the so-called 'km 30' locality near Marhouma) but the Famennian ammonoids were not revised. Since the study of Göddertz (1987), Devonian ammonoids from Algeria have been only documented in few publications; sporadic information have been included in recent papers (Korn, 2004; Ebbighausen and Korn, 2007; Korn et al., 2014) and only one study entirely focusing on Algerian assemblages have been published (Korn et al. 2017). Korn et al. (2017) studied late Famennian sections from several localities in the vicinity of Béni Abbès (Saoura Valley, Algeria). They recognized several taxa already observed in Morocco, and they also described seven new species. Furthermore, according to Korn et al. (2017), the late Famennian succession in the Saoura Valley of Algeria is constituted of four distinct ammonoid assemblages: by stratigraphic order, the *Gonioclymenia*, *Medioclymenia*, *Cymaclymenia lambidia* and *Wocklumeria* assemblages. However their stratigraphic range is not clearly defined and the correlations of these assemblages with the Moroccan biozonations have not been precisely established. Although since several years, the systematic and biostratigraphic revision of Devonian invertebrates from the Saoura Valley of Algeria have received a renewed interest (e.g., for brachiopods: Mottequin et al., 2015; for trilobites: Crônier et al., 2013, Feist et al., 2016; for ammonoids: Korn et al., 2017), the ammonoids still remained scarcely described and not precisely sampled.

The recent intensive sampling of new material from several sections in this area gives us the opportunity to better document the diversity of the Devonian ammonoid from the North Gondwanian platform. In this article we first focus on the ammonoid assemblages from one section located near Béni-Abbès: the Ouarourout section. Therefore, the aim of this paper is to describe the Late Devonian ammonoid assemblages collected in this section and to correlate them with the ammonoid assemblages from Morocco (same paleogeographic area, North Gondwana).

The ammonoids from the Ouarourout section correspond to middle and basal late Famennian assemblages. In this respect, our work complements the study of Korn et al. (2017) who focused on late Famennian assemblages from the same area.

2. Geological setting

All the material described in this paper comes from the Ouarourout section (labelled 'On') which is located in the eastern part of the Ougarta Mountains (Saoura Valley, Algerian Sahara), north-west of Béni Abbès (Fig. 2). For a description of the section and its palaeoenvironmental interpretation, see Menchikoff (1930), Petter (1959), Elmi and Ameur (1984), Benhamou et al. (2004), Ouali Mehadji et al. (2012), and Abbache et al. (2019).

FIGURE 2 AROUND HERE

This area belongs to a major structural unit corresponding to the Saharan Platform. It comprises a Precambrian basement unconformably overlain by thick sediments occurring in several Palaeozoic basins, which include the Ougarta Range (western Algeria). The Ougarta Mountains extend over 400 km in length and 200 km in width, and form an elongated structure with a NW/SE orientation. It is a folded domain which links the Moroccan Anti-Atlas (NW) with the hills of Bled El Mass and Tanezrouft (SE). The Ougarta Mountains encompasses a northern unit ('Saoura'), which is constituted by anticlines corresponding to Cambrian–Ordovician deposits and by synclines corresponding to Silurian–Devonian deposits (Menchikoff, 1930; Donzeau, 1983; Boumendjel et al., 1997a; Fabre et al., 2005).

Our material originates from the 'Argiles de Marhouma' Formation (Fig. 3), which is primarily characterized by fine-grained turbidite successions, interspersed with 'griotte' limestones bearing a pelagic fauna and showing a wide variety of fossil traces (Bendella and Ouali Mehadji, 2015). According to ammonoid, brachiopod, trilobite, conodont, and ostracod assemblages (Petter, 1959, 1960; Casier, 1983; Malti, 2012; Crônier et al., 2013; Mottequin et al., 2015; Abbache et al., 2019), this formation contains Frasnian to Famennian (Late Devonian) deposits. This succession is overlaid by the sandstones of the uppermost Famennian Ouarourout Formation (Fabre et al., 2005). The 'Argiles de Marhouma' Formation (260 m thick; Ouali Mehadji et al., 2012) corresponds to calcareous red nodular limestones rich in ammonoids, called 'griotte' limestones, which suggests an epicontinental platform (Benhamou et al., 2004; Abbache et al. 2019). These facies are linked to slope deposits of deepening basins along their transition toward the platform. These red nodular

limestones is observed in the Tafilalt and Maider basins in Morocco and as far as in the Ougarta Mountains (Saoura Valley) in Algeria. A Hercynian distension phase controlled this spatial extension as understood by modelling the physical geography of basins with 'griotte' facies in an insular palaeogeography (Benhamou et al., 2004).

The 'Argiles de Marhouma' Formation has been subdivided in four successive members (Malti, 2012; Crônier et al., 2013). Member 1 consists of calcareous shales which correspond to late Frasnian deposits according to ammonoids (*Manticoceras*) and entomozoacean ostracods (Casier, 1983). Member 2 includes silty shales with 'griotte' nodules and is divided in two sub-members: 1) the unit 'M2a' comprises silty shales with numerous rhynchonellids (*Evanidisinurostrum saouraense*, *Sphaeridiorhynchus*; possibly from the early Famennian, see Mottequin et al., 2015) in thin calcareous lenses rich in horizontal burrows; and 2) the unit 'M2b' consists of alternating shales and 'griotte' limestones containing the Famennian conodont *Palmatolepis minuta*, as well as the middle Famennian trilobite *Trimerocephalus caecus* and rhynchonellid *Leptoterorhynchus*. Member 3 consists of 'griotte' limestones divided into three sub-members (M3a, b, c) corresponding to late Famennian levels according to conodonts (*Palmatolepis expansa*), trilobites (*Dianops*), rhynchonellids, and ammonoids. Member 4 consists of shales including 'griotte' levels associated to sandy and silty deposits. The succession outcropping in Ouarourout corresponds to the middle and upper parts of the Member 3 (sub-members M3b and M3c), and to the lower part of the Member 4 (sub-member M4a).

FIGURE 3 AROUND HERE

3. **Biostratigraphy**

The ammonoids described here are distributed among 15 levels in the Ouarourout section. Their stratigraphic distribution is summarized in Figure 4. Three major informal ammonoid assemblages (groups of beds with roughly the same taxonomic composition) can be identified: in stratigraphic order, a *Planitornoceras* interval, a *Platyclymenia* interval, and a *Medioclymenia* interval. 1) The *Planitornoceras* interval is poorly diversified and mainly characterized by relatively abundant *P. euryomphalum*. 2) The *Platyclymenia* interval is the most diversified and mainly contains *Platyclymenia*, *Protactoclymenia*, *Trigonoclymenia*, *Erfoudites*, and *Prionoceras*. 3) The *Medioclymenia* interval is mainly characterized by *Medioclymenia saourensis*, *Muessenbiaergia*, *Kosmoclymenia inaequistriata*, *Cymaclymenia subvexa*, and *Mimimitoceras*. The *Platyclymenia* interval can be subdivided in two parts: a lower part with *Erfoudites zizensis* and *Prionoceras*

lamellosum, and an upper part with *Erfoudites rherisensis*, *Sporadoceras muensteri* and *Procymaclymenia ebbighauseni*, among others. Furthermore, two distinct but poorly represented levels can be identified between the *Platyclymenia* and *Medioclymenia* intervals: the lower one contains *Costaclymenia ornata*, and the upper one *Gonioclymenia* cf. *ali*.

FIGURE 4 AROUND HERE

Based on material from several localities in the Saoura Valley, Menchikoff (1930) and Petter (1959, 1960) established a rough biozonation reflecting the German standard biozonation. They recognized five zones within the Famennian succession in Algeria and correlated them to the major subdivisions established by Wedekind (1908) in Germany: by stratigraphic order, the *Cheiloceras* Zone, the *P. planidorsatum/P. sandbergeri* Zone, the *Platyclymenia* Zone, the *Gonioclymenia* Zone, and the *Kalloclymenia* Zone. The stratigraphic distribution of the material described in this study corroborates this biostratigraphic division, and three biozones can be recognized: the *P. planidorsatum/P. sandbergeri* Zone (*Planitornoceras* interval), the *Platyclymenia* Zone (*Platyclymenia* interval) and the *Gonioclymenia* Zone (*Medioclymenia* interval). Therefore, the sedimentary succession studied herein (Ouarourout section, Fig.4) corresponds to middle and late Famennian (basal part) deposits. Interestingly, in Algeria the transitions between the three zones are characterized by sudden changes in ammonoid assemblages. These faunal changes respectively correspond to the global *Annulata* and Dasberg bioevents (see the reviews of Hartenfels and Becker (2016a) for the *Annulata* Event and Hartenfels and Becker (2009) for the Dasberg Crisis).

Our newly collected material also enables identifying a finer biostratigraphic sequence for the Famennian deposits of Algeria. Indeed, finer subdivisions can be recognized for some part of the sequence, especially the *Platyclymenia* and *Gonioclymenia* intervals (see above), that can be tentatively correlated with the high-resolution of the Moroccan biozonation (see below). Note that Korn et al. (2017) identified two distinct ammonoid assemblages in Algeria for the *Gonioclymenia* zone of Petter (1959, 1960) based on a new collection: a lower one characterized by *Gonioclymenia*, and an upper one with *Medioclymenia* as the most conspicuous index genus. In the Ouarourout section, the identification of *Gonioclymenia* below the *Medioclymenia* interval (level On8f, Fig. 4) allows to confirm this subdivision. Interestingly, an additional subdivision can be also documented with the identification of *Costaclymenia ornata* at the base of the late Famennian succession. This species has been previously recognized in Morocco (Becker et al., 2002; Korn et al., 2018c) but not in Algeria.

As mentioned by Korn et al. (2017), the Algerian ammonoids show close relationship with time equivalent occurrences of the Anti-Atlas of Morocco (same paleogeographic area, Fig. 1);

furthermore, the Famennian ammonoids assemblages from Morocco are well documented and recent taxonomic and biostratigraphic descriptions and revisions have been made (see the reviews of Korn and De Baets, 2015; Korn and Klug, 2015). Thus the ammonoid assemblages from Algeria described in this study are here tentatively correlated to the Moroccan assemblages considering the biozonations of Becker et al. (2002, 2013), Klein and Korn (2014), Korn et al. (2014, 2015a, b) and Hartenfels and Becker (2016a, b). The correlations with these Moroccan biozonations are reported in Figure 5. For a general review of the Devonian ammonoid biostratigraphy, see Korn and Klug (2015).

The most comprehensive and precise ammonoid zonation has been proposed by Becker et al. (2002, 2013); it was subsequently updated for the middle and late Famennian by Hartenfels and Becker 2016a and b. This biozonation is composed of interval zones defined by the appearance of an index species. In addition, Klein and Korn (2014) and Korn et al. (2014, 2015a, b) created restricted biozones based on the occurrences of the successive species of different families or genera in Morocco (e.g., Cymaclymeniidae, *Prionoceras*, *Mimimitoceras*, Sporadoceratidae). Overall, the correlation among the Moroccan biozonations and the described Algerian material is complicated by the absence of several index species. The proposed correlation relies more on the coexistence of several taxa, rather than single index species. On the one hand, the genozones of Wedekind (1908) are clearly recognized as already noted by Menchikoff (1930) and Petter (1959, 1960). On the other hand, the species zones of Becker et al. (2002, 2013) are less straightforward to correlate. The poorly diversified *Planitornoceras* interval of Ouarourout does not contain the index species of the *Sulcoclymenia sulcata* and *Afrolobites* sp. Zones, and thus, can only be roughly correlated to the *P. euryomphalum* Zone according to the presence of *P. euryomphalum* (*Planitornoceras* genozone of Klein and Korn 2014). The *Platyclymenia* interval contains two distinct assemblages which can be tentatively correlated to the *Protoxyclymenia dunkeri* and *Procymaclymenia ebbighauseni* Zones, respectively, based on the presence of *E. zizensis* with *P. lamellosum*, and of *P. ebbighauseni* with *E. rherisensis* and *P. ouarouroutense* (*Platyclymenia* genozone of Klein and Korn 2014). The uppermost part with *Prionoceras* cf. *subtum* may correspond to the *Sporadoceras muensteri -orbiculare* Zone, however some *Prionoceras* species show different ranges compared to the Moroccan record. For example, in Ouarourout, *P. lentis* is associated with *P. ouarouroutense* and not *with P. lamellosum* as in the Anti-Atlas.

The *Medioclymenia* assemblage coupled with the *Costaclymenia* and *Gonioclymenia* levels can be correlated with the UD V interval of Becker (2002, 2013) which corresponds to the *Costaclymenia* and *Gonioclymenia* genozones of Klein and Korn (2014) (= *Gonioclymenia* Zone of Petter, 1960). The presence of *Cymaclymenia subvexa* in the *Medioclymenia* interval confirms the correlation with the *Gonioclymenia* genozone (Klein and Korn, 2014) and excludes the correlation with the *Kalloclymenia* genozone. The *Costaclymenia* level, although poorly represented in Ouarourout, is nevertheless in a

congruent position with the *Costaclymenia ornata* Zone (Becker et al., 2002, 2013; Korn et al., 2018c) (= *Costaclymenia* genozone of Klein and Korn 2014). As documented and discussed by Korn et al. (2017), the genera *Gonioclymenia* and *Medioclymenia* do not coexist and constitute two distinct successive zones in Algeria. These authors already discussed the correlation of these zones with the Moroccan biozonation: 1) the different species of *Gonioclymenia* co-occur in Algeria (Korn, 2017; Korn and Bockwinkel, 2017) and thus, do not constitute distinct biozones as in Morocco (Becker et al., 2002; Hartenfels and Becker, 2016b); 2) the "*Gonioclymenia hoevelensis*" Zone (= *G. spiniger*) containing "*Sphenoclymenia intermedia*" (= *Medioclymenia saourensis*), and the *Linguaclymenia similis-Kalloclymenia subarmata* Zone are separated by the *Medioclymenia aguelmousensis* Zone (Hartenfels and Becker, 2016b). This separation is confirmed in Algeria by the non-coexistence of both genera *Gonioclymenia* and *Kalloclymenia* (Korn et al., 2017; this study). In conclusion, despite slight differences, the Algerian and Moroccan assemblages are very close and most of the common species show similar biostratigraphic ranges which facilitate correlations.

FIGURE 5 AROUND HERE

4. Systematic palaeontology

The material described and figured here is based on around 250 irregularly preserved and relatively small-sized specimens. Almost 200 of them have been identified at the species rank. They often correspond to internal moulds; most of them preserved the ornamentation, but the shell is rarely present. The preservation is in three dimensions and the deformation is minor. The suture lines are often visible and they were drawn with a light chamber microscope. The described and figured specimens were analysed at the University of Lille and are stored at the University of Mascara in Algeria. All the material was collected by one of us (A. Abbache).

The systematic nomenclature follows Korn and Klug (2002). The terminology used to describe the conch geometry, the ornamentation and the suture line follows Arkell et al. (1957), Korn (2010), Klug et al. (2015c) and Klug and Hoffmann (2015). The morphological abbreviations used for the biometric measurements are (Fig. 6; all dimensions are given in millimetres): **D**: shell diameter; **W**: whorl width; **H**: whorl height; **U**: umbilical diameter; **CWI**: conch width index = W/D; **WWI**: whorl width index = W/H; **UWI**: umbilical width index = U/D; **WER**: whorl expansion rate **=** $(D/d)^2$. The abbreviations used for the suture line terminology are (Fig. 6): E lobe: external lobe; M saddle (M saddle); A lobe: adventive lobe; A_2/A_1 saddle (between the first and the second A lobe); E/A saddle (between E lobe and A_2 lobe); L lobe: lateral lobe; U lobe: umbilical lobe; I lobe: internal lobe.

The ammonoids collected in the Ouarourout section (Famennian part of the 'Argiles de Marhouma' Formation) include 122 specimens of Clymeniida (suborders Clymeniina and Cyrtoclymeniina) and 74 specimens of Goniatitida (suborder Tornoceratina). The Clymeniida are represented by four superfamilies (Cyrtoclymenioidea, 46 specimens; Platyclymenioidea, 37 specimens; Clymenioidea, 24 specimens; Gonioclymenioidea, 15 specimens), and the Goniatitida by two superfamilies (Tornoceratoidea, 24 specimens; Prionoceratoidea, 50 specimens). Overall, the identified ammonoids include 11 families, 19 genera, and 30 species. These ammonoid assemblages from Ouarourout are thus dominated by Clymeniida.

FIGURE 6 AROUND HERE

Phylum Mollusca Linnaeus, 1758

Class Cephalopoda Cuvier, 1797

Subclass Ammonoidea Zittel, 1884

Order Goniatitida Hyatt, 1884

Suborder Tornoceratina Wedekind, 1914

Superfamily Tornoceratoidea Arthaber, 1911

Family Tornoceratidae Arthaber, 1911

Subfamily Falcitornoceratinae Becker, 1993a

Genus ***Gundolficeras*** Becker, 1995

Type-species: *Lobotornoceras bicaniculatum* Petter, 1959, p. 208; by original designation.

Remarks: Becker (1995) and Korn et al. (2016a, b) discussed in details the genus *Gundolficeras* and its species, especially those from the Anti-Atlas of Morocco.

Gundolficeras fezzouense (Becker, 1995)

(Figure 7A–D)

? 1959 *Lobotornoceras delepinei* – Petter, p. 209, pl. 15, fig. 15

1995 *Exotornoceras fezzouense* – Becker, p. 618, pl. 2, figs 10–13, text-fig. 5a–f

1995 ?*Exotornoceras sylviae* – Becker, p. 619, pl. 2, figs 4–9, text-fig. 6

2016a *Gundolficeras fezzouense* – Korn et al., p. 206, figs 4–5

2017 *Gundolficeras fezzouense* – Korn et al., p. 128, figs 4–5

Material: Two poorly preserved specimens from samples On9 (*Planitornoceras* interval) and On14 (*Medioclymenia* interval).

Description: Specimen On14.16 (Fig. 7A, C) has a diameter of 32 mm; its conch is thinly discoidal (CWI = 0.45) and involute (UWI = 0.01), with a weakly compressed whorl cross section (WWI

= 0.87) and a high whorl expansion rate (WER = 2.08). The whorl section is oval; the venter is rounded and the flanks are converging (conch widest near the umbilicus); the umbilical margin is subangular and the umbilical wall is oblique. The shell is not preserved (growth lines not visible). The suture line (Fig. 7C) shows a narrow E lobe; a large and broadly rounded E/A saddle; a deep, rounded and asymmetric A lobe; a wide and broadly rounded A/L_2 saddle; and two shallow lateral lobes (L_2, L_1). Specimen On9.2 (Fig. 7B, D) has a smaller diameter (D = 13 mm) and a stouter conch) it is thickly discoidal (CWI = 0.52) and involute (UWI = 0.01), with a weakly compressed whorl cross section (WWI = 0.88) and an extremely high whorl expansion rate (WER = 2.64). Except the E/A ventrolateral saddle which is weakly flattened in On9.2 (Fig. 7D), there is no shape difference when comparing the suture line of both specimens.

Discussion: The suture line of both studied specimens is characteristic of the genus *Gundolficeras* (narrow E lobe; deep, rounded weakly asymmetric A lobe; large broadly rounded E/A saddle; shallow lateral lobes). Among the Moroccan species of *Gundolficeras*, *G. fezzouense* differs by its discoidal conch, by its rounded A lobe, and by the absence of ventrolateral grooves.

Occurrence: In the Ouarourout area (Algeria), *Gundolficeras fezzouense* is relatively rare and occurs in the *Planitornoceras* and *Medioclymenia* intervals (middle and late Famennian; Fig. 4). Korn et al. (2017) documented *G. fezzouense* in two localities in Algeria (Ouarourout and Cheffar Ahmar) and recorded it in the *Gonioclymenia* and *Medioclymenia* assemblages (late Famennian). In Morocco, the genus displays a long range within the Famennian, from the *Planitornoceras euryomphalum* Zone to the *Effenbergia falx* Zone (middle and late Famennian; Becker, 1995; Becker et al., 2002, 2013).

Subfamily Aulatornoceratinae Becker, 1993a

Genus ***Planitornoceras*** Becker, 1995

Type-species: *Planitornoceras pugnax* Becker, 1995, p. 611; by original designation.

Planitornoceras euryomphalum (Wedekind, 1918)

(Figure 7E–L)

1918 *Pseudoclymenia planidorsata* var. *euryomphala* – Wedekind, p. 138

1959 *Tornoceras* (*Protornoceras*) *planidorsatum* var. *euryomphala* – Petter, p. 203, pl. 15, figs 4–5

2002 *Planitornoceras euryomphalum* – Becker et al., pl. 4, fig. 1

2002 *Planitornoceras euryomphalum* – Korn and Klug, p. 162, text-fig. 148e

Material: 21 specimens from samples On4, On6, On7, On8p and On9 (*Planitornoceras* interval).

Description: The diameter of the specimens assigned to *P. euryomphalum* varies from 10.8 to

30.5 mm. They exhibit an extremely discoidal conch (CWI = 0.25–0.34; decreasing through ontogeny) with a weakly compressed whorl cross section (WWI = 0.60–0.78; decreasing through ontogeny). The umbilicus is relatively narrow; most of the specimens have a subinvolute conch (UWI = 0.18–0.34). The whorl expansion rate decreases considerably during the ontogeny, from very high (WER = 2.41 at D = 10.8 mm) to low (WER = 1.73 at D = 30.5 mm). The whorl section is subtrapezoidal; the venter is flat (subangular ventrolateral margins) and the flanks are slightly converging; the umbilical margin is subangular and the umbilical wall is oblique (Fig. 7 E–H). The ornamentation is composed of weak, slightly prorsiradiate, moderately spaced, sinuous ribs, which are thicker on the upper flanks. Growth lines are rectiradiate, biconvex, and projected backward on the venter (well visible in On9.12, Fig. 7F). The suture line shows a shallow V-shaped E lobe; a strongly asymmetric, shallow and rounded A lobe which is elongated toward the venter; and an asymmetric, shallow and rounded L lobe (Fig. 7I–L).

Discussion: The very wide and asymmetric A lobe, the absence of ventrolateral grooves and constrictions, and the compressed subtrapezoidal whorl section (slightly converging flanks and angular venter), are characteristic of the genus *Planitornoceras*. *P. euryomphalum* shows a wide intraspecific variation regarding the thickness of the ornamentation, the conch width and the degree of involution. In Ouarourout, the genus is only represented by the species *P. euryomphalum* (the most evolute species of the genus); the species *P. pugnax* Becker, 1995 described in the Maider region (Morocco) has not been recognized.

Occurrence: In the Ouarourout area (Algeria), *Planitornoceras euryomphalum* is relatively abundant and occurs through the *Planitornoceras* interval (middle Famennian; Fig. 4). In Morocco, *P. euryomphalum* ranges from the *Planitornoceras euryomphalum* Zone to the *Sulcoclymenia sulcata* Zone (middle Famennian; Becker, 1995; Becker et al., 2002, 2013; Fig. 5).

FIGURE 7 AROUND HERE

Family Posttornoceratidae Bogoslovsky, 1971

Subfamily Discoclymeniinae Korn and Klug, 2002

Genus ***Discoclymenia*** Hyatt, 1884

Type-species: *Goniatites Haueri* Münster, 1840, p. 109; by monotypy.

Discoclymenia atlantea Korn et al., 2016a

(Figure 8A–B)

1950 *Discoclymenia cucullata* – Termier and Termier, p. 60, pl. 53, figs 38–45, pl. 54, figs 1–3

1959 *Discoclymenia cucullata* – Petter, p. 210, pl. 15, figs 8–10

? 1959 *Discoclymenia cucullata* n. var.? – Petter, p. 211, pl. 15, fig. 16

1983 *Discoclymenia cucullata* – Gupta and Erben, p. 94, text-figs 1a–d, 6.1

1995 *Discoclymenia cucullata* – Becker, p. 622, pl. 3, figs 3–7, text-fig. 8b–d

1999 *Discoclymenia cucullata* – Korn, p. 164, pl. 1, figs 7, 8

2002 Discoclymenia cucullata – Becker, p. 66

? 2002 *Discoclymenia cucullata*– Becker et al., p.171–173

2002 *Discoclymenia cucullata* – Korn and Klug, p. 170, text-figs 153a, d–f, 154c–e

2016a *Discoclymenia atlantea* – Korn et al., p. 214, figs 13–15

2017 *Discoclymenia atlantea* – Korn et al., p. 130, figs 8–9

Material: One fragmented specimen from sample On13 (*Medioclymenia* interval).

Description: Specimen On13.12 (Fig. 8A–B) is a fragment of conch with an estimated diameter of 40 mm. The proportions of this fragment indicate a thinly discoidal conch, with a weakly compressed whorl cross section. The whorl section is oval; the venter is narrowly rounded and the flanks are converging. The suture line shows a narrow and subparallel-sided E lobe; a shallow and rounded second adventive lobe (A_2 lobe) bordered by small rounded saddles; a deep, and nearly symmetric V-shaped first adventive lobe (A_1 lobe); and a skewed V-shaped L lobe which is shallower than the A_1 lobe. The shell is not preserved.

Discussion: The shallow, very short and rounded A_2lobe is characteristic of the genus *Discoclymenia*. Among the Moroccan species of *Discoclymenia*, the single specimen described here, although fragmented, fits with *D. atlantea,* and therefore it is tentatively assigned to this taxa. The older *D. pola* differs by its subangular and flattened venter (ventrolateral shoulder often pronounced) and by its deeper E lobe, (Korn et al., 2016a, b).

Occurrence: In the Ouarourout area (Algeria), *Discoclymenia atlantea* seems extremely rare and occurs in the *Medioclymenia* interval (late Famennian; Fig. 4). Korn et al. (2016a, 2017) also documented *D. atlantea* in the Ouarourout area and recorded it in the *Medioclymenia* assemblage (late Famennian). In Morocco, the stratigraphic range of *D. atlantea* is unclear. Becker et al. (2002) documented it ("*D. cucullata"*) from the "*Endosiphonites muensteri*" Zone (=*Costaclymenia muensteri* Zone, UD V.A1) to the "*Mayneoceras nucle*us" Subzone (=*Parawocklumeria paradoxa* Zone, UD VI.C2, see Becker et al. 2013). Korn et al. (2016a) considered that in Morocco, *D. atlantea* is probably restricted to a shorter stratigraphic interval, corresponding to the time equivalent of the Algerian *Medioclymenia* assemblage (Korn et al., 2017). This assemblage constitutes a distinct interval mostly characterized by the presence of *Medioclymenia* coupled to the absence of *Gonioclymenia* and *Kalloclymenia* (Korn et al., 2016a, 2017); thus, it can be considered as time equivalent of the Moroccan *Medioclymenia aguelmousensi*s Zone of Becker et al. (2013; see Fig. 5).

FIGURE 8 AROUND HERE

Superfamily Prionoceratoidea Miller and Furnish, 1957

Family Sporadoceratidae Miller and Furnish, 1957

Subfamily Sporadoceratinae Miller and Furnish, 1957

Genus ***Sporadoceras*** Hyatt, 1884

Type species: *Goniatites bidens* Sandberger and Sandberger, 1851, pl. 8; by original designation.

Remarks: Two sporadoceratid genera occurred in the Ouarourout section: *Sporadoceras* and *Erfoudites*. Korn et al. (2015b) revised and discussed in detail these genera and other Sporadoceratidae from the Anti-Atlas of Morocco. *Sporadoceras* differs from *Erfoudites* by its convex growth lines, by the absence of spiral ornament, and by its characteristic suture line which shows a very deep A_2 lobe.

Sporadoceras* cf. *muensteri (von Buch, 1832)

(Figure 9A–C)

For the synonymy list of *S. muensteri,* see Korn et al., 2015b.

Material: Four specimens from sample On12 (*Platyclymenia* interval).

Description: Specimen On12.19 (Fig. 9A, C) has a diameter of 19.3 mm; its conch is thickly pachyconic (CWI = 0.80) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.34) and a high whorl expansion rate (WER = 2.01). The whorl section is oval; the venter is broadly rounded and the flanks are converging; the umbilical margin is rounded and the umbilical wall is oblique. The shell shows convex growth lines, otherwise smooth. The suture line shows a narrow V-shaped E lobe; a deep and asymmetric V-shaped A_2 lobe; a deep, relatively wide and asymmetric A_1 lobe; wide and rounded E/A_2 and A_2/ A_1 saddles; and an asymmetric, wide and broadly rounded dorsolateral saddle. Specimen On12.26 (Fig. 9 B), with an estimated diameter of 40 mm, shows a very similar suture line. Specimen On12.23' (not illustrated), with a diameter of 23.1 mm, has a similar morphology; its conch is pachyconic (CWI = 0.72) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.26) and a high whorl expansion rate (WER = 2.08). The whorl section is oval; the venter is broadly rounded and the flanks are converging. The surface of the shell is smooth. The suture line is partly visible and shows a narrow V-shaped E lobe and a deep V-shaped A_2 lobe.

Discussion: The convex growth lines, the absence of spiral ornament on the shell, and the suture line shape, enable the attribution of this material to the genus *Sporadoceras*. The conch proportions and the deep A_2 lobe showed by these Algerian specimens are characteristic of *S.*

muensteri, and differentiate this taxon from the other Moroccan species of *Sporadoceras*; however, they does not show constrictions on the internal mould (steinkern).

Occurrence: In the Ouarourout area (Algeria), *Sporadoceras* cf. *muensteri* occurs in the *Platyclymenia* interval (late Famennian, Fig. 4). In Morocco, *S. muensteri* ranges from the *Prionoceras ouarouroutense* Zone to the *Prionoceras jeranense* Zone (late Famennian; Korn et al., 2015b), but the most frequent occurrences is in the *Prionoceras subtum* Zone (= time equivalent of the *S. muensteri-orbiculare* Zone; see Fig. 5).

Sporadoceras* aff. *conforme Korn et al., 2015b

For the synonymy list of *S. conforme,* see Korn et al., 2015b.

(Figure 9D–F)

Material: Two specimens from samples On3 (before the *Planitornoceras* interval) and On4 (*Planitornoceras* interval).

Description: Specimens On4.6 (D = 17.6 mm; Fig. 9D, F) and On3.7 (D = 18.0 mm; Fig. 9E) have similar conch proportions. Their conch is thickly discoidal (CWI = 0.56 and 0.50) and involute (UWI = 0.02), with a weakly compressed whorl cross section (WWI = 1.00 and 0.82) and a moderate whorl expansion rate (WER = 1.92 and 1.98). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilicus is almost closed and the umbilical wall is oblique. The shell is not preserved (growth lines not visible). Both specimens show three steinkern constrictions on the last whorl. These constrictions are convex with a shallow ventral sinus, and they are more pronounced on the venter and on the upper part of the flanks. The suture lines are visible on both specimens, and they show a similar shape; however the surface of the fossils is altered and some sutural elements (as the adventive lobes) may appear more rounded than they were. At H = 7 mm, the suture line of specimen On4.6 (Fig. 9D) shows a narrow V-shaped E lobe; a narrow, deep and rounded U-shaped A_2 lobe; a deep, relatively wide and slightly asymmetric V-shaped A_1 lobe; a rounded and slightly asymmetric E/A_2 saddle; a relatively wide, rounded and symmetric A_2/A_1 saddle; and a very wide and rounded dorsolateral saddle.

Discussion: The conch proportions, the presence of steinkern constrictions, and the suture line with a slightly asymmetric V-shaped A_1 lobe showed by the studied specimens are characteristic of *S. conforme*. However, in Morocco *S. conforme* has been recorded in younger levels (late Famennian, *Prionoceras vetus* and *Prionoceras lamellosum* zones; Korn et al., 2015b); and among the middle Famennian species of *Sporadoceras* documented in Morocco, *S. bidens* does not possess constrictions and has a very asymmetric A_2 lobe (Korn et al., 2015b), and *S. equale* also does not possess constrictions and has narrower adventive lobes (Becker et al., 2002). The state of preservation of both specimens (absence of preserved shell, poorly preserved suture) prevents to

reach a better assignment.

Occurrence: In the Ouarourout area (Algeria), *Sporadoceras* aff. *conforme* occurs in the *Planitornoceras* interval (middle Famennian, Fig. 4). In Morocco, *S. conforme* has been documented in younger deposits (late Famennian, *Prionoceras vetus* and *Prionoceras lamellosum* zones; Korn et al., 2015b; time equivalent of the *Platyclymenia annulata* and *Protoxyclymenia dunkeri* zones; see Fig. 5).

Subfamily Xenosporadoceratinae Korn, 2002

Genus ***Erfoudites*** Korn, 1999

Type species: *Erfoudites zizensis* Korn, 1999, p. 158; by original designation.

Remarks: The genus *Erfoudites* and its species, especially those from the Anti-Atlas of Morocco, have been recently discussed in detail (Korn et al., 2015b).

Erfoudites rherisensis Korn, 1999

(Figure 9G–M)

1959 *Sporadoceras biferum* – Petter, p. 260, pl. 20, figs 1, 3, pl. 21, figs 3, 4 (only)

1959 *Sporadoceras rotundolobatum* – Petter, p. 267, pl. 21, figs 1, 2

1999 *Erfoudites rherisensis* – Korn, p. 158, pl. 2, figs 4-6

2000 *"Maeneceras" ungeri ungeri* – Becker et al., p. 80, 81

2000 "Maeneceras" ungeri rotundolobatum – Becker et al., p. 80, 81

2002 *Erfoudites ungeri* – Becker et al., p. 171.

2002 *Erfoudites ungeri rotundolobatus* – Bockwinkel et al., p. 283, text-fig. 4d

2002 *Erfoudites rherisensis* – Korn and Klug, p. 189, textfig. 167A, B

2013 *Erfoudites ungeri* – Becker et al., p. 70, text-fig. 12.4

2015b *Erfoudites rherisensis* – Korn et al., p. 70, figs 23–31

Material: 12 specimens from samples On10, On11 and On12 (*Platyclymenia* interval).

Description: Specimens On12.47 (D = 41.8 mm), On12.48 (D = 44.0 mm) and On10.41 (= 36.0 mm; Fig. 9G) show similar conch proportions. Their conch is thickly discoidal (CWI = 0.46–0.53) and involute (UWI = 0.01), with a weakly compressed whorl cross section (WWI = 0.83–0.91) and a high whorl expansion rate (WER = 2.30 and 2.01). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded and the umbilical wall is oblique. The shell is not preserved, but the internal mould shows steinkern constrictions (seven on the last whorl for the three specimens); these constrictions are more prominent on the venter and on the upper part of the flanks, and fade toward the umbilicus; they are concavo-convex and projected backward on the venter (these constrictions are well visible in specimen On 10.41, see Fig. 9G). Suture lines are visible

in specimens On 10.41 and On12.47; they show a wide V-shaped A_1 lobe, and a shallow and rounded A_2 lobe. Specimen On12.25 (Fig. 9H) has a diameter of 30.6 mm; its conch is thickly discoidal (CWI = 0.59) and involute (UWI = 0.01), with a weakly compressed whorl cross section (WWI = 0.97) and a very high whorl expansion rate (WER = 2.34). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded and the umbilical wall is oblique. The shell is partly preserved and four concavo -convex constrictions can be seen on the internal mould. The shell is covered by a very fine and dense spiral ornament; the spiral lines are narrower than the spaces between them. The growth lines are slightly biconvex and projected backward on the venter. Suture lines are well visible in specimens On 10.43 and On10.42 (Fig. 9J, K); they show a narrow V-shaped E lobe; a shallow and rounded A_2lobe; and a deep and pointed V-shaped A_1 lobe. Specimen On12.20 (Fig. 9L, M) has a diameter of 20.3 mm; its conch is thickly discoidal (CWI = 0.62) and involute (UWI = 0.02), with a weakly depressed whorl cross section (WWI = 1.15) and a high whorl expansion rate (WER = 2.10). The whorl section is oval; the venter is rounded and the flanks are converging. The shell is preserved and shows biconvex growth lines forming a thin spiral ornament (Fig. 9L, M). The suture line is partly visible, and shows a rounded and shallow A_2 lobe, and a deep V-shaped A_1 lobe. Specimen On12.18 (Fig. 9I) has a diameter of 14.7 mm; its conch is thickly discoidal (CWI = 0.60) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.02) and a very high whorl expansion rate (WER = 2.39). The whorl section is oval; the venter is rounded and the flanks are converging. The spiral ornament formed by the thin biconvex growth lines is visible, but is less pronounced than in larger specimens. The series of specimens described herein illustrate the decrease of CWI and WWI through the ontogeny (more discoidal and compressed conch at the adult stage).

Discussion: The suture line with a shallow and rounded A_2 lobe and a deep V-shaped A_1 lobe, the steinkern constrictions, and the spiral ornament, are characteristic of the genus *Erfoudites*. Among the Moroccan species of *Erfoudites*, the high whorl expansion rate and the thin anddense spiral ornament are characteristic of *E. rherisensis*, and differentiate it from the older *E. zizensis*.

Occurrence: In the Ouarourout area (Algeria), *Erfoudites rherisensis* occurs in the upper part of the *Platyclymenia* interval (late Famennian; Fig. 4). According to Becker et al. (2002), in Morocco, *E. rherisensis* ("*E. ungeri*") ranges from the *Platyclymenia annulata* Zone to the *Kalloclymenia subarmata* Zone (late Famennian; Fig. 5). Korn et al. (2015b) documented a shorter range; they indicated that *E. rherisensis* occurs from the *Prionoceras mrakibense* Zone to the *Prionoceras jeranense* Zone (Fig. 5), and that the most frequent occurrence of the species is in the *P. jeranense* Zone (time equivalent of the *Costaclymenia muensteri* Zone; see Fig. 5).

Erfoudites* cf. *zizensis Korn, 1999

559 For the synonymy list of *E. zizensis,* see Korn et al., 2015b.

560 **Material:** Two poorly preserved specimens from sample On8 (*Platyclymenia* interval).

561 **Description:** Specimens On8.60 (D = 28.6 mm) and On8.61 (D = 24.5 mm) have similar conch
562 proportions. Their conch is thickly discoidal (CWI = 0.57 and 0.64) and involute (UWI = 0.01), with a
563 weakly depressed whorl cross section (WWI = 0.98 and 1.12) and a low whorl expansion rate (WER ≈
564 1.7). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical wall
565 is oblique. The internal mould shows several constrictions (five on the last whorl); they are more
566 prominent on the venter and on the upper part of the flanks

567 **Discussion:** The state of preservation of the material prevents to reach a firm identification,
568 both at the genus and at the species ranks. The conch morphology (thickly discoidal, involute, weakly
569 depressed, with an oval whorl section) and the few convex constrictions projected backward on the
570 venter are suggestive of *Erfoudites*, but the absence of preserved shell and suture line prevent to
571 corroborate this hypothesis. These two specimens are tentatively assigned to *Erfoudites* cf. *zizensis*,
572 based on the low whorl expansion rate (WER < 2.00).

573 **Occurrence:** In the Ouarourout area (Algeria), *Erfoudites* cf. *zizensis* occurs in the lower part
574 of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, *E. zizensis* occurs in the
575 *Prionoceras lamellosum* Zone (Korn et al., 2015b; time equivalent of the *Protoxyclymenia dunkeri*
576 Zone, see Fig. 5).

577

578 ***Erfoudites* aff. *spirifer*** (Lange, 1929)

579 (Figure 9N–Q)

580 **Material:** Three poorly preserved specimens from samples On2 and On3 (levels below the
581 *Planitornoceras* interval).

582 **Description:** Specimen On3.2 (Fig. 9N, O) has a diameter of 23.0 mm; its conch is thinly
583 pachyconic (CWI = 0.63) and involute (UWI = 0.06), with a weakly depressed whorl cross section
584 (WWI = 1.10) and a moderate whorl expansion rate (WER = 1.98). The whorl section is oval; the
585 venter is broadly rounded and the flanks are converging; the umbilical margin and the umbilical wall
586 are rounded. The suture line shows a V-shaped E lobe; a shallow and asymmetric A_2 lobe; a deep and
587 lanceolate A_1 lobe; and a large and broadly rounded dorsolateral saddle. Specimens On2.4 (D = 14
588 mm) and On2.5 (D = 19.7 mm; Fig. 9P, Q) have very similar conch proportions (UWI ≈ 0.09; CWI ≈
589 0.66; WWI ≈ 1.29; WER = 1.56 and 1.77). Their internal moulds show few slightly convex
590 constrictions. The suture line of these specimens shows an A_2 lobe less asymmetric than this of
591 specimen On3.2 (see Fig. 9O, P).

592 **Discussion:** The poorly preserved material prevents to reach a firm identification both at the genus
593 and species ranks. The conch geometry (involute, weakly depressed, thickly discoidal, oval whorl

section) and the few convex constrictions are suggestive of *Erfoudites* and *Maenoceras*. The spirally ornamented shell surface is not preserved but the suture line shape resembles to this of the Moroccan species of *Erfoudites* (*E. zizensis* and *E. rherisensis*). These specimens are tentatively assigned to *Erfoudites* aff. *spirifer* (for illustrations of the species *E. spirifer*, see Korn and Klug, 2002; and Becker et al., 2002) because they differ from *E. zizensis* and *E. rherisensis* by a more depressed conch and a highly asymmetric A_2 lobe. This type of suture line resembles those of *Felisporadoceras*, but this genus has a more depressed conch and a much higher whorl expansion rate (Korn et al., 2015b). The genus *Erfoudites* can also be confused with the genus *Ungusporadoceras*; they have similar conch proportions and they both possess spiral ornament, but in *Ungusporadoceras* the A_2 lobe is clearly deeper (Korn et al., 2015b).

Occurrence: In the Ouarourout area (Algeria), *Erfoudites* aff. *spirifer* occurs in the *Planitornoceras* interval (middle Famennian; Fig. 4). In Morocco, *E. spirifer* occurs from the *Planitornoceras euryomphalum* Zone to the *Sulcoclymenia sulcata* Zone (middle Famennian; Becker et al., 2002).

FIGURE 9 AROUND HERE

Family Prionoceratidae Hyatt, 1884

Subfamily Prionoceratinae Hyatt, 1884

Genus ***Prionoceras*** Hyatt, 1884

Type species: *Goniatites divisus* Münster, 1832, p. 24; by original designation.

Remarks: The genus *Prionoceras* and its species, especially those from the Anti-Atlas of Morocco, have been recently discussed in detail (Korn et al., 2014).

Prionoceras ouarouroutense Korn et al., 2014

(Figure 10A–B)

1959 *Prionoceras frechi* – Petter, p. 243, pl. 18, figs 1–3, 17–18

2014 *Prionoceras ouarouroutense* – Korn et al., p. 193, figs 25–27

Material: Three specimens (internal moulds) from samples On10 and On11 (*Platyclymenia* interval).

Description: The three specimens assigned to *Prionoceras ouarouroutense* (On11.24, D = 25.4 mm, Fig. 10A; On10.31, D = 19.6 mm, Fig. 10B; On11.25, D = 20.4 mm) have similar proportions. Their conch is thinly discoidal (CWI = 0.45–0.54) and involute (UWI = 0.01), with a weakly compressed whorl cross section (WWI = 0.80–0.91) and a low whorl expansion rate (WER = 1.48–1.69). The whorl section is oval; the venter is rounded and the flanks are slightly converging; the umbilicus is almost

closed. They show five steinkern constrictions standing in distances of 70°; most of them are linear with a relatively deep ventral sinus, but interestingly the last constriction of specimen On 11.24 has a slightly convex course (Fig. 10A), and the last constriction of specimen On10.31 seems to have an irregularity in its course (Fig. 10B). In all specimens, the shell is not preserved, and the suture lines are not visible.

Discussion: The conch geometry (thickly discoidal, involute, oval whorl section) and the steinkern constrictions are characteristic of the genus *Prionoceras*. These specimens are assigned to *Prionoceras ouarouroutense* based on the number of constrictions (five at a diameter of 15 mm) and on their shape (deep ventral sinus), and on the conch width (compressed conch). Among the species having also five constrictions at similar sizes (Korn et al., 2014), *P. lamellosum* has constrictions without ventral sinus, a higher CWI (> 0.6) and a higher WWI (> 1.20); *P. subtum* has constrictions with shallow ventral sinus, a higher CWI (0.58) and a higher WWI (> 1.10); and *P. jeranense* has constrictions without ventral sinus, a higher CWI (> 0.65) and a higher WWI (> 1.15).

Occurrence: In the Ouarourout area (Algeria), *Prionoceras ouarouroutense* occurs in the middle part of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, this species marks the *P. ouarouroutense* Zone (late Famennian; Korn et al., 2014; see Fig. 5).

Prionoceras lamellosum Korn et al., 2014

(Figure 10C–D)

? 1959 *Prionoceras substriatum* – Petter, p. 247, pl. 18, fig. 10 (pars)

1994 *Prionoceras divisum* – Korn, text-figs 29B, 30E (only)

2002 *Prionoceras divisum* – Korn and Klug, text-fig. 171A

2014 *Prionoceras lamellosum* – Korn et al., p. 183, figs 15–18

Material: Five specimens from sample On8 (*Platyclymenia* interval).

Description: Specimen On8.58 (Fig. 10D) has a diameter of 20.1 mm; its conch is thinly pachyconic (CWI = 0.70) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.24) and a low whorl expansion rate (WER = 1.58). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded and the umbilical wall is convex. The internal mould shows three constrictions; they extend linearly on the flanks and on the venter, and they stand in distances of around 120°. Specimens On8.51–8.54 (around 10 mm conch diameter) have similar conch proportions (thinly pachyconic, CWI = 0.58–0.80; involute, UWI = 0.02; weakly depressed, WWI = 1.05–1.57; low whorl expansion rate, WER = 1.65). The whorl section is oval; the venter is broadly rounded and the flanks are converging; the umbilical margin is rounded and the umbilical wall is convex. The internal mould shows three or four constrictions, which have a slightly sinuous course. Specimen 8.51 (Fig. 10C) shows four steinkern constrictions; they are slightly

concave on the flanks, with a low ventral projection, and stand in distances of around 90°. In all specimens, the shell is not preserved, and the suture lines are not visible.

Discussion: The conch shape (thinly pachyconic, involute, weakly depressed, oval whorl section) and the steinkern constrictions are characteristic of the genus *Prionoceras*. These specimens are assigned to *Prionocera*s *lamellosum* based on the number of constrictions (three at a diameter of 20 mm) and on their shape (linear), and on the conch width (depressed conch). *Prionocera*s *lamellosum* has a typical ornamentation (lamellose and wide-standing growth lines with convex course), but it cannot be observed in our Algerian material because none of the studied specimens have preserved their shell surface. As noted by Korn et al. (2014), the CWI and the WWI of this species show a large variability, but not the WER. Among the Moroccan species of *Prionoceras, P. divisum* also has three linear constrictions at similar size (Korn et al., 2014), but it has a slightly higher WWI (> 1.30) and a lower WER (< 1.55). *P. lentis*, *P. mrakibense* and *P. triens*, also have three constrictions, but all these species have a more compressed conch (WWI < 1.00).

Occurrence: In the Ouarourout area (Algeria), *Prionoceras lamellosum* occurs in the lower part of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, this species marks the *P. lamellosum* Zone (late Famennian; Korn et al., 2014; see Fig. 5).

Prionoceras* aff. *frechi (Wedekind, 1913)

(Figure 10E–G)

For the synonymy list of *P. frechi,* see Korn et al. 2014.

Material: Three specimens from samples On8 and On10 (*Platyclymenia* interval).

Description: Specimen On10.34 (Fig. 10F) has a diameter of 32.4 mm; its conch is thinly discoidal (CWI = 0.38) and involute (UWI = 0.01), with a weakly compressed whorl cross section (WWI = 0.72) and a low whorl expansion rate (WER = 1.63). The whorl section is oval; the venter is narrowly rounded and the flanks are subparallel (conch widest at the midflank area); the umbilical margin is rounded and the umbilical wall is convex. The internal mould shows four constrictions, which are linear on the flanks and slightly convex on the venter; they are irregularly-spaced and stand in distances of 120° and 90°. Specimen On10.33 (D = 26.1 mm; Fig.10E, G) has similar conch proportions (thinly discoidal, CWI = 0.39; involute, UWI = 0.04; weakly compressed, WWI = 0.67; low whorl expansion rate, WER = 1.57). The whorl section is oval; the venter is narrowly rounded and the flanks are subparallel; the umbilical margin is rounded and the umbilical wall is convex. The internal mould shows three constrictions, which are relatively linear on the flanks and slightly convex on the venter; they stand in distances of around 110°. The suture line shows a deep, narrow and parallel-sided E lobe; a narrow and relatively deep V-shaped L lobe; a wide, rounded and asymmetric ventrolateral saddle; and a very wide and broadly rounded dorsolateral saddle.

Discussion: The conch geometry (thinly discoidal, involute, weakly compressed, oval whorl section) and the steinkern constrictions are characteristic of the genus *Prionoceras*. These specimens are tentatively assigned to *Prionoceras* aff. *frechi* based on the number of constrictions (four at 20–30 mm diameter) and on their shape (linear with a shallow ventral sinus), on the conch proportions (weakly compressed conch), and on the shape of the flanks (subparallel) Two species of *Prionoceras*, which resemble to the European species *P. frechi*, are known from Morocco: *P. mrakibense* and *P. lentis* (see Korn et al., 2014). *P. mrakibense* differs by having a stouter conch (WWI > 0.90); *P. lentis* has similar conch proportions but differs by having converging flanks (they are subparallel in *P. lentis*).

Occurrence: In the Ouarourout area (Algeria), *Prionoceras* aff. *frechi* occurs in the *Platyclymenia* interval (late Famennian; Fig. 4). Becker et al. (2002) recognized *P. frechi* in the Anti-Atlas of Morocco, and documented it from the *Platyclymenia annulata* Zone to the *Sporadoceras muensteri- orbiculare* Zone ; however according to Korn et al. (2014) this species only occurs in Europe where it is restricted to the *Platyclymenia annulata* Zone.

Prionoceras lentis Korn et al., 2014

(Figure 10H–I)

1994 *Prionoceras frechi* – Korn, text-figs 29A, 30D (only)

1999 *Prionoceras frechi* – Korn, pl. 2, fig. 7

2002 *Prionoceras frechi* – Korn and Klug, text-fig. 171B

2014 *Prionoceras lentis* – Korn et al., p. 189, figs 21–22

Material: Three specimens from sample On11 (*Platyclymenia* interval).

Description: Specimens On11.20 (D = 15.8 mm; Fig. 10H) and On11.22 (D = 18.5 mm; Fig. 10I) have a similar conch geometry; their conch is thinly discoidal (CWI = 0.45 and 0.47) and involute (UWI = 0.01 and 0.03), with a weakly compressed whorl cross section (WWI = 0.79 and 0.80) and a low whorl expansion rate (WER = 1.56 and1.61). The whorl section is oval; the venter is narrowly rounded and the flanks are converging; the umbilical margin is rounded and the umbilical wall is convex. The internal mould shows three constrictions standing in distance of 120°; they are linear with a shallow ventral sinus. In all specimens, the shell is not preserved, and the suture lines are not visible.

Discussion: These specimens are assigned to *Prionoceras lentis* based on the number of constrictions (three) and on their shape (linear with a shallow ventral sinus), and on the conch proportions (weakly compressed conch). In Morocco, two species of *Prionoceras* resemble *P. lentis*: *P. mrakibense* and *P. ouarouroutense* (see Korn et al., 2014); but these both species have a stouter conch at comparable diameter (in *P. mrakibense* and *P. ouarouroutense* WWI = 0.50–0.60 at D = 20 mm, but 0.35–0.40 in *P. lentis*). In Algeria, *P. lentis* and *P. aff. frechi* have a very close morphology;

they differs only by the shape of their flanks (converging in *P. lentis* and subparallel in *P*. aff. *frechi*). Intermediary shapes (from converging to subparallel flanks) may exist between these two morphotypes and that would indicate that these species could be actually considered as synonym. However, more material is needed to evaluate this morphological variability and confirm or not this hypothesis.

Occurrence: In the Ouarourout area (Algeria), *Prionoceras lentis* occurs in the middle part of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, *P. lentis* is restricted to the *Prionoceras lamellosum* Zone (Korn et al., 2014; see Fig. 5).

Prionoceras* cf. *subtum Korn et al., 2014

(Figure 10J–K)

Material: Two specimens from sample On12 (*Platyclymenia* interval).

Description: Specimen On12.22 (Fig. 10J) has a diameter of 21.7 mm; its conch is thinly pachyconic (CWI = 0.67) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.14) and a moderate whorl expansion rate (WER = 1.92). The whorl section is subglobular; the venter is broadly rounded and the flanks are converging. The internal mould shows three irregularly-spaced constrictions, which are convex with a shallow ventral sinus. Specimen On12.13 (Fig. 10K) has a diameter of 19.7 mm; its conch is thinly pachyconic (CWI = 0.60) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.04) and a low whorl expansion rate (WER = 1.62). The whorl section is subglobular; the venter is rounded and the flanks are converging; the umbilical margin is rounded. The internal mould shows three prominent constrictions, irregularly spaced, and standing in distances of around 90° or 110°; they show a slightly convex course on the flanks with a very shallow ventral sinus. The shell is partly preserved; the growth lines are sinuous, very fine, and densely arranged. The suture lines are not visible.

Discussion: These specimens are tentatively assigned to *Prionoceras* cf. *subtum* based on the conch proportions (at D ≈ 20 mm: CWI = 0.60–0.70; WWI = 1.05–1.15) and on the constriction shape (slightly convex with a shallow ventral sinus). However, this Algerian material shows only three constrictions, while *P. subtum* is supposed to have four constrictions at a diameter of 20 mm. Specimen On12.22 has a higher whorl expansion rate than the type material from the Anti-Atlas described by Korn et al. (2014; in *P. subtum* WER ≈ 1.60 at 20 mm). In Morocco, the *Prionoceras* species having close conch proportions are *P. mrakibense*, *P. ouarouroutense*, *P. jeranense*, and *P. takhbtitense* (see Korn et al., 2014). *P. ouarouroutense* and *P. mrakibense* differ by having a slender conch (CWI < 0.55; WWI < 1.05); *P. ouarouroutense* differs also by having five constrictions. *P. jeranense* has a slightly more depressed whorl section (WWI > 1.15) and up to six constrictions. *P.*

takhbtitense differs by having linear constrictions.

Occurrence: In the Ouarourout area (Algeria), *Prionoceras* cf. *subtum* occurs in the upper part of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, this species marks the *Prionoceras subtum* Zone (Korn et al., 2014; see Fig. 5).

Prionoceras* cf. *triens Korn et al., 2014

(Figure 10L)

Material: One specimens from sample On12 (*Platyclymenia* interval).

Description: Specimen On12.46 (Fig. 10L) has a diameter of 27.7 mm; its conch is thinly pachyconic (CWI = 0.60) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.04) and a low whorl expansion rate (WER = 1.72). The whorl section is subglobular; the venter is rounded and the flanks are converging; the umbilicus is almost closed. The internal mould shows three irregularly-spaced constrictions (standing in distances of around 140° and 180°), which are concave on flanks and relatively linear on the venter.

Discussion: This specimen is tentatively assigned to *Prionoceras* cf. *triens* based on the conch proportions and on the constriction shape (concave on flanks, with a shallow ventral sinus) and number (only 3). However, this Algerian specimen has a lower WER and a higher shell diameter than the typical material from Morocco (see Korn et al., 2014).

Occurrence: In the Ouarourout area (Algeria), *Prionoceras* cf. *triens* occurs in the upper part of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, *P. triens* occurs in the slightly younger *Prionoceras jeranense* Zone (Korn et al., 2014; see Fig. 5).

Genus ***Mimimitoceras*** Korn, 1988

Type species: *Mimimitoceras trizonatum* Korn, 1988, p. 607; by original designation.

Remarks: The genus *Mimimitoceras* and its species from the Anti-Atlas (Morocco) and from the Saoura Valley (Algeria) have been recently discussed in detail (Korn et al., 2015a, 2017).

Mimimitoceras* cf. *carnatum Korn et al., 2015a

(Figure 10M–N)

For the synonymy list of *M. carnatum,* see Korn et al. 2015a.

Material: Two specimens from samples On13 and On14 (*Medioclymenia* interval).

Description: Specimens On13.1 (D = 10.1 mm; Fig. 10N) and On14.13 (D = 17.9 mm; Fig. 10M) have similar conch proportions; their conch is thinly pachyconic (CWI = 0.72–0.82) and involute (UWI = 0.01), with a weakly depressed whorl cross section (WWI = 1.30–1.37). Specimen On13.1 has

804 a low whorl expansion rate (WER = 1.59); and specimen On14.13 has a very low whorl expansion rate
805 (WER = 1.45). The whorl section is globular; the venter is broadly rounded and the flanks are
806 subparallel; the umbilical margin is rounded and the umbilicus is almost closed. The both specimens
807 show three steinkern constrictions standing in distance of around 120°; their course is almost linear
808 on the flanks and on the venter. In both specimens, the shell is not preserved, and the suture lines
809 are not visible.
810 **Discussion:** The globular and involute conch is typical of the genus *Mimimitoceras*. These
811 specimens are assigned to *Mimimitoceras* cf. *carnatum* based on the conch proportions (at a
812 diameter of 15 mm: CWI = 0.75–0.85; WWI = 1.30–1.40; WER = 1.45–1.50). Among the Moroccan
813 species of *Mimimitoceras* revised by Korn et al. (2015a), *M. carnatum* has the stoutest conch (CWI >
814 0.70; WWI > 1.30). *M. endocuboide* differs by having a lower whorl expansion rate (WER < 1.40) and
815 by the course of its constrictions which are often interrupted for a short interval on the midventer
816 (Korn et al., 2015a); but the both species have a very similar conch morphology and can be easily
817 confused. According to Korn et al. (2015a), specimens cannot be attributed with confidence to *M.*
818 *carnatum* and *M. endocuboide* if the whorl section shape of the juvenile stage (circular in *M.*
819 *carnatum* and cuboid with a wider umbilicus in *M. endocuboide*) is unknown. Therefore, it seems
820 reasonable to identify these Algerian specimens as *Mimimitoceras* cf. *carnatum*. The Algerian species
821 *M. callumbilicum* differs by its concave umbilical wall due to a shell thickening near the umbilicus
822 (Korn et al., 2017).
823 **Occurrence:** In the Ouarourout area (Algeria), *Mimimitoceras* cf. *carnatum* occurs in the
824 *Medioclymenia* interval (late Famennian; Fig. 4). Korn et al. (2017) documented the occurrence of
825 *M. carnatum* in Ouarourout (*Medioclymenia* assemblage, see Fig. 5). In Morocco, the stratigraphic
826 range of this species is not well constrained, but it probably occurs in the *Gonioclymenia* beds (Korn
827 et al., 2015a; see Fig. 5).
828
829 ***Mimimitoceras* cf. *comtum*** Korn et al., 2015b
830 (Figure 10O–P)
831 For the synonymy list of *M. comtum,* see Korn et al. 2015a.
832 **Material:** Seven specimens from samples On13 and On14 (*Medioclymenia* interval).
833 **Description:** Specimen On14.17 (Fig. 10O) is an internal mould with a diameter of 36 mm. Its
834 conch is thinly pachyconic (CWI = 0.60) and involute (UWI = 0.04), with a weakly depressed whorl
835 cross section (WWI = 1.09) and a low whorl expansion rate (WER = 1.62). The whorl section is
836 subglobular; the venter is rounded and the flanks are converging; the umbilical margin is rounded
837 and the umbilicus is almost closed. The conch shows four steinkern constrictions irregularly-spaced;
838 they are slightly convex with a shallow ventral sinus. Specimen On13.3 (Fig. 10P) is also an internal

mould, with a diameter of 28.5 mm. Its conch is thinly pachyconic (CWI = 0.62) and involute (UWI = 0.03), with a weakly depressed whorl cross section (WWI = 1.11) and a low whorl expansion rate (WER = 1.65). The whorl section is globular; the venter is rounded and the flanks are converging; the umbilical margin is rounded and the umbilicus is almost closed. The conch shows four steinkern constrictions standing in distance of 90°; their course is slightly convex with a shallow ventral sinus. In all specimens, the shell is not preserved, and the suture lines are not visible.

Discussion: The globular and involute conch is characteristic of the genus *Mimimitoceras*. These specimens are tentatively assigned to *Mimimitoceras* cf. *comtum* based on the conch proportions (at a diameter of 30 mm: CWI = 0.60–0.65; WWI = 1.05–1.15; WER = 1.60–1.80). However, these Algerian specimens slightly differs from the Moroccan type material by having a higher whorl expansion rate (WER = 1.60–1.80 at D = 30 mm, but 1.55–1.65 in *M. comtum*). Among the Moroccan and Algerian species of *Mimimitoceras* (see Korn et al., 2015b, 2017), *M. taourirtense* is the closest species in conch proportions, but it differs by having a significantly higher whorl expansion rate (WER > 1.80).

Occurrence: In the Ouarourout area (Algeria), *Mimimitoceras* cf. *comtum* occurs in the *Medioclymenia* interval (late Famennian; Fig. 4). Korn et al. (2017) also reported the occurrence of *M. comtum* in Ouarourout (*Medioclymenia* assemblage, see Fig. 5). In Morocco, this species probably occurs in the *Gonioclymenia* beds (Korn et al., 2015a; see Fig. 5).

FIGURE 10 AROUND HERE

Order Clymeniida Hyatt, 1884

Suborder Cyrtoclymeniina Korn and Klug, 2002

Superfamily Cyrtoclymenioidea Hyatt, 1884

Family Cyrtoclymeniidae Hyatt, 1884

Subfamily Cyrtoclymeniinae Hyatt, 1884

Genus ***Protactoclymenia*** Wedekind, 1908

Type species: *Clymenia pulcherrima* Wedekind, 1908, p. 608; by subsequent designation (Price and Korn, 1989).

***Protactoclymenia* sp. indet. A**

Material: Six poorly preserved specimens from samples On8, On10 and On11 (*Platyclymenia* interval).

Description: These poorly preserved specimens (not illustrated) have a diameter of around 22 mm; their conch is thinly discoidal (CWI ≈ 0.40) and subinvolute (UWI ≈ 0.29), with a weakly

compressed whorl cross section (WWI ≈ 0.98). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded. The suture lines have a rounded and shallow ventral saddle; and a broadly rounded, shallow and symmetric L lobe. The ornamentation of the inner whorls is composed of weak and prorsiradiate ribs, rapidly fading on the flanks. Specimen On10.21 shows widely spaced and sinuous growth lines projected backward on the venter.

Discussion: Based on the suture line shape (shallow ventral saddle, shallow and symmetric L lobe) and on the conch proportions (weakly compressed, subinvolute and thinly discoidal conch), these specimens are attributed to the genus *Protactoclymenia*. However, the poorly preserved material prevents to reach a specific comparison and identification. Petter (1960) described a species from Algeria (*Cyrtoclymenia tenuicostata*) considered as *Protactoclymenia* by Korn and Klug (2002); however, our specimens differ by having a narrower umbilicus, a more depressed conch, and a smooth shell.

Occurrence: In the Ouarourout area (Algeria), *Protactoclymenia* sp. indet. A occurs in the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, the genus *Protactoclymenia* ranges from the *Platyclymenia annulata* Zone to the *Sporadoceras orbiculare* Zone (Becker et al., 2002; see Fig. 5).

***Protactoclymenia* sp. indet. B**

(Figure 11F)

Material: Three specimens from samples On8 and On10 (*Platyclymenia* interval).

Description: Specimen On8.3 (Fig. 11F) has a diameter of 18.55 mm; its conch is thinly discoidal and subinvolute (CWI = 0.36; UWI = 0.27), with a whorl cross section weakly compressed (WWI = 0.82), and a moderate whorl expansion rate (WER = 1.87). The whorl section is oval; the venter is narrowly rounded and the flanks are converging; the umbilical margin is rounded. The ornamentation is composed of very weak and prorsiradiate ribs, rapidly fading on the flanks. The last part of the conch shows two constrictions; they are convex with a deep V-shaped ventral sinus, and they fade on the flanks toward the umbilicus. The suture line shows a rounded and shallow ventral saddle followed by a broadly rounded, shallow and symmetric L lobe. Interestingly the last sutures of the phragmocone are crowded. Specimen On8.1, at D = 14.3 mm, has the following conch proportions: thinly discoidal (CWI = 0.37) and subinvolute (UWI = 0.26), with a weakly compressed whorl cross section (WWI = 0.83) and a high whorl expansion rate (WER = 2.04). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded. The conch exhibits two steinkern constrictions which are prominent on the venter where they form a deep and V-shaped ventral sinus. The suture line shows a rounded and shallow ventral saddle; and a wide, shallow, rounded and symmetric L lobe.

Discussion: The suture line shape (shallow and symmetric L lobe) and the conch proportions

(thinly discoidal, subinvolute and weakly compressed) are characteristic of the genus *Protactoclymenia*. However, the state of preservation of the material prevents to reach a detailed specific comparison and a firm identification. The presence of ventral constrictions clearly distinguished these specimens from *Protactoclymenia* sp. indet. A.

Occurrence: In the Ouarourout area (Algeria), *Protactoclymenia* sp. indet. B occurs in the *Platyclymenia* interval (late Famennian, Fig. 4). In Morocco, the genus *Protactoclymenia* ranges from the *Platyclymenia annulata* Zone to the *Sporadoceras orbiculare* Zone (Becker et al., 2002; see Fig. 5).

Genus ***Cyrtoclymenia*** Hyatt, 1884

Type species: *Planulites angustiseptatus* Münster, 1832, p. 7; by original designation.

Cyrtoclymenia* cf. *frechi (Tokarenko, 1903)

(Figure 11A–E)

For the synonyms of *C. frechi,* see Korn and Klug, 2002.

Material: 15 specimens from samples On8, On10, On11 and On12 (*Platyclymenia* interval).

Description: Specimen On12.37 has a diameter of 27.5 mm; its conch is thinly discoidal (CWI = 0.45) and subinvolute (UWI = 0.27), with a weakly depressed whorl cross section (WWI = 1.05) and a very high whorl expansion rate (WER = 2.23). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded. The ornamentation is composed of weak, slightly concave, prorsiradiate ribs (eight ribs per half whorl), fading on the flanks; the ribs are thicker on the inner whorls. The suture line shows a rounded, shallow and wide ventral saddle, followed by a broadly rounded, deep and symmetric L lobe. Specimen On12.33 (Fig. 11A) has a diameter of 22.8 mm; its conch is thinly discoidal (CWI = 0.47) and subevolute (UWI = 0.31) with a weakly depressed whorl cross section (WWI = 1.11) and a very high whorl expansion rate (WER = 2.54). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded. The conch bears moderately spaced (12 ribs per half whorl), prorsiradiate and slightly concave ribs, rapidly fading on the flanks. The suture lines are partly eroded, but clearly show a rounded ventral saddle, and a symmetric and rounded L lobe. Specimen On10.19 (D = 18.9 mm; Fig. 11E) has a thinly discoidal (CWI = 0.51) and subevolute conch (UWI = 0.31), with a weakly compressed whorl cross section (WWI = 1.21) and a very high whorl expansion rate (WER = 2.08). The whorl section is subtrapezoidal; the venter is rounded and the flanks are strongly converging; the umbilical margin is rounded. The conch shows relatively wide ribs which are relatively prominent near the umbilicus and fading toward the venter. Specimen On10.18 (D = 17.2 mm; Fig. 11D) shows very thick and prominent ribs on its inner whorls, but they suddenly disappear on the last whorl. The suture lines

show a rounded ventral saddle, and a slightly asymmetric, wide and rounded L lobe (Fig. 11C). Specimen On10.17 (D = 15.7 mm; Fig. 11B) has a thinly discoidal (CWI = 0.45) and subevolute (UWI = 0.32) conch, with a weakly depressed whorl cross section (WWI = 1.15) and very high whorl expansion rate (WER = 2.28). The whorl section is oval; the venter is rounded and the flanks are converging; the umbilical margin is rounded. The conch bears moderately-spaced (12 ribs per half whorl), prorsiradiate and slightly concave ribs, fading on the flanks. The suture lines show a rounded ventral saddle and a wide, symmetric and rounded L lobe.

Discussion: The suture line shape (rounded ventral saddle, moderately deep and relatively symmetric L lobe) and the conch proportions (thinly discoidal conch with a weakly depressed whorl cross section, and a narrow umbilicus) are characteristic of the genus *Cyrtoclymenia*. There are many species of *Cyrtoclymenia* (see synthesis of Korn and Klug, 2002), and the rounded and slightly curved umbilical ribs fading on the flanks displayed by the studied specimens, remind the species *C. frechi*; therefore, they are tentatively attributed to this species. These specimens differ from the Algerian *C. nodifera* (Korn et al., 2017) mainly by having a much higher whorl expansion rate (WER = 2.2).

Occurrence: In the Ouarourout area (Algeria), *Cyrtoclymenia* cf. *frechi* occurs in the *Platyclymenia* interval (late Famennian; Fig. 4). *C. frechi* has not been reported in Morocco, but the genus has a very long range in the Famennian (Korn, 1999; Becker et al., 2002; Korn et al., 2017).

FIGURE 11 AROUND HERE

Family Cymaclymeniidae Hyatt, 1884

Subfamily Genuclymeniinae Korn and Klug, 2002

Genus ***Genuclymenia*** Wedekind, 1908

Type-species: *Clymenia frechi* Wedekind, 1908, p. 617; by subsequent designation (Schindewolf, 1957).

***Genuclymenia* sp. indet**.

(Figure 12O–P)

Material: One specimen from sample On9 (*Planitornoceras* interval).

Description: Specimen On9.17 (Fig. 12O) has a diameter of 16.1 mm; its conch is thinly discoidal (CWI = 0.37) and subevolute (UWI = 0.35), with a weakly compressed whorl cross section (WWI = 0.97) and a high whorl expansion rate (WER = 2.11). The whorl section is oval; the venter is narrowly rounded and the flanks are converging; the umbilical margin is rounded. The suture lines show a rounded, shallow and very wide ventral saddle; followed by a broadly rounded, relatively deep and slightly asymmetric L lobe (Fig. 12P).

Discussion: Based on the conch geometry and on the suture line shape, the single specimen from Ouarourout clearly belongs to the genus *Genuclymenia*. However, without additional material, the specific attribution remains uncertain.

Occurrence: In the Ouarourout area (Algeria), *Genuclymenia* sp. indet. occurs in the upper part of the *Planitornoceras* interval (middle Famennian; Fig. 4). *Genuclymenia* is unknown in Morocco, but in Germany this genus occurs in the *Platyclymenia delphinus* and *Platyclymenia annulata* zones (see House, 1970; Korn, 2004).

Subfamily Cymaclymeniinae Hyatt, 1884

Genus ***Procymaclymenia*** Korn and Klug, 2002

Type-species: *Cymaclymenia inflata* Czarnocki, 1989, p. 67; by original designation.

Remarks: Klein and Korn (2014) revised the Cymaclymeniinae from the Anti-Atlas of Morocco, and erected new species of *Cymaclymenia* and related genera (*Procymaclymenia* and *Postclymenia*). The morphology of both genera *Procymaclymenia* and *Cymaclymenia* are very close. In *Procymaclymenia*, the lateral lobe is more rounded and less asymmetric, and the venter is slightly flattened (in *Cymaclymenia*, the venter is rounded). Only one species of *Procymaclymenia* is known from Morocco (*P. ebbighauseni*).

Procymaclymenia ebbighauseni Klein and Korn, 2014

(Figure 12A–I)

1960 *Cymaclymenia striata* – Petter, p. 45, pl. 8, figs 3, 5, 11, 14 (only)

1999 *Cymaclymenia* sp. – Korn, p. 170, pl. 4, fig. 6

2002 *Cymaclymenia pudica* – Becker et al., p. 171, pl. 4, figs 4, 5

2002 *Procymaclymenia* sp. – Korn and Klug, p. 220, fig. 193d

2014 *Procymaclymenia ebbighauseni* – Klein and Korn, p. 11, figs 4a, 11, 12

Material: Seven specimens from samples On10 and On12 (*Platyclymenia* interval).

Description: Specimen On12.44 (Fig. 12A) has a diameter of 34.4 mm; its conch is extremely discoidal (CWI = 0.28), with a weakly compressed whorl cross section (WWI = 0.68) and a high whorl expansion rate (WER = 2.05); the umbilicus is not visible. The whorl section is subrectangular; the venter is slightly flattened and separated from the flanks by a subangular margin; the flanks are subparallel. The shell exhibits very faint riblets on the upper part of the flanks. The suture line shows a very wide and relatively flat ventral saddle, followed by a rounded, shallow and slightly asymmetric L lobe. Specimen On12.40 (Fig. 12C, H) has a diameter of 22.85 mm; its conch is extremely discoidal (CWI = 0.28) and subinvolute (UWI = 0.30), with a weakly compressed whorl cross section (WWI =

0.65) and a very high whorl expansion rate (WER = 2.32). The whorl section is subrectangular; the venter is flattened and separated from the flanks by a subangular margin; the flanks are subparallel; the umbilical margin is rounded. The shell exhibits faint, rectiradiate and slightly concave riblets, which are more prominent toward the ventrolateral and umbilical margins. The suture line shows a very wide and flat ventral saddle, and a rounded, shallow and slightly asymmetric L lobe. Specimens On12.38 (D = 16.4 mm; Fig. 12B, G), On12.39 (D = 19.9 mm; Fig.12D, F) and On10.25 (D = 20.0 mm; Fig. 12E, I) have a smaller diameter, but are very similar to On12.40 in conch proportions and suture line shape (CWI = 0.29–0.34; UWI = 0.24–0.27; WWI = 0.65–0.79; WER = 2.21–2.44). . Their suture lines show a blunt and slightly asymmetric L lobe, which is characteristic of the genus *Procymaclymenia*.

Discussion: The conch proportions (extremely discoidal, subinvolute, weakly compressed, subrectangular whorl section) and the suture line shape (small, blunt and slightly asymmetric L lobe) of these specimens are characteristic of the genus *Procymaclymenia*. Only the species *P. ebbighauseni* is clearly established for Morocco (see Klein and Korn, 2014). Although eroded, the described specimens from Algeria are very similar to those from Morocco and can be assigned to *P. ebbighauseni*. As noted by Klein and Korn (2014), *P. ebbighauseni* differs from *P. inflata* (Czarnocki, 1989) and *P. pudica* (Czarnocki, 1989) from the Holy Cross Mountains, by the smooth internal mould without constrictions, and the nearly absence of umbilical riblets.

Occurrence: In the Ouarourout area (Algeria), *P. ebbighauseni* occurs in the upper part of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, *P. ebbighauseni* occurs above the *Platyclymenia annulata* Zone and ranges until the *Costaclymenia* genozone (Klein and Korn, 2014; see Fig. 5).

Genus ***Cymaclymenia*** Hyatt, 1884

Type-species: *Cymaclymenia striata* Münster, 1843, p. 11; by original designation.

Remarks: Based on large new collections, Klein and Korn (2014) revised the species of *Cymaclymenia* from the Anti-Atlas of Morocco; these are endemic and differ from the European species (for their review, see Korn, 1981). *Cymaclymenia* is characterized by a suture line showing a pointed and asymmetric L lobe, and by a rounded venter.

Cymaclymenia subvexa Klein and Korn, 2014

(Figure 12J–N)

1960 *Cymaclymenia striata* – Petter, p. 45, pl. 8, figs 1, 4, 13 (only)

? 1960 *Cymaclymenia striata* – Petter, p. 45, pl. 7, figs 16, 17, 19 (only)

1999 *Cymaclymenia cordata* – Korn, p. 170, pl. 4, fig. 5

2002 *Procymaclymenia* sp. – Korn and Klug, p. 220, fig. 193d

2014 *Cymaclymenia subvexa* – Klein and Korn, p. 13, figs 4b, 13, 14

2017 *Cymaclymenia subvexa* – Korn et al., p. 152, figs 37, 38, table 11

Material: 14 specimens from samples On13 and On14 (*Medioclymenia* interval).

Description: Specimen On13.27 (not illustrated) has a diameter of 40.25 mm; its conch is extremely discoidal (CWI = 0.30) and subinvolute (UWI = 0.21), with a weakly compressed whorl cross section (WWI = 0.63) and a high whorl expansion rate (WER = 2.10). The whorl section is oval; the venter is rounded and the flanks are slightly converging; the umbilical margin is slightly oblique. The growth lines are poorly preserved, but they show a biconvex course. The suture line shows a shallow and rounded M saddle; a faint A lobe; and a pointed and asymmetric L lobe. Specimen On13.28 (not illustrated) is very similar to On13.27 in conch proportion, ornamentation, and suture line shape (D = 39.2 mm; CWI = 0.33; UWI = 0.22; WWI = 0.69). It slightly differs by the presence on the body chamber of two backward-projected U-shaped ventral constrictions. Specimen On13.26 (D = 35.4 mm; Fig. 12K) has similar conch proportions (CWI = 0.27 and WWI = 0.64). Its suture line shows a shallow, wide and rounded M saddle; a very shallow and rounded A lobe; and a very pointed and very asymmetric L lobe (Fig. 12L). Specimen On13.24 (Fig. 12J) has a diameter of 33.4 mm; its conch is extremely discoidal (CWI = 0.34) and subinvolute (UWI = 0.19), with a weakly compressed whorl cross section (WWI = 0.70) and very high whorl expansion rate (WER = 2.30). The whorl section is oval; the venter is narrowly rounded and the flanks are slightly converging; the umbilical margin is slightly oblique. The growth lines are poorly preserved, but they show a biconvex course. The suture line shows a shallow and rounded M saddle; a faint A lobe; and a pointed, but slightly blunt, and very asymmetric L lobe (Fig. 12N). Specimen On13.22 has a diameter of 29.0 mm; its conch is extremely discoidal (CWI = 0.28) and subinvolute (UWI = 0.27), with a whorl cross section weakly compressed (WWI = 0.64). The whorl section is oval and similar to the previously described specimens. The suture line shows a shallow and rounded M saddle; a very shallow and rounded A lobe; and a pointed and very asymmetric L lobe (Fig. 12M).

Discussion: The suture line shape (pointed and strongly asymmetric L lobe) and the conch proportions (extremely discoidal and subinvolute conch with a weakly compressed whorl cross section) of these specimens are characteristic of the genus *Cymaclymenia*. The specimens closely resemble, in conch shape, ornament and suture line, the material described by Klein and Korn (2014) in Morocco and by Korn et al. (2017) in Algeria, and can be unambiguously assigned to the species *C. subvexa*. One specimen (On13.28) slightly differs by the presence of ventral constrictions at the end of the growth; this characteristic remind the morphology of some European species such as *C. silesiaca* (Renz, 1914); but without additional material a firm identification is compromised and this

specimen is here attributed to *C. subvexa*.

Occurrence: In the Ouarourout area (Algeria), *Cymaclymenia subvexa* occurs in the *Medioclymenia* interval (late Famennian; Fig. 4). Korn et al. (2017) documented *C. subvexa* in two localities in Algeria (Ouarourout and Cheffar Ahmar) and recorded it in the *Gonioclymenia* assemblage (late Famennian; see Fig. 5). In Morocco, *C. subvexa* occurs in the *Gonioclymenia* genozone (Klein and Korn, 2014; see Fig. 5).

FIGURE 12 AROUND HERE

Suborder Clymeniina Edwards, 1849

Superfamily Platyclymenioidea Wedekind, 1914

Family Platyclymeniidae Wedekind, 1914

Subfamily Platyclymeniinae Wedekind, 1914

Genus ***Platyclymenia*** Hyatt, 1884

Type-species: *Goniatites annulatus* Münster, 1832, p. 3; by original designation.

Remarks: Price and Korn (1989) discussed in details this genus and its German species. Interestingly, they pointed out that all named species of the subgenus *Platyclymenia (Platyclymenia)* could be placed in a continuous range of variation in strength and density of ribs, and shape of the whorl section.

Platyclymenia annulata (Münster, 1832)

(Figure 13A–D)

1832 *Goniatites annulatus* – Münster, p. 3, pl. 6, fig. 6

1914 *Platyclymenia richteri* – Wedekind, p. 34, pl. 3, fig. 1

1960 *Platyclymenia annulata* – Petter, p. 23, pl. 4, figs 4–4a, 7–7a, 9, 10–10a

1960 *Platyclymenia annulata* var. *densicosta* – Petter, p. 24, pl. 4, fig. 5, pl. 5, figs 13–13a, 23

1960 *Platyclymenia richteri* – Petter, p. 25, pl. 4, figs 13–13a

1960 *Platyclymenia richteri* var. *semperornata* – Petter, p. 25, pl. 4, figs 6–6a, 11–11a

1960 *Platyclymenia ruedemanni* var. *semiornata* – Petter, p. 27, pl. 5, figs 12–12a

? 1960 *Platyclymenia geminicostata* – Petter, p. 26, pl. 5, figs 6–6a

1999 *Platyclymenia annulata* – Korn, pl. 5, figs 2, 3, 10

Material: 18 specimens from samples On8 and On10 (*Platyclymenia* interval).

Description: Specimen On8.23 (not illustrated) has a diameter of 27.2 mm; its conch is extremely discoidal (CWI = 0.26) and evolute (UWI = 0.46), with a weakly compressed whorl cross section (WWI = 0.86) and a moderate whorl expansion rate (WER = 1.83).The whorl section is

subrectangular; the venter is slightly tabulate, the ventrolateral margins are narrow and slightly angular, and the flanks are subparallel; the umbilical margin is subangular. The ornamentation consists of weak, widely spaced (10 ribs per half whorl), prorsiradiate and concave ribs, fading toward the ventrolateral margins. The suture line shows a flattened M saddle; and a wide, moderately deep and rounded L lobe. Specimen On10.13 (Fig. 13A) has a diameter of 21.7 mm; its conch is extremely discoidal (CWI = 0.27) and evolute (UWI = 0.51), with a weakly compressed whorl cross section (WWI = 0.97) and a high whorl expansion rate (WER = 1.96). The whorl section is oval to subrectangular; the venter is narrowly rounded and the flanks are subparallel; the umbilical margin is subangular. The conch shows widely spaced (14 ribs per half whorl), prorsiradiate and concave ribs fading toward the venter. The suture line is characterized by a very large, rounded and moderately deep L lobe. Specimen On8.16 (not illustrated) has a diameter of 20 mm; its conch is extremely discoidal (CWI = 0.31) and subevolute (UWI = 0.40), with a weakly compressed whorl cross section (WWI = 0.87) and a moderate whorl expansion rate (WER = 1.93). The whorl section is oval; the venter is narrowly rounded, but shows slightly subangular ventrolateral margins, and the flanks are subparallel; the umbilical margin is subangular. The conch bears thin, moderately spaced (17 ribs per half whorl), prorsiradiate and concave ribs, fading toward the venter. Specimen On10.8 (D = 14.7 mm; Fig. 13B) has a similar conch geometry (extremely discoidal, CWI = 0.32; subevolute, UWI = 0.43; weakly compressed, WWI = 0.98; moderate whorl expansion rate, WER = 1.98; oval whorl section). The ribs are characteristically concave, prorsiradiate, and fading toward the venter; but they are closely spaced (23 ribs per half whorl). The suture shows a flattened M saddle; and a wide, moderately deep L lobe. Specimens On8.31 (Fig. 13C) and On8.35 (Fig. 13D) have a diameter of 17.5 mm; their conch is extremely discoidal (CWI = 0.27 and 0.28) and evolute (UWI = 0.45 and 0.53), with a weakly compressed whorl cross section (WWI = 0.82) and a moderate whorl expansion rate (WER = 1.98). The whorl section of specimen On8.31is oval (Fig. 13C); the venter is narrowly rounded and the flanks are subparallel; the umbilical margin is rounded and slightly oblique. The conch bears thin, moderately spaced (15 ribs per half whorl), prorsiradiate and concave ribs, fading toward the venter. The shell is partly preserved and shows thin concave growth lines which are projected backward on the venter. The whorl section of specimen On8.35 is subquadrate; the venter is flattened and the flanks are subparallel; the umbilical margin is rounded. The conch is smooth and does not show any ribs.

Discussion: As pointed out by Price and Korn (1989), the genus *Platyclymenia* contains numerous species, which differ by very minor differences in ornament, and most of them probably should be synonymised. The material studied here cannot enable this revision. This Algerian material shows a wide range of morphologies, notably in the thickness and density of ribbing and in the shape of whorl sections (circular to subquadrate). Two groups can be distinguished: the first one has a WER

ranging from 1.81 to 2.06 and a UWI ranging from 0.39 to 0.51, and is assigned to *P. annulata*; the second one has a WER ranging from 2.04 to 2.26 and a UWI ranging from 0.34 to 0.43, and is tentatively assigned to *P.* cf. *ibnsinai*, which is also characterized by a high whorl expansion rate and a narrow umbilicus according to Korn (1999).

Occurrence: In the Ouarourout area (Algeria), *Platyclymenia annulata* occurs in the lower and middle parts of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, *Platyclymenia annulata* ranges from its zone to the *Sporadoceras orbiculare* zone (Becker et al., 2002; see Fig. 5).

Platyclymenia* cf. *ibnsinai Korn, 1999

(Figure 13E–J)

Material: 12 specimens from samples On8, On10, On11 and On12 (*Platyclymenia* interval).

Description: Specimen On12.29 has a diameter of 24.6 mm; its conch is extremely discoidal (CWI = 0.31) and subevolute (UWI = 0.39), with a weakly compressed whorl cross section (WWI = 0.84) and a high whorl expansion rate (WER = 2.05). The suture line shows a flat M saddle; and a wide, relatively shallow and rounded L lobe (Fig. 13J). Specimen On10.14 (Fig. 13E) has a diameter of 22.7 mm; its conch is extremely discoidal (CWI = 0.31) and subevolute (UWI = 0.42), with a weakly compressed whorl cross section (WWI = 0.94) and a high whorl expansion rate (WER = 2.12). The whorl section is oval; the venter is narrowly rounded and the flanks are subparallel; the umbilical margin is rounded but slightly subangular. The conch shows widely spaced (13 ribs per half whorl), thin, prorsiradiate and concave ribs, fading toward the venter. Specimen On8.38 (Fig. 13H–I) has a diameter of 21.8 mm; its conch is extremely discoidal (CWI = 0.27) and subevolute (UWI = 0.40), with a weakly compressed whorl cross section (WWI = 0.74) and a high whorl expansion rate (WER = 2.11). The whorl section is subrectangular; the venter is slightly tabulate (subangular ventrolateral margins) and the flanks are subparallel; the umbilical margin is rounded. The ornamentation consists of weak, widely spaced, prorsiradiate and concave ribs, fading toward the venter. The suture line shows a flattened M saddle; and a wide, moderately deep and rounded L lobe (Fig. 13I). Specimens On10.11 (Fig. 13G) and On10.12 (Fig. 13F) have a similar conch geometry (extremely discoidal, CWI = 0.34; subevolute, UWI = 0.40; weakly compressed, WWI = 0.98; high whorl expansion rate, WER = 2.12; oval whorl section). These specimens bear thin, prorsiradiate and concave ribs fading toward the ventrolateral margins; one has a dense ribbing (On10.12, 22 ribs per half whorl; Fig. 13F), and the other one a widely-spaced ribbing (On10.11, 11 ribs per half whorl; Fig. 13G).

Discussion: As discussed previously, this group of *Platyclymenia* specimens from Ouarourout is tentatively assigned to *Platyclymenia* cf. *ibnsinai* based on their high whorl expansion rate and their narrow umbilicus. However, our material prevents to reach a firm identification, because it is restricted to small specimens showing a wide variation in conch proportions, partly overlapping the

range of values of *P. annulata*.

Occurrence: In the Ouarourout area (Algeria), *Platyclymenia* cf. *ibnsinai* occurs in the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, *P. ibnsinai* ranges from the *Platyclymenia annulata* Zone to the *Cymaclymenia pudica* Zone (Becker et al., 2002; *C. pudica* Zone = time equivalent of the *P. ebbighauseni* and *P. dunkeri* zones; see Fig. 5).

Genus ***Trigonoclymenia*** Schindewolf, 1934

Type-species: *Clymenia spinosa* Münster, 1842, p. 122; by original designation.

Trigonoclymenia cf. *spinosa* (Münster, 1842)

(Figure 13K–M)

Material: Seven specimens from samples On8, On10 and On11 (*Platyclymenia* interval).

Description: Specimen On10.40 (Fig. 13K) has a diameter of 31.7 mm; its conch is extremely discoidal (CWI = 0.31) and evolute (UWI = 0.51), with a weakly depressed whorl cross section (WWI = 1.23) and a moderate whorl expansion rate (WER = 1.94). The whorl section is subquadrate; the venter is slightly flattened (subangular ventrolateral margins) and the flanks are subparallel; the umbilical margin is slightly subangular. The ornamentation consists of widely spaced, rectiradiate and concave ribs, enlarged on mid-flanks and without crossing the venter; these ribs are projected forward on the ventrolateral shoulder, irregularly leading to parabolic nodes. The suture line shows a flat M saddle; and a shallow and very large L lobe going forward near the umbilicus (Fig. 13M). Specimen On8.22 (Fig. 13L) has a diameter of 19.7 mm; its conch is extremely discoidal (CWI = 0.29); and evolute (UWI = 0.49), with a weakly depressed whorl cross section (WWI = 1.04) and a moderate whorl expansion rate (WER = 1.82). The whorl section is subquadrate; the venter is flat (subangular ventrolateral margins) and the flanks are subparallel; the umbilical margin is subangular. The conch bears widely spaced, thin, rectiradiate and concave ribs, projected forward on the ventrolateral shoulder, without crossing the venter; some ribs show weak, ventrolateral, parabolic nodes. Specimen On10.3 (not illustrated) has a diameter of 14.9 mm; its conch is extremely discoidal (CWI = 0.34) and evolute (UWI = 0.48), with a weakly depressed whorl cross section (WWI = 1.19) and a moderate whorl expansion rate (WER = 1.87). The whorl section is subquadrate; the venter is narrowly and the flanks are subparallel; the umbilical margin is oblique. The ornamentation is characterized by weak, rectiradiate and concave ribs bearing weak, ventrolateral and parabolic nodes.

Discussion: Based on the widely-spaced concave ribs bearing ventrolateral parabolic nodes, the studied specimens from Ouarourout can be assigned to *Trigonoclymenia*. Many species of

Trigonoclymenia have been described; they differ by very minor subtle differences and they may constitute transitional forms (see Petter, 1960). The parabolic ribs bearing weak nodes near the ventrolateral shoulders are distinctive of *T. spinosa*, but our limited material prevents to reach a confident species identification.

Occurrence: In the Ouarourout area (Algeria), *Trigonoclymenia* cf. *spinosa* occurs in the lower and middle parts of the *Platyclymenia* interval (late Famennian; Fig. 4). In Morocco, *T. spinosa* ranges from the *Platyclymenia annulata* Zone to the *Cymaclymenia pudica* Zone (Becker et al., 2002; *C. pudica* Zone = time equivalent of the *P. ebbighauseni* and *P. dunkeri* zones; see Fig. 5).

FIGURE 13 AROUND HERE

Superfamily Clymenioidea Edwards, 1849

Family Kosmoclymeniidae Korn and Price, 1987

Subfamily Kosmoclymeniinae Korn and Price, 1987

Genus ***Kosmoclymenia*** Schindewolf, 1949

Type species: *Planulites undulatus* Münster, 1832, p. 9; by original designation.

Kosmoclymenia inaequistriata (Münster, 1832)

(Figure 14A–K)

1832 *Planulites inaequistriatus* – Münster, p. 10, pl. 2, fig. 4

? 1960 *Kosmoclymenia sedgwickii* – Petter, p. 36, pl. 6, figs 1, 3, 6 (only)

1987 *Kosmoclymenia (Kosmoclymenia) inaequistriata inaequistriata* – Korn and Price, p. 29, pl. 3, figs 18–21, pl. 4, figs 22–28, text-fig. 13F, G

1999 *Kosmoclymenia inaequistriata* – Korn, pl. 6, fig. 7

? 2017 *Kosmoclymenia* sp. – Korn et al., p. 137, fig. 17

Material: 19 specimens from samples On13 andOn14 (*Medioclymenia* interval).

Description: Specimen On13.18 (Fig. 14A) has a diameter of 51.1 mm; its conch is extremely discoidal (CWI = 0.25) and subevolute (UWI = 0.41), with a weakly compressed whorl cross section (WWI = 0.75) and a high whorl expansion rate (WER = 2.12). The whorl section is oval; the venter is tabulate and bounded by slight ventrolateral furrows forming a ventral band; the flanks are slightly converging; the umbilical margin is rounded and slightly oblique. At a diameter of 40 mm, the venter is rounded without ventral band. The last half of the conch shows faint biconvex ribs projected backward on the venter. Specimen On14.32 (Fig. 14B) has a diameter of 36 mm; its conch is extremely discoidal (CWI = 0.23) and evolute (UWI = 0.46), with a weakly compressed whorl cross section (WWI = 0.75) and a high whorl expansion rate (WER = 2.12). At a diameter of 26 mm, the

venter is rounded without ventrolateral furrows. The shell geometry is therefore similar to the previous specimen On13.18, but in On14.32 the slight ventrolateral furrows appears earlier. The shell shows dense, closely spaced, biconvex growth lines projected backward on the venter. The suture is partly visible and shows a typical Z-shaped L lobe. Specimen On13.9 (Fig. 14H) has a diameter of 34.4 mm; its conch is extremely discoidal (CWI = 0.27) and evolute (UWI = 0.46), with a weakly compressed whorl cross section (WWI = 0.86) and a high whorl expansion rate (WER = 2.05). The whorl section is oval without slight ventrolateral furrows; the flanks are slightly converging; the umbilical margin is rounded and slightly oblique. The shell is characterized by dense, closely spaced, biconvex growth lines projected backward on the venter; this ventral projection forms a relatively wide ventral band; the growth lines are bunched into groups of approximately six, forming faint ribs. Specimen On13.8 (not illustrated) has a diameter of 27.1 mm; its conch is extremely discoidal (CWI = 0.28) and subevolute (UWI = 0.43), with a weakly compressed whorl cross section (WWI = 0.86) and a high whorl expansion rate (WER = 2.23). The whorl section is oval without ventrolateral grooves; the flanks are slightly converging; the umbilical margin is rounded and slightly oblique. The shell shows dense, biconvex growth lines projected backward on the venter and forming a relatively large ventral band; this ventral band shows periodic U-shaped lines corresponding to the growth lines bunched into groups of approximately six (for a similar example, see Korn and Price, 1987, pl. 3, fig. 20b). Specimen On13.6 (Fig. 14G) has a diameter of 19.5 mm; its conch is extremely discoidal (CWI = 0.30) and evolute (UWI = 0.47), with a weakly compressed whorl cross section (WWI = 0.98) and a moderate whorl expansion rate (WER = 1.91). The whorl section is oval; the venter is rounded and the flanks are subparallel; the umbilical margin is rounded and slightly oblique. The suture line is well exposed and shows the typical asymmetric, relatively deep and pointed L lobe, associated to a rather flat M saddle. Specimens On13.10 (Fig. 14E, J), On13.7 (Fig. 14F, K), On14.10 (Fig. 14D, I), and On14.7 (Fig. 14C) show the suture line at various size (from H = 3 to 8.5 mm); it is characterized by a relatively flat M saddle, followed by an asymmetric, pointed, Z-shaped L lobe; at the largest size, an additional rounded, shallow A lobe is visible.

Discussion: The specimens from Ouarourout closely resemble, in conch shape, ornament and suture line, the material from Germany and Morocco (see Korn and Price, 1987; Korn, 1999); they display the ventral band typical of the genus. *Kosmoclymenia inaequistriata* differ from the closely allied *K. lamellosa* by more biconvex and more closely spaced growth lines appearing at a diameter of about 15 mm. It differs from other species of *Kosmoclymenia* by a more compressed whorl section and by a wider ventral band.

Occurrence: In the Ouarourout area (Algeria), *Kosmoclymenia inaequistriata* occurs in the *Medioclymenia* interval (late Famennian; Fig. 4). In Morocco, *K. inaequistriata* occurs in the *Gonioclymenia hoevelensis* and *Kalloclymenia subarmata* zones; the closely related *K. lamellosa* is

older and occurs in the *Costaclymenia muensteri* and *Gonioclymenia subcarinata* zones (Becker et al., 2002; see Fig. 5).

Genus ***Muessenbiaergia*** Korn and Price, 1987

Type species: *Planulites sublaevis* Münster, 1832, p. 10; by original designation.

Muessenbiaergia* cf. *ouarouroutensis Korn et al., 2017

(Figure 14L)

Material: One incomplete specimen from sample On14 (*Medioclymenia* interval).

Description: Specimen On14.36 (Fig. 14L) has a diameter of 47.1 mm; its conch is extremely discoidal (CWI = 0.26) and subevolute (UWI = 0.42), with a weakly compressed whorl cross section (WWI = 0.71) and a very high whorl expansion rate (WER = 2.28). The whorl section is oval; the venter exhibits weak, but distinct ventral grooves, forming a broad ventral keel; the flanks are subparallel; the umbilical margin is rounded. At a diameter of 33 mm, the venter is rounded without ventral band. The shell is poorly preserved, but partly shows fine, widely spaced and slightly biconvex growth lines.

Discussion: This specimen from Ouarourout shows a broad ventral keel (only visible in the outer whorls) associated to a slightly flattened venter. Its morphology is close to the European species *M. sublaevis* (Münster, 1832) and *M. diversa* (Korn and Price, 1987), but the formers have more closely spaced growth lines, and a less pronounced ventral band. Nevertheless, specimens characterized by this late appearance of a wide ventral keel accompanied with weak ventrolateral grooves have been assigned to a new species, *M. ouarouroutensis*, by Korn et al. (2017) based on Algerian material from Ouarourout.

Occurrence: In the Ouarourout area (Algeria), *Muessenbiaergia* cf. *ouarouroutensis* occurs in the *Medioclymenia* interval (late Famennian; Fig. 4). Korn et al. (2017) identified this species in Ouarourout within the *Medioclymenia* assemblage (see Fig. 5). In Morocco, *M. diversa* occurs from the *Gonioclymenia hoevelensis* to the *Kalloclymenia subarmata* zone, while *M. sublaevis* ranges above, up to the *Parawocklumeria patens* zone (Becker et al., 2002).

Muessenbiaergia beniabbesensis Korn et al., 2017

(Figure 14M–N)

? 1960 *Kosmoclymenia bisulcata* – Petter, p. 38, pl. 6, figs 2, 7, 8

2017 *Muessenbiaergia beniabbesensis* – Korn et al., p. 139, figs 20, 21, table 7

Material: Two specimens from samples On13 and On14 (*Medioclymenia* interval).

Description: Specimen On14.35 (Fig. 14M–N) has a diameter of 36.8 mm; its conch is extremely discoidal (CWI = 0.24) and moderately evolute (UWI = 0.45), with a weakly compressed whorl cross section (WWI = 0.80) and a high whorl expansion rate (WER = 2.17). The venter is tabulate with a relatively high and narrow keel, which is bounded by two shallow grooves; the flanks are slightly converging; the umbilical margin is rounded and the umbilical wall is slightly oblique. The shell is poorly preserved, and partly shows fine, biconvex, rursiradiate growth lines, and faint ribs parallel to the growth lines which are fading toward the umbilicus. The suture line (partly visible) is characterized by a deep, asymmetric and pointed L lobe (Fig. 14N). The fragmentary specimen On13.19 (not illustrated) has a diameter of 33.2 mm; its conch geometry and ornamentation are similar to specimen On14.35 (tabulate venter bounded by sharp grooves forming a narrow keel). At a diameter of 25 mm, the venter is already keeled, but the ventrolateral furrows are only weakly developed leading to a more rounded venter.

Discussion: The specimens characterized by the early appearance of a sharp tabulate venter bordered by ventrolateral grooves forming a narrow keel are assigned to *Muessenbiaergia beniabbesensis*. Our specimens slightly differ from those figured by Korn et al. (2017) by their higher WER (> 2). This species is close to the European group of *M. bisulcata* (see Korn and Price, 1987) based on the tabulate venter with sharp ventral furrows; but it differs by the biconvex growth lines not projected forward near the umbilicus, and by the absence of a lateral groove at the adult stage (Korn et al. 2017).

Occurrence: In the Ouarourout area (Algeria), *Muessenbiaergia beniabbesensis* occurs in the *Medioclymenia* interval (late Famennian; Fig. 4). Korn et al. (2017) also identified this species in Ouarourout within the *Medioclymenia* assemblage (see Fig. 5). *M. beniabbesensis* have not been reported in Morocco.

FIGURE 14 AROUND HERE

Superfamily Gonioclymenioidea Hyatt, 1884

Family Gonioclymeniidae Hyatt, 1884

Genus ***Gonioclymenia*** Hyatt, 1884

Type species: *Goniatites speciosus* Münster, 1831, p. 177; by original designation.

Remarks: This genus has been recently revised by Korn (2017) and Korn and Bockwinkel (2017) for the European and Moroccan occurrences, respectively. They gave a full discussion about this genus, which seems to have different species among these regions. In the Anti-Atlas of Morocco, Korn and Bockwinkel (2017) discussed and distinguished six species; three of them have been also recognized in Algeria by Korn et al. (2017; *G. wendti*, *G. ali* and *G. spiniger*).

Gonioclymenia* cf. *ali Korn and Bockwinkel, 2017

(Figure 15A–B)

Material: Eight incomplete specimens from sample On8f (*Gonioclymenia* level).

Description: Specimen On8.49 (Fig. 15A) has a diameter of 41.1 mm; its conch is extremely discoidal (CWI = 0.23) and subevolute (UWI = 0.41), with a weakly compressed whorl cross section (WWI = 0.59) and a relatively high whorl expansion rate (WER = 2.15). At this diameter, the venter is sharply concave. The ornamentation consists of weak, dense, prorsiradiate ribs, without ventrolateral nodes. Specimen On8.48 (not illustrated) has an estimated diameter of 65 mm and still shows weak ribs and a sharp concave venter. At a diameter of 16 mm, the suture lines of specimens On8.44 and On8.45 (poorly visible, not illustrated) show a deep V-shaped L lobe; a shallow A lobe; and a wide and asymmetric L/U saddle with a curved left-flank. Specimen On8.46 (Fig. 15B) has a diameter of 21.7 mm and a stouter conch; it is extremely discoidal (CWI = 0.25) and subevolute (UWI = 0.41), with a weakly compressed whorl cross section (WWI = 0.65) and a high whorl expansion rate (WER = 2.27). The whorl section is subrectangular; the venter is concave (typical ventral groove) and the flanks are slightly converging; the umbilical margin is rounded. The ornamentation consists of dense, straight to sinuous, prorsiradiate ribs (16 per half-whorl) extending from the umbilicus to the ventrolateral margins where they fade without crossing the venter. The inner whorls are badly preserved but show several ventrolateral nodes, which disappear around a diameter of 15 mm.

Discussion: The concave venter with a ventral groove in juvenile and intermediate stages, and the early disappearance of the ventrolateral nodes are typical of the genus *Gonioclymenia*. The specimens from Ouarourout are close to the species *G. ali*, identified in Morocco and in Algeria (Korn and Bockwinkel, 2017; Korn et al., 2017). The absence of adult specimens and the poor preservation of the sutures within our material prevent to reach a firm conclusion, but the sculpture (coarse ribs; small ventrolateral nodes only in juvenile stage) suggests an affinity with *G. ali*. It differs from other revised species of *Gonioclymenia* from Morocco by the absence of prominent ventrolateral nodes (in contrast to *G. wendti*, *G. spiniger* and *G. ebbighauseni*) and by the development of coarse ribs during the middle stage of the growth (in contrast to *G. inornata*); it differs from *G. subcostulata* (Petter, 1960) by a coarser and a more widely spaced ribbing.

Occurrence: In the Ouarourout area (Algeria), *Gonioclymenia* cf. *ali* occurs in the *Gonioclymenia* level (late Famennian; Fig. 4). Korn et al. (2017) identified *Gonioclymenia ali* in Ouarourout within the *Medioclymenia* assemblage (see Fig. 5). In Morocco, it occurs in the '*Gonioclymenia* Limestone' (Hartenfels and Becker, 2016b; Korn and Bockwinkel 2017); this interval is not precisely dated, and can belong to the *Gonioclymenia subcarinata* and/or to the *Gonioclymenia hoevelensis* zones (see Becker et al., 2002; Korn and Bockwinkel, 2017; Fig. 5).

Family Costaclymeniidae Ruzhencev, 1957

Genus ***Costaclymenia*** Schindewolf, 1920

Type species: *Goniatites binodosus* Münster, 1832, p. 31; by original designation.

Remarks: This genus and the taxonomic problems related to its type species have been recently revised by Korn et al. (2018a, b). It appears that most Moroccan occurrences attributed to *Endosiphonites muensteri* and its homonym zone (see Becker et al., 2002) belong to the species *Costaclymenia ornata* (see Korn et al., 2018c).

Costaclymenia ornata (Petter, 1960)

(Figure 15G)

1950 *Costaclymenia binodosa* – Termier and Termier, p. 77, pl. 160, fig. 28.10

1960 *Trochoclymenia ornata* – Petter, p. 34, pl. 3, figs 1, 2, 4, 7, 8

1999 *Endosiphonites muensteri* – Korn, p. 161, text-fig. 8A–E, pl. 7, figs 1–3

2002 *Endosiphonites muensteri* – Becker et al., pl. 5, figs 7, 8

2018c *Costaclymenia ornata* – Korn et al., p. 36, figs 1–3 [with additional synonymy]

Material: One specimen from a loose block collected just above the sample On12 (*Costaclymenia* level, sample On12f).

Description: Specimen On12.31 (Fig. 15G) has a diameter of 49.3 mm; its conch is extremely discoidal (CWI = 0.20) and evolute (UWI = 0.47), with a weakly compressed whorl cross section (WWI = 0.64) and a high whorl expansion rate (WER = 2.10). The whorl section is subrectangular; the venter is flat and slightly arched, and the flanks are very slightly converging toward subangular ventrolateral margins; the umbilical margin is rounded and slightly oblique. The ornamentation shows moderately spaced, weak, ventrolateral riblets (around 20 on the last half whorl, which in the meantime shows nine sutures). The suture line shows a very shallow E lobe; a large asymmetric and broadly rounded L lobe; and a shallow U lobe.

Discussion: Although a single specimen from Ouarourout is assigned to *Costaclymenia ornata*, it perfectly fits with the description and the illustrated Moroccan material of Korn et al. (2018c), as well as the Algerian material of Petter (1960). Our specimen has a weak ornamentation, but the whorl shape and the suture line are clearly characteristic of *C. ornata*; thus, it constitutes a slender variant of the species.

Occurrence: In the Ouarourout area (Algeria), *Costaclymenia ornata* seems rare and usually found in loose blocks. Nevertheless, it probably occurs in a stratigraphic position equivalent to the Moroccan specimens (*Endosiphonites* (= *Costaclymenia*) *muensteri* Zone of Becker et al., 2002), between the *Platyclymenia* interval and the *Gonioclymenia* level (late Famennian; see Figs 4–5).

Family Sphenoclymeniidae Korn, 1992

Genus ***Medioclymenia*** Korn in Korn and Klug, 2002

Type species: *Goniatites intermedius* Münster, 1839, p. 53; by original designation.

Medioclymenia saourensis Korn et al., 2017

(Figure 15C–F)

1960 *Sphenoclymenia intermedia* – Petter, p. 18, fig. 2A, pl. 2, figs 15, 15a, 16

2002 *Sphenoclymenia intermedia* – Becker et al., pl. 5, figs 5, 6

2017 *Medioclymenia saourensis* – Korn et al., p. 146, figs 29, 30, table 9

Material: Six specimens from sample On14 (*Medioclymenia* interval).

Description: Specimen On14.1 (Fig. 15D, F) has a diameter of 16.7 mm; its conch is extremely discoidal (CWI = 0.22) and subevolute (UWI = 0.41), with a weakly compressed whorl cross section (WWI = 0.62) and a very high whorl expansion rate (WER = 2.39). The whorl section is subtrapezoidal; the venter is flat and the flanks are slightly converging toward subangular ventrolateral margins; the umbilical margin is oblique and rounded. The inner whorls show coarse, distant, spiny ventrolateral nodes (seven per whorl at a diameter of 8 mm), which disappear at a diameter of 10 mm; these nodes influence the shape of the subsequent whorl by preventing embracement of the outer flank, thus leading to a polygonal outline of the umbilicus. At a diameter of 12.8 mm, the suture line shows: a shallow and rounded E lobe; a shallow, rounded and symmetric A lobe; a wide, relatively deep, slightly acute and asymmetric L lobe; and a rounded and shallow U lobe (Fig. 15F). Similarly, specimen On14.40 (Fig. 15C), at an estimated diameter of 45 mm, exhibits a smooth conch with a subtrapezoidal whorl section, and a polygonal umbilicus resulting from spiny ventrolateral tubercles present until a diameter of 13 mm. Specimen On14.39 has a diameter of 43.1 mm; its conch is extremely discoidal (CWI = 0.20) and subevolute (UWI = 0.39), with a weakly compressed whorl cross section (WWI = 0.53) and a very high whorl expansion rate (WER = 2.33). The whorl section is subrectangular; the venter is concave and the flanks are slightly converging toward subangular ventrolateral margins; the umbilical margin is rounded. The concave venter is clearly visible at a diameter of 28 mm, but it progressively flattens toward a diameter of 40 mm. The ornamentation shows only weak prorsiradiate, straight to sinuous folds fading toward the umbilicus and venter. At H = 11.0 mm, the suture line shows a relatively shallow, rounded and symmetric E lobe; a moderately deep, rounded and symmetric A lobe; a deep, rounded and slightly asymmetric L lobe; and a rounded and asymmetric U lobe (Fig. 15E). Specimen On14.41 (not illustrated) has an estimated diameter of about 62 mm. The conch geometry and the ornamentation are similar to the specimen On14.39, but the ventral groove has disappeared and consequently the venter is rounded and slightly convex.

Specimen On14.43 (not illustrated) also shows this rounded and convex venter at an estimated diameter of 120 mm. This specimen shows an eroded suture line with a zigzag course constituted of: a narrow and deep E lobe; a deep, acute, and narrow A lobe; and an asymmetric and lanceolate L lobe.

Discussion: These specimens from Ouarourout are close to the European species *Sphenoclymenia intermedia*. However, recent material from Algeria showing the typical polygonal umbilicus and ventrolateral spines in the inner whorls, as well as a subrectangular whorl section, have been assigned to a new species, *Medioclymenia saourensis*, by Korn et al. (2017). The A_2 lobe characterizing *S. intermedia* (Petter, 1960; Price and Korn, 1989) cannot be observed in our specimens because of their small size. Nevertheless, our material clearly matched the specimens figured by Becker et al. (2002) and Korn et al. (2017).

Occurrence: In the Ouarourout area (Algeria), *Medioclymenia saourensis* occurs in the *Medioclymenia* interval (late Famennian; Fig. 4). Korn et al. (2017) identified this species in Ouarourout within the *Medioclymenia* assemblage (see Fig. 5). In Morocco, *M. saourensis* ("*S. intermedia"*) is restricted to the *Gonioclymenia hoevelensis* Zone (Becker et al., 2002; see Fig. 5).

FIGURE 15 AROUND HERE

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Figures

Fig. 1. Palaeogeographic map of the Famennian for the North Atlantic region (modified after Korn and De Baets, 2015, and based on an image from Ron Blakey, http://jan.ucc.nau.edu/rcb7/), with the position of major ammonoid localities (MT Montana, OK Oklahoma; DC Devon and Cornwall; RM Rhenish Mountains; SU Sudetes; FT Franconia and Thuringia; HC Holy Cross Mountains; SU South Urals; CM Cantabrian Mountains; MN Montagne Noire; CA Carnic Alps; AA Anti–Atlas; SV Saoura Valley). The map shows the close affinity of Morocco and Algeria during the Devonian, both located on the northern Gondwana margin.

Carte paléogéographique de l'Atlantique Nord au Famennien (modifiée d'après Korn et De Baets, 2015, et basée sur une image de Ron Blakey, http://jan.ucc.nau.edu/rcb7/) indiquant la position des principales localités caractérisées par la présence d'ammonoïdes. La carte montre les affinités étroites entre le Maroc et l'Algérie, situés sur la marge nord du Gondwana.

Fig. 2. Location of the studied area. The outcrop of Ouarourout (gray star) is located north-west of Béni-Abbès (**C**), in the Saoura Valley (**B**; background from Google Earth) in Algeria (**A**; simplified geological context modified after Fabre et al., 1978).

*Localisation de la zone d'étude. L'affleurement de Ouarourout (étoile grise) est situé au nord-ouest de Béni-Abbès (**C**), dans la vallée de la Saoura (**B** ; fond d'après Google Earth) en Algérie (**A** ; contexte géologique simplifié d'après Fabre et al., 1978).*

Fig. 3. Stratigraphic log and views of the Ouarourout section near Béni-Abbès (Saoura Valley, Algeria). The numbers On1–On14 refer to the fossiliferous samples containing ammonoids. **A,** Late Devonian strata outcroping as an anticline fold unconformably overlain by Neogene sediments. **B,** The 'griotte limestones' unit. **C–D,** The 'griotte shaly limestones' unit.

*Colonne stratigraphique et vues de la section de Ouarourout près de Béni-Abbès (vallée de la Saoura, Algérie). Les numéros On1–On14 font référence aux échantillons fossilifères contenant des ammonoïdes. **A**, Dépôts du Dévonien supérieur formant un pli anticlinal recouvert de manière discordante par des sédiments néogènes. **B**, Unité des 'calcaires griottes'. **C–D**, Unité des 'calcaires-argileux à griottes'.*

Fig. 4. Stratigraphic ranges of the ammonoids identified in the Ouarourout section near Béni-Abbès (Saoura Valley, Algeria).

Distributions stratigraphiques des ammonoïdes identifiés au sein de la coupe de Ouarourout près de Béni-Abbès (vallée de la Saoura, Algérie).

1796

1797 **Fig. 5**. Correlation of the Moroccan biozonations (Famennian) with the intervals and levels identified
1798 in the Ouarourout section near Béni-Abbès (Algeria).
1799 *Corrélation des biozonations marocaines (Famennien) avec les intervalles et niveaux identifiés au sein*
1800 *de la coupe de Ouarourout près de Béni-Abbès (Algérie).*
1801

1802 **Fig. 6**. Explanatory diagram of the classical shell parameters measured for the present study (for
1803 details see text).
1804 *Schéma explicatif des paramètres classiques de la coquille mesurés pour cette étude (pour plus de*
1805 *détails, voir le texte).*
1806

1807 **Fig. 7**. Tornoceratidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–D,** *Gundolficeras fezzouense*
1808 (Becker, 1995); **A,** Specimen On14.16; **B,** Specimen On9.2; **C,** Suture line of On14.16 at H = 16.0 mm;
1809 **D,** Suture lines of On9.2 at H = 7.5 mm and H = 5.5 mm. **E–L,** *Planitornoceras euryomphalum*
1810 (Wedekind, 1918); **E,** Specimen On9.9; **F,** Specimen On9.12; **G,** Specimen On9.15; **H,** Specimen
1811 On8.41; **I,** Suture line of On9.9 at H = 7.3 mm; **J,** Suture lines of On9.15 at H = 5.7 mm and H = 4.5
1812 mm; **K,** Suture line of On9.12 at H = 4.5 mm; **L,** Suture line of On8.41 at H = 3.0 mm.
1813 *Tornoceratidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm.* ***A–D,*** Gundolficeras
1814 fezzouense *(Becker, 1995) ;* ***A,*** *Spécimen On14.16 ;* ***B,*** *Spécimen On9.2 ;* ***C,*** *Ligne de suture de On14.16*
1815 *à H = 16,0 mm ;* ***D,*** *Lignes de suture de On9.2 à H = 7,5 mm et H = 5,5 mm.* ***E–L,*** Planitornoceras
1816 euryomphalum *(Wedekind, 1918) ;* ***E,*** *Spécimen On9.9 ;* ***F,*** *Spécimen On9.12 ;* ***G,*** *Spécimen On9.15 ;* ***H,***
1817 *Spécimen On8.41 ;* ***I,*** *Ligne de suture de On9.9 à H = 7,3 mm ;* ***J,*** *Lignes de suture de On9.15 à H = 5,7*
1818 *mm et H = 4,5 mm ;* ***K,*** *Ligne de suture de On9.12 à H = 4,5 mm ;* ***L,*** *Ligne de suture de On8.41 à H =*
1819 *3,0 mm.*
1820

1821 **Fig. 8**. Posttornoceratidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–B,** *Discoclymenia atlantea*
1822 Korn et al., 2016a; **A,** Specimen On13.12; **B,** Suture line of On13.12 at H = 17.5 mm.
1823 *Posttornoceratidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm.* ***A–B,*** Discoclymenia
1824 atlantea *Korn et al., 2016a ;* ***A,*** *Spécimen On13.12 ;* ***B,*** *Ligne de suture de On13.12 à H = 17,5 mm.*
1825

1826 **Fig. 9**. Sporadoceratidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–C,** *Sporadoceras* cf.
1827 *muensteri* (von Buch, 1832); **A,** Specimen On12.19; **B,** Specimen On12.26; **C,** Suture lines of On12.19
1828 at H = 10.2 mm and at H = 8.4 mm. **D–F,** *Sporadoceras* aff. *conforme* Korn et al., 2015a; **D,** Suture line
1829 of On4.6 at H = 7 mm; **E,** Specimen On3.7; **F,** Specimen On4.6. **G–M,** *Erfoudites rherisensis* Korn,
1830 1999; **G,** Specimen On10.41; **H,** Specimen On12.25; **I,** Specimen On12.18; **J,** Suture line of On10.43 at

H = 12 mm; **K,** Suture line of On10.42 at H = 7.3 mm; **L,** Specimen On12.20; **M,** Zoom on the upper flank of On12.20 showing the spiral ornament. **N–Q,** *Erfoudites* aff. *spirifer* (Lange, 1929); **N,** Specimen On3.2; **O,** Suture line of On3.2 at H = 10 mm; **P,** Suture line of On2.5 at H = 7 mm; **Q,** Specimen On2.5.

Sporadoceratidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm. ***A–C,*** Sporadoceras *cf.* muensteri *(von Buch, 1832) ;* ***A,*** *Spécimen On12.19 ;* ***B,*** *Spécimen On12.26 ;* ***C,*** *Lignes de suture de On12.19 à H = 10,2 mm et à H = 8,4 mm.* ***D–F,*** Sporadoceras *aff.* conforme *Korn et al., 2015a ;* ***D,*** *Ligne de suture de On4.6 à H = 7 mm ;* ***E,*** *Spécimen On3.7 ;* ***F,*** *Spécimen On4.6.* ***G–M,*** Erfoudites rherisensis *Korn, 1999 ;* ***G,*** *Spécimen On10.41 ;* ***H,*** *Spécimen On12.25 ;* ***I,*** *Spécimen On12.18 ;* ***J,*** *Ligne de suture de On10.43 à H = 12 mm ;* ***K,*** *Ligne de suture de On10.42 à H = 7,3 mm ;* ***L,*** *Spécimen On12.20 ;* ***M,*** *Zoom sur le flanc supérieur de On12.20 montrant l'ornementation spirale.* ***N–Q,*** Erfoudites *aff.* spirifer *(Lange, 1929) ;* ***N,*** *Spécimen On3.2 ;* ***O,*** *Ligne de suture de On3.2 à H = 10 mm ;* ***P,*** *Ligne de suture de On2.5 à H = 7 mm ;* ***Q,*** *Spécimen On2.5.*

Fig. 10. Prionoceratidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–B,** *Prionoceras ouarouroutense* Korn et al., 2014; **A,** Specimen On11.24; **B,** Specimen On10.31. **C–D,** *Prionoceras lamellosum* Korn et al., 2014; **C,** Specimen On8.51; **D,** Specimen On8.58. **E–G,** *Prionoceras* aff. *frechi* (Wedekind, 1913); **E,** Specimen On10.33; **F,** Specimen On10.34; **G,** Suture line of On10.33 at H = 8.3 mm. **H–I,** *Prionoceras lentis* Korn et al., 2014; **H,** Specimen On11.20; **I,** Specimen On11.22. **J–K,** *Prionoceras* cf. *subtum* Korn et al., 2014; **J,** Specimen On12.13; **K,** Specimen On12.22. **L,** *Prionoceras* cf. *triens* Korn et al., 2014, specimen On12.46. **M–N,** *Mimimitoceras* cf. *carnatum* Korn et al., 2015b; **M,** Specimen On14.13; **N,** Specimen On13.1. **O–P,** *Mimimitoceras* cf. *comtum* Korn et al., 2015b; **O,** Specimen On14.17; **P,** Specimen On13.3.

Prionoceratidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm. ***A–B,*** Prionoceras ouarouroutense *Korn et al., 2014 ;* ***A,*** *Spécimen On11.24 ;* ***B,*** *Spécimen On10.31.* ***C–D,*** Prionoceras lamellosum *Korn et al., 2014 ;* ***C,*** *Spécimen On8.58 ;* ***D,*** *Spécimen On8.51.* ***E–G,*** Prionoceras *aff.* frechi *(Wedekind, 1913) ;* ***E,*** *Spécimen On10.33 ;* ***F,*** *Spécimen On10.34 ;* ***G,*** *Ligne de suture de On10.33 à H = 8,3 mm.* ***H–I,*** Prionoceras lentis *Korn et al., 2014 ;* ***H,*** *Spécimen On11.20 ;* ***I,*** *Spécimen On11.22.* ***J–K,*** Prionoceras *cf.* subtum *Korn et al., 2014 ;* ***J,*** *Spécimen On12.13 ;* ***K,*** *Spécimen On12.22.* ***L,*** Prionoceras *cf.* triens *Korn et al., 2014, Spécimen On12.46.* ***M–N,*** Mimimitoceras *cf. carnatum Korn et al., 2015b ;* ***M,*** *Spécimen On14.13 ;* ***N,*** *Spécimen On13.1.* ***O–P,*** Mimimitoceras *cf.* comtum *Korn et al., 2015b ;* ***O,*** *Spécimen On14.17 ;* ***P,*** *Spécimen On13.3.*

Fig. 11. Cyrtoclymeniidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–E,** *Cyrtoclymenia* cf. *frechi* (Tokarenko, 1903); **A,** Specimen On12.33; **B,** Specimen On10.17; **C,** Suture lines of On10.18 at H = 5

mm and at H = 4 mm; **D,** Specimen On10.18; **E,** Specimen On10.19. **F,** *Protactoclymenia* sp. indet. B; Specimen On8.3.

Cyrtoclymeniidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm. ***A–E,*** Cyrtoclymenia *cf.* frechi *(Tokarenko, 1903) ;* ***A,*** *Spécimen On12.33 ;* ***B,*** *Spécimen On10.17 ;* ***C,*** *Lignes de suture de On10.18 à H = 5 mm et à H = 4 mm ;* ***D,*** *Spécimen On10.18 ;* ***E,*** *Spécimen On10.19.* ***F,*** Protactoclymenia *sp. indet. B ; Spécimen On8.3*.

Fig. 12. Cymaclymeniidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–I,** *Procymaclymenia ebbighauseni* Klein and Korn, 2014; **A,** Specimen On12.44; **B,** Specimen On12.38; **C,** Specimen On12.40; **D,** Specimen On12.39; **E,** Suture line of On10.25 at H = 6.5 mm; **F,** Suture line of On12.39 at H = 6.5 mm; **G,** Suture line of On12.38 at H = 6.8 mm; **H,** Suture line of On12.40 at H = 6.2 mm; **I,** Specimen On10.25. **J–N,** *Cymaclymenia subvexa* Klein and Korn, 2014; **J,** Specimen On13.24; **K,** Specimen On13.26; **L,** Suture line of On13.26 at H = 14 mm; **M,** Suture line of On13.22 at H = 15 mm; **N,** Suture line of On13.24 at H = 9.8 mm. **O–P,** *Genuclymenia* sp. indet.; **O,** Specimen On9.17; **P,** Suture lines of On9.17at H = 5.5 mm and at H = 3 mm.

Cymaclymeniidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm. ***A–I,*** Procymaclymenia ebbighauseni *Klein and Korn, 2014 ;* ***A,*** *Spécimen On12.44 ;* ***B,*** *Spécimen On12.38 ;* ***C,*** *Spécimen On12.40 ;* ***D,*** *Spécimen On12.39 ;* ***E,*** *Ligne de suture de On10.25 à H = 6,5 mm ;* ***F,*** *Ligne de suture de On12.39 à H = 6,5 mm ;* ***G,*** *Ligne de suture de On12.38 à H = 6,8 mm ;* ***H,*** *Ligne de suture de On12.40 à H = 6,2 mm ;* ***I,*** *Spécimen On10.25.* ***J–N,*** Cymaclymenia subvexa *Klein et Korn, 2014 ;* ***J,*** *Spécimen On13.24 ;* ***K,*** *Spécimen On13.26 ;* ***L,*** *Ligne de suture de On13.26 à H = 14 mm ;* ***M,*** *Ligne de suture de On13.22 à H = 15 mm ;* ***N,*** *Ligne de suture de On13.24 à H = 9,8 mm.* ***O–P,*** Genuclymenia *sp. indet. ;* ***O,*** *Spécimen On9.17 ;* ***P,*** *Lignes de suture de On9.17 à H = 5,5 mm et à H = 3 mm.*

Fig. 13. Platyclymeniidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–D,** *Platyclymenia annulata* (Münster, 1832); **A,** Specimen On10.13; **B,** Specimen On10.8; **C,** Specimen On8.31; **D,** Specimen On8.35. **E–J,** *Platyclymenia* cf. *ibnsinai* Korn, 1999; **E,** Specimen On10.14; **F,** Specimen On10.12; **G,** Specimen On10.11; **H,** Specimen On8.38; **I,** Suture line of On8.38 at H = 6.8 mm; **J,** Suture line of On12.29 at H = 7 mm. **K–M,** *Trigonoclymenia* cf. *spinosa* (Münster, 1842); **K,** Specimen On10.40; **L,** Specimen On8.22; **M,** Suture line of On10.40 at H = 6.5 mm.

Platyclymeniidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm. ***A–D,*** Platyclymenia annulata *(Münster, 1832) ;* ***A,*** *Spécimen On10.13 ;* ***B,*** *Spécimen On10.8 ;* ***C,*** *Spécimen On8.31 ;* ***D,*** *Spécimen On8.35.* ***E–J,*** Platyclymenia *cf.* ibnsinai *Korn, 1999 ;* ***E,*** *Spécimen On10.14 ;* ***F,*** *Spécimen On10.12 ;* ***G,*** *Spécimen On10.11 ;* ***H,*** *Spécimen On8.38 ;* ***I,*** *Ligne de suture de On8.38 à H = 6,8 mm ;* ***J,*** *Ligne de suture de On12.29 à H = 7 mm.* ***K–M,*** Trigonoclymenia *cf.* spinosa *(Münster, 1842) ;* ***K,***

*Spécimen On10.40 ; **L,** Spécimen On8.22 ; **M,** Ligne de suture de On10.40 à H = 6,5 mm.*

Fig. 14. Kosmoclymeniidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–K,** *Kosmoclymenia inaequistriata* (Münster, 1832); **A,** Specimen On13.18; **B,** Specimen On14.32; **C,** Specimen On14.7; **D,** Specimen On14.10; **E,** Specimen On13.10; **F,** Specimen On13.7; **G,** Specimen On13.6; **H,** Growth line of On13.9 at H = 10.4 mm; **I,** Suture line of On14.10 at H = 8.5 mm; **J,** Suture line of On13.10 at H = 8.4 mm; **K,** Suture line of On13.7 at H = 4.5 mm. **L,** *Muessenbiaergia* cf. *ouarouroutensis* Korn et al., 2017, specimen On14.36. **M–N,** *Muessenbiaergia beniabbesensis* Korn et al., 2017; **M,** Specimen On14.35; **N,** Suture line of On14.35 at H = 8.2 mm.

*Kosmoclymeniidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm. **A–K,** Kosmoclymenia inaequistriata (Münster, 1832) ; **A,** Spécimen On13.18 ; **B,** Spécimen On14.32 ; **C,** Spécimen On14.7 ; **D,** Spécimen On14.10 ; **E,** Spécimen On13.10 ; **F,** Spécimen On13.7 ; **G,** Spécimen On13.6 ; **H,** Ligne de croissance de On13.9 à H = 10,4 mm ; **I,** Ligne de suture de On14.10 à H = 8,5 mm ; **J,** Ligne de suture de On13.10 à H = 8,4 mm ; **K,** Ligne de suture de On13.7 à H = 4,5 mm. **L,** Muessenbiaergia cf. ouarouroutensis Korn et al., 2017, spécimen On14.36. **M–N,** Muessenbiaergia beniabbesensis Korn et al., 2017 ; **M,** Spécimen On14.35 ; **N,** Ligne de suture de On14.35 à H = 8,2 mm.*

Fig. 15. Gonioclymeniidae, Sphenoclymeniidae and Costaclymenidae from Ouarourout (Algeria). Scale bar = 5 mm. **A–B,** *Gonioclymenia* cf. *ali* Korn and Bockwinkel, 2017; **A,** Specimen On8.49; **B,** Specimen On8.46. **C–F,** *Medioclymenia saourensis* Korn et al., 2017; **C,** Specimen On14.40; **D,** Specimen On14.1; **E,** Suture line of On14.39 at H = 11.0 mm. **F,** Suture line of On14.1 at H = 4 mm. **G**, *Costaclymenia ornata* (Petter 1960), specimen On12.31.

*Gonioclymeniidae, Sphenoclymeniidae et Costaclymenidae provenant de Ouarourout (Algérie). Barre d'échelle = 5 mm. **A–B,** Gonioclymenia cf. ali Korn et Bockwinkel, 2017 ; **A,** Spécimen On8.49 ; **B,** Spécimen On8.46. **C–F,** Medioclymenia saourensis Korn et al., 2017 ; **C,** Spécimen On14.40 ; **D,** Spécimen On14.1 ; **E,** Ligne de suture de On14.39 à H = 11,0 mm ; **F,** Ligne de suture de On14.1 à H = 4 mm. **G,** Costaclymenia ornata (Petter 1960), spécimen On12.31.*

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30°
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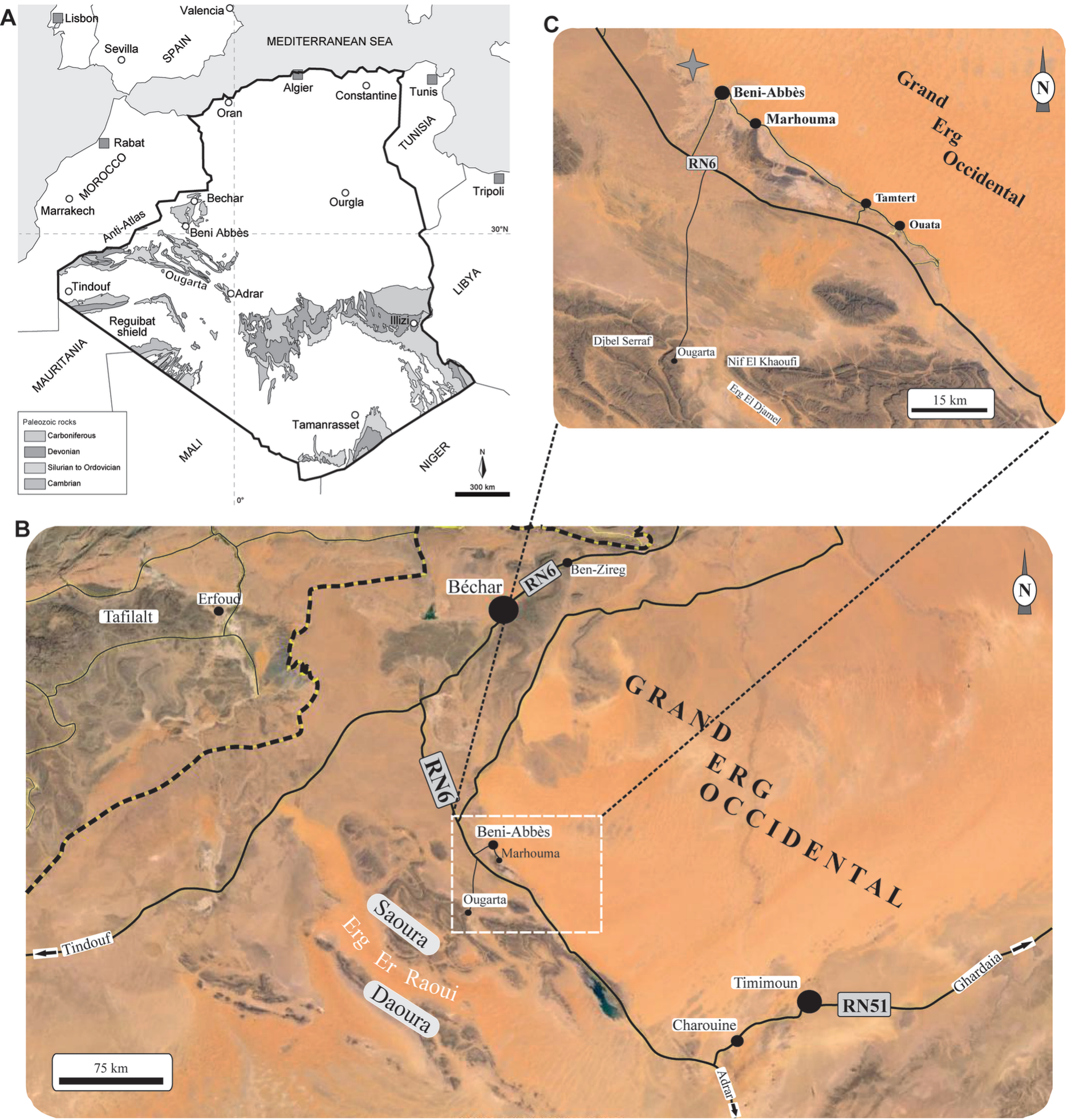
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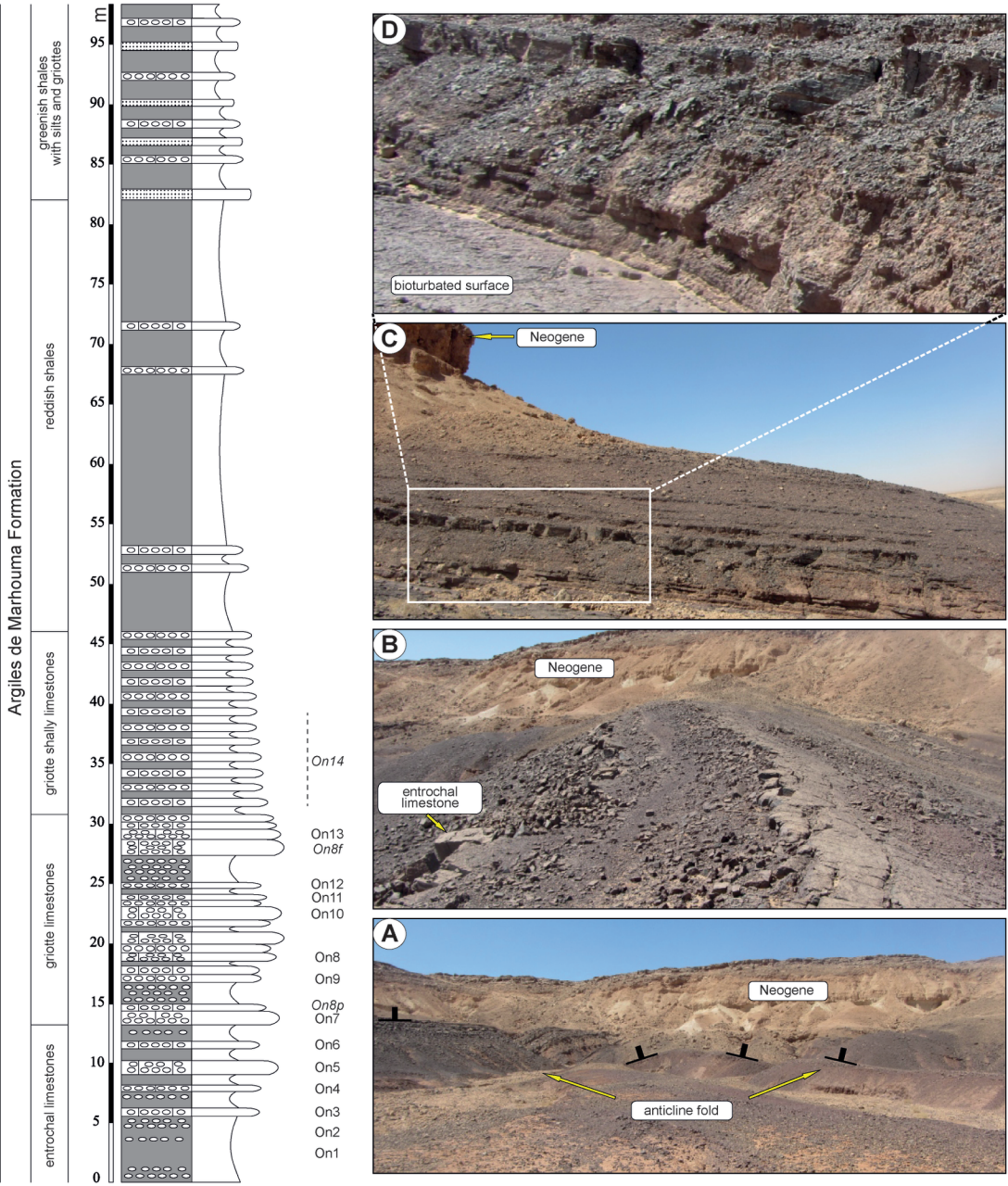
Lisbon
Valencia
Sevilla
SPAIN
MEDITERRANEAN SEA
Algier
Constantine
Tunis
Oran
TUNISIA
Rabat
MOROCCO
Marrakech
Bechar
Ourgla
Tripoli
Anti-Atlas
Beni Abbès
30°N
Ougarta
Tindouf
Adrar
LIBYA
Reguibat shield
Illizi
MAURITANIA
Tamanrasset
MALI
NIGER
0°
N
300 km
Paleozoic rocks
Carboniferous
Devonian
Silurian to Ordovician
Cambrian
C
Beni-Abbès
Marhouma
Grand Erg Occidental
N
RN6
Tamtert
Ouata
Djbel Serraf
Ougarta
Nif El Khaoufi
Erg El Djamel
15 km
B
Béchar
RN6
Ben-Zireg
Erfoud
Tafilalt
N
GRAND ERG OCCIDENTAL
RN6
Beni-Abbès
Marhouma
Ougarta
Saoura
Erg Er Raoui
Daoura
Tindouf
Timimoun
RN51
Ghardaia
Charouine
Adrar
75 km


Argiles de Marhouma Formation
greenish shales with silts and griottes
reddish shales
griotte shally limestones
griotte limestones
entrochal limestones
m
95
90
85
80
75
70
65
60
55
50
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15
10
5
0
On14
On13
On8f
On12
On11
On10
On8
On9
On8p
On7
On6
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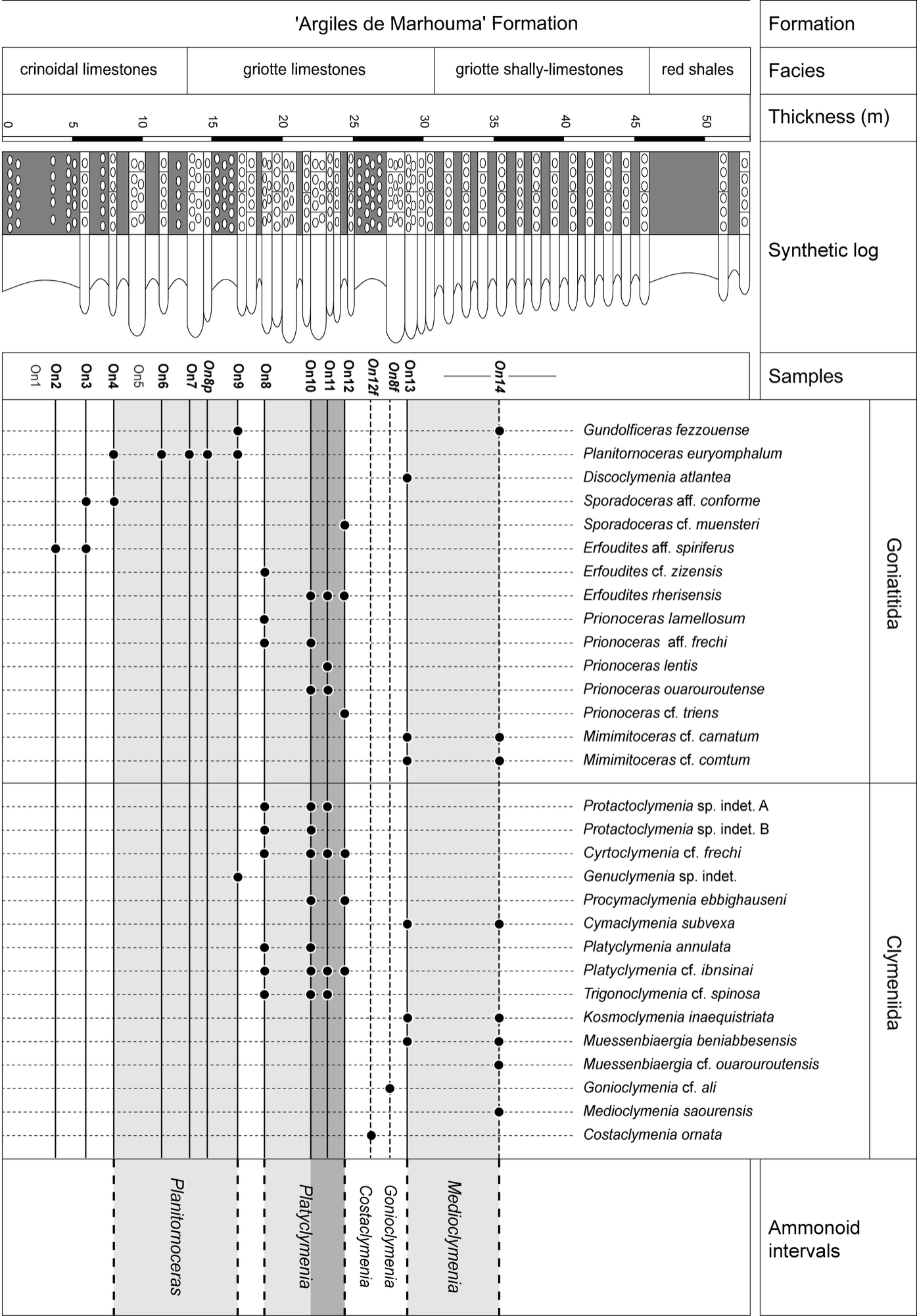
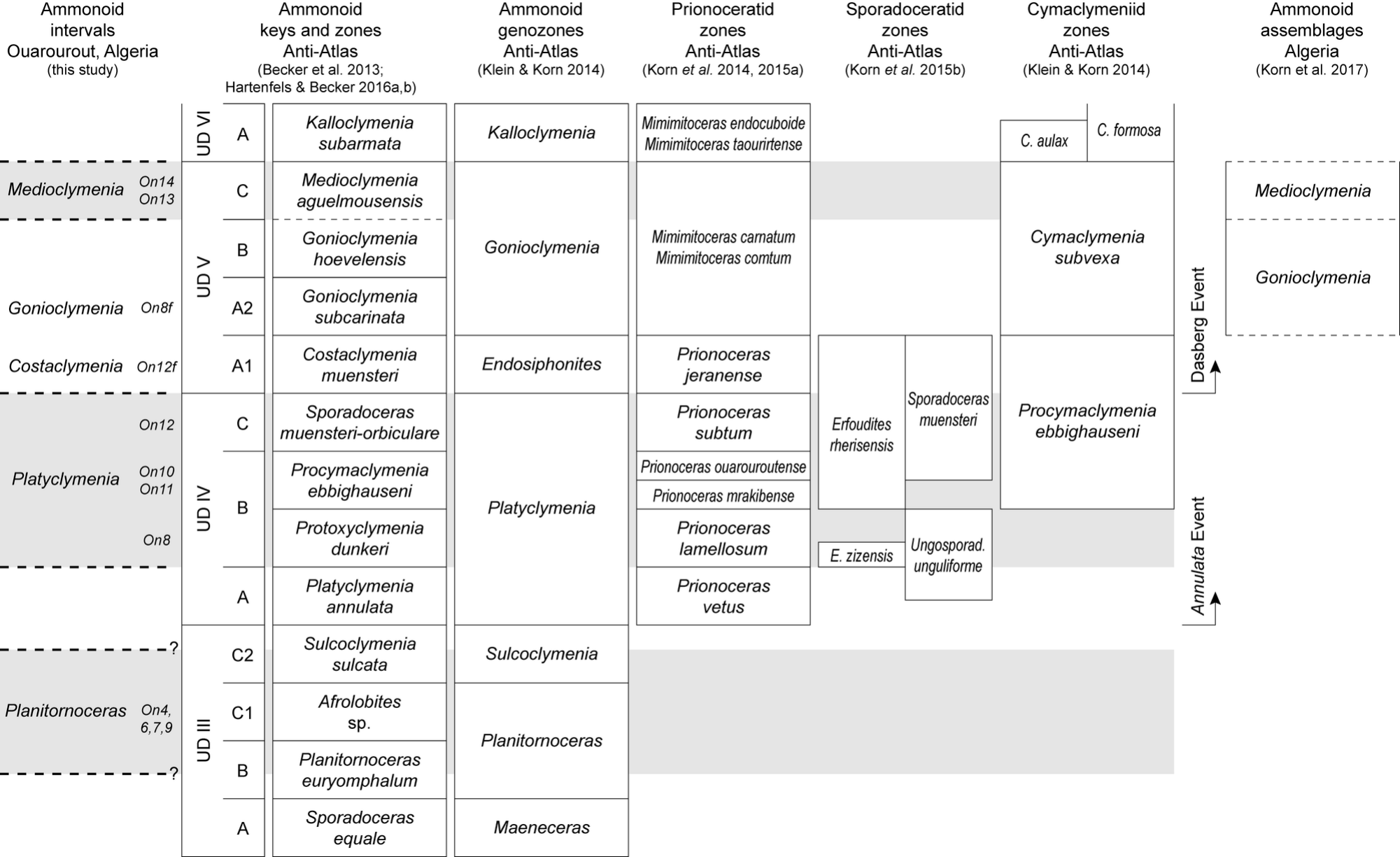
On1
D
bioturbated surface
C
Neogene
B
Neogene
entrochal limestone
A
Neogene
anticline fold


'Argiles de Marhouma' Formation
Formation
crinoidal limestones
griotte limestones
griotte shally-limestones
red shales
Facies
0
5
10
15
20
25
30
35
40
45
50
Thickness (m)
Synthetic log
On1
On2
On3
On4
On5
On6
On7
On8p
On9
On8
On10
On11
On12
On12f
On8f
On13
On14
Samples
Gundolficeras fezzouense
Planitornoceras euryomphalum
Discoclymenia atlantea
Sporadoceras aff. conforme
Sporadoceras cf. muensteri
Erfoudites aff. spiriferus
Erfoudites cf. zizensis
Erfoudites rherisensis
Prionoceras lamellosum
Prionoceras aff. frechi
Prionoceras lentis
Prionoceras ouarouroutense
Prionoceras cf. triens
Mimimitoceras cf. carnatum
Mimimitoceras cf. comtum
Goniatitida
Protactoclymenia sp. indet. A
Protactoclymenia sp. indet. B
Cyrtoclymenia cf. frechi
Genuclymenia sp. indet.
Procymaclymenia ebbighauseni
Cymaclymenia subvexa
Platyclymenia annulata
Platyclymenia cf. ibnsinai
Trigonoclymenia cf. spinosa
Kosmoclymenia inaequistriata
Muessenbiaergia beniabbesensis
Muessenbiaergia cf. ouarouroutensis
Gonioclymenia cf. ali
Medioclymenia saourensis
Costaclymenia ornata
Clymeniida
Planitornoceras
Platyclymenia
Costaclymenia
Gonioclymenia
Medioclymenia
Ammonoid intervals


Ammonoid intervals Ouarourout, Algeria (this study)
Ammonoid keys and zones Anti-Atlas (Becker et al. 2013; Hartenfels & Becker 2016a,b)
Ammonoid genozones Anti-Atlas (Klein & Korn 2014)
Prionoceratid zones Anti-Atlas (Korn et al. 2014, 2015a)
Sporadoceratid zones Anti-Atlas (Korn et al. 2015b)
Cymaclymeniid zones Anti-Atlas (Klein & Korn 2014)
Ammonoid assemblages Algeria (Korn et al. 2017)
UD VI
UD V
UD IV
UD III
A
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A2
A1
C
B
A
C2
C1
B
A
Kalloclymenia subarmata
Medioclymenia aguelmousensis
Gonioclymenia hoevelensis
Gonioclymenia subcarinata
Costaclymenia muensteri
Sporadoceras muensteri-orbiculare
Procymaclymenia ebbighauseni
Protoxyclymenia dunkeri
Platyclymenia annulata
Sulcoclymenia sulcata
Afrolobites sp.
Planitornoceras euryomphalum
Sporadoceras equale
Kalloclymenia
Gonioclymenia
Endosiphonites
Platyclymenia
Sulcoclymenia
Planitornoceras
Maeneceras
Mimimitoceras endocuboide
Mimimitoceras taourirtense
Mimimitoceras carnatum
Mimimitoceras comtum
Prionoceras jeranense
Prionoceras subtum
Prionoceras ouarouroutense
Prionoceras mrakibense
Prionoceras lamellosum
Prionoceras vetus
Erfoudites rherisensis
E. zizensis
Sporadoceras muensteri
Ungosporad. unguliforme
C. aulax
C. formosa
Cymaclymenia subvexa
Procymaclymenia ebbighauseni
Dasberg Event
Annulata Event
Medioclymenia
Gonioclymenia
Medioclymenia
On14
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Gonioclymenia
On8f
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Planitornoceras
On4, 6,7,9
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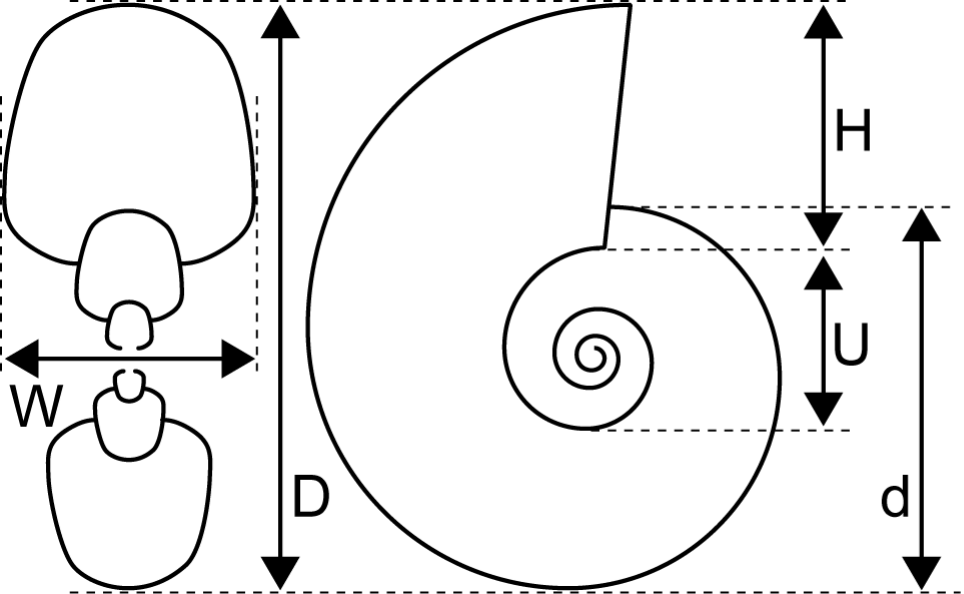

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WWI = W / H

UWI = U / D

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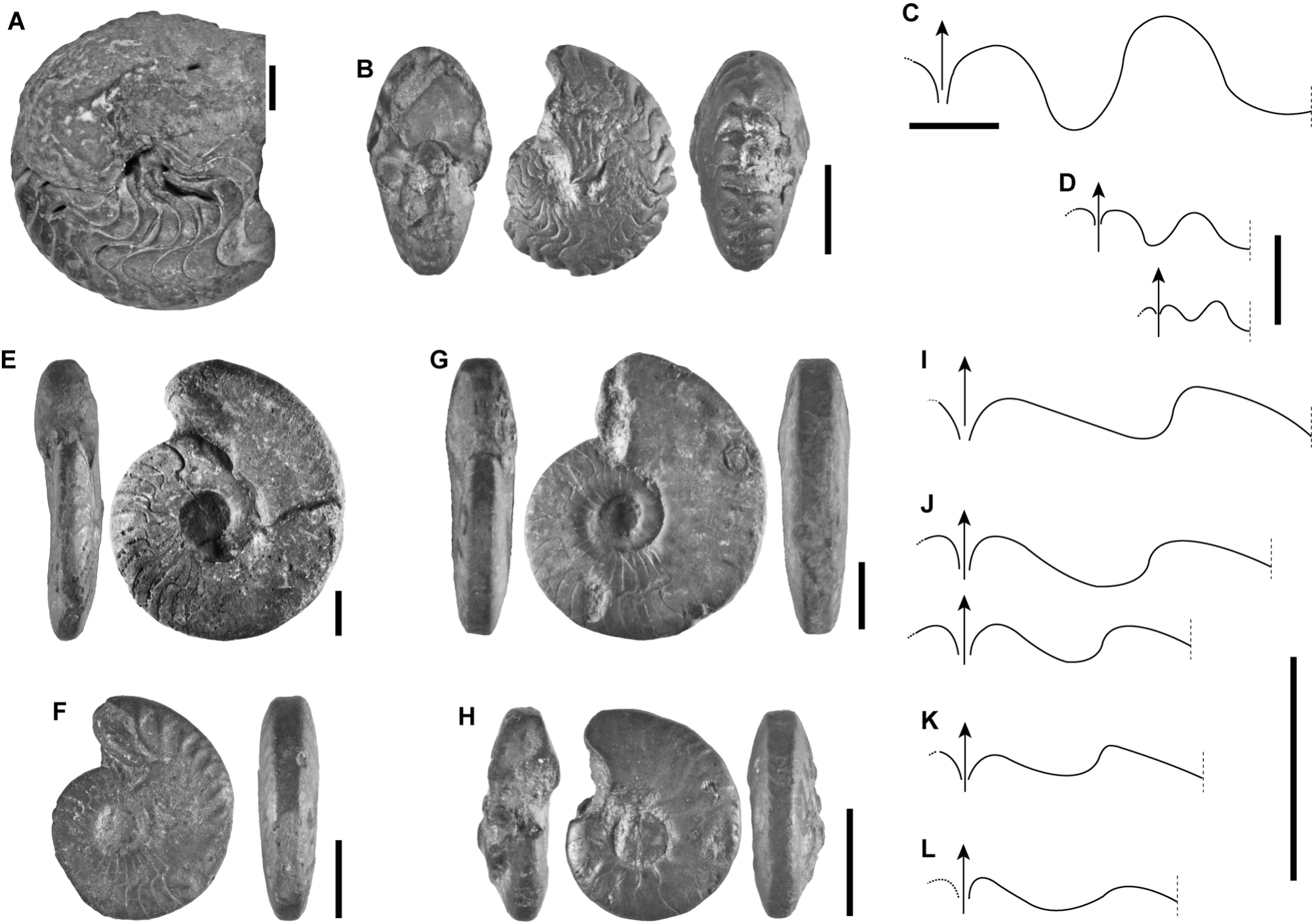
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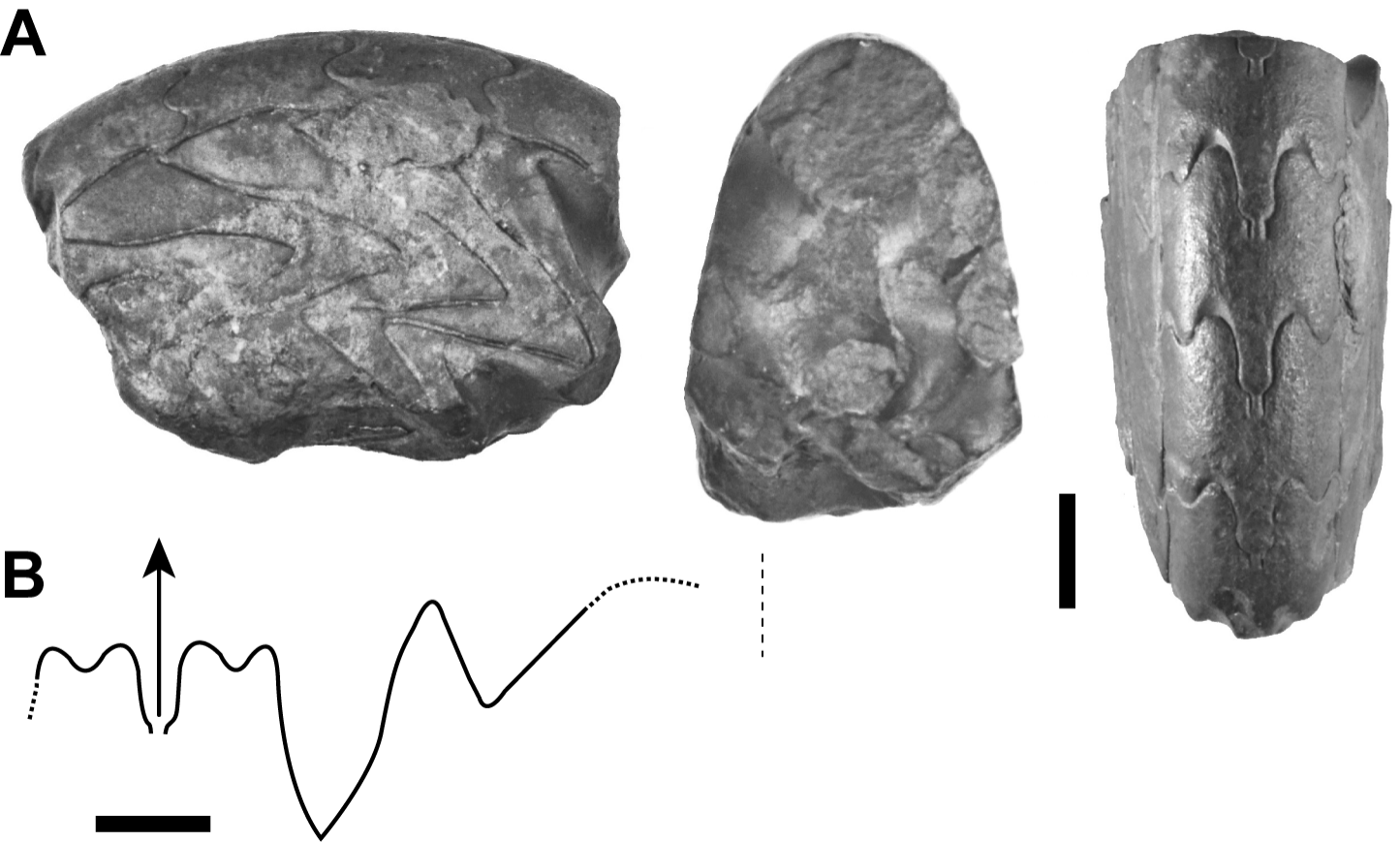
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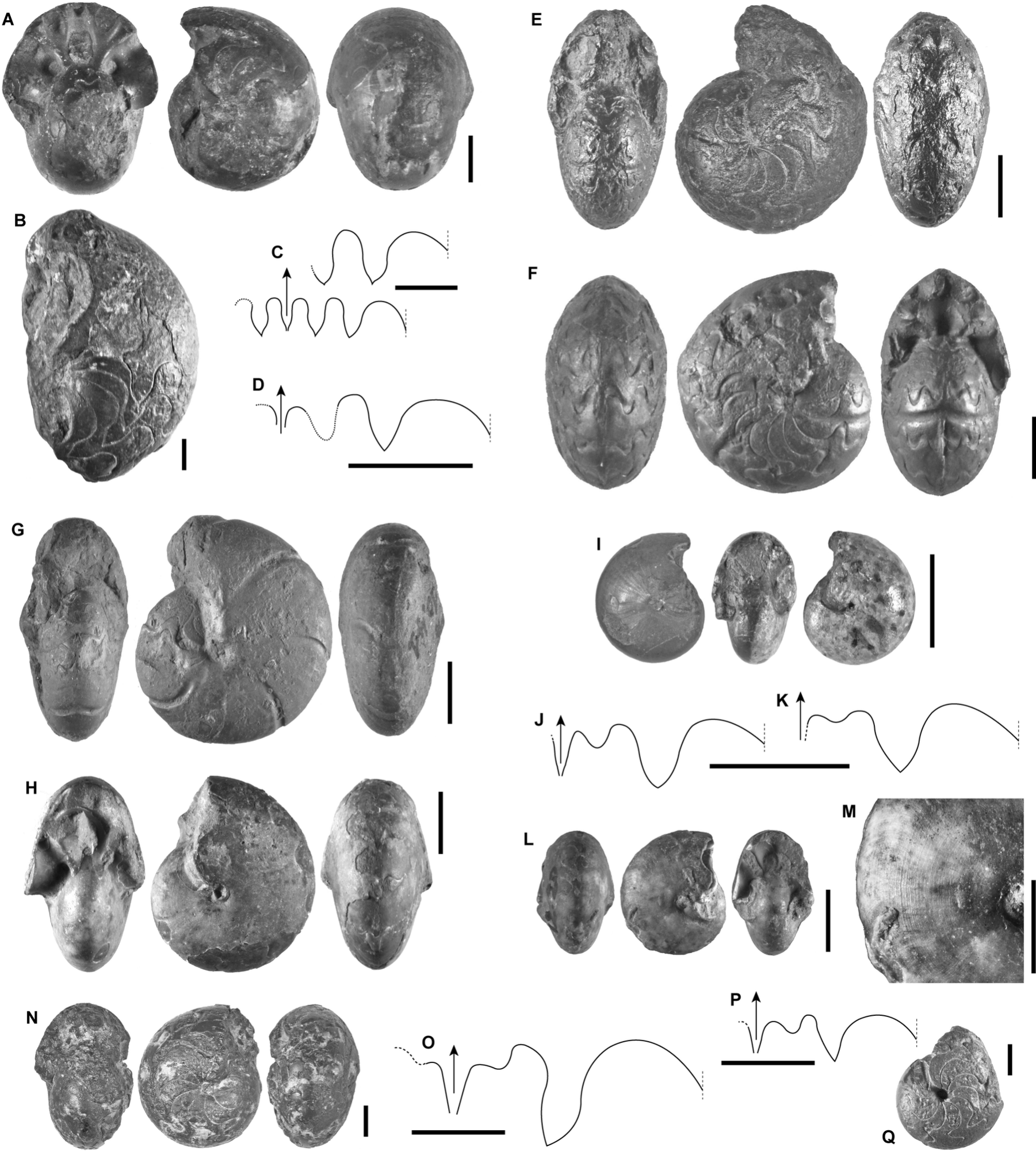
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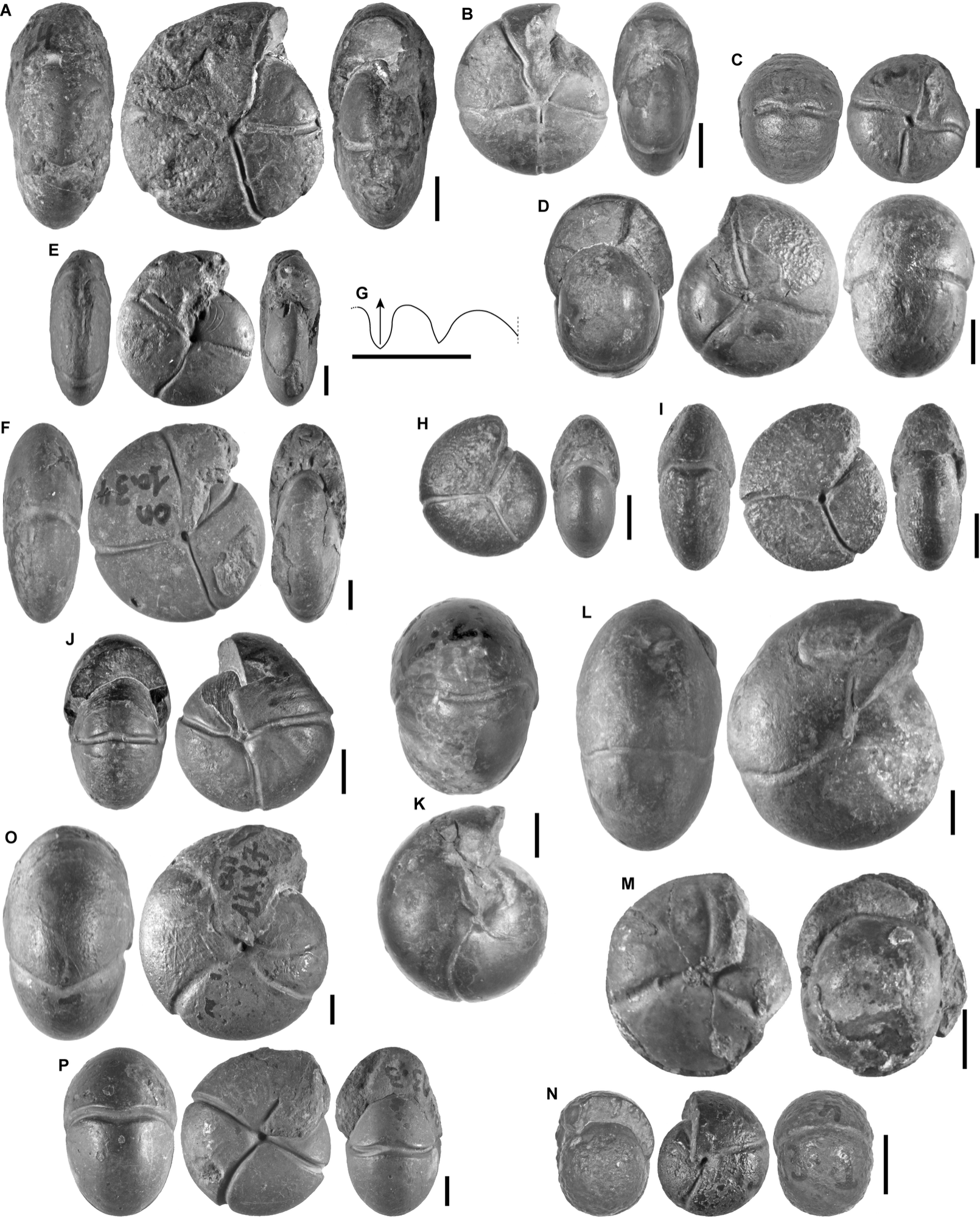
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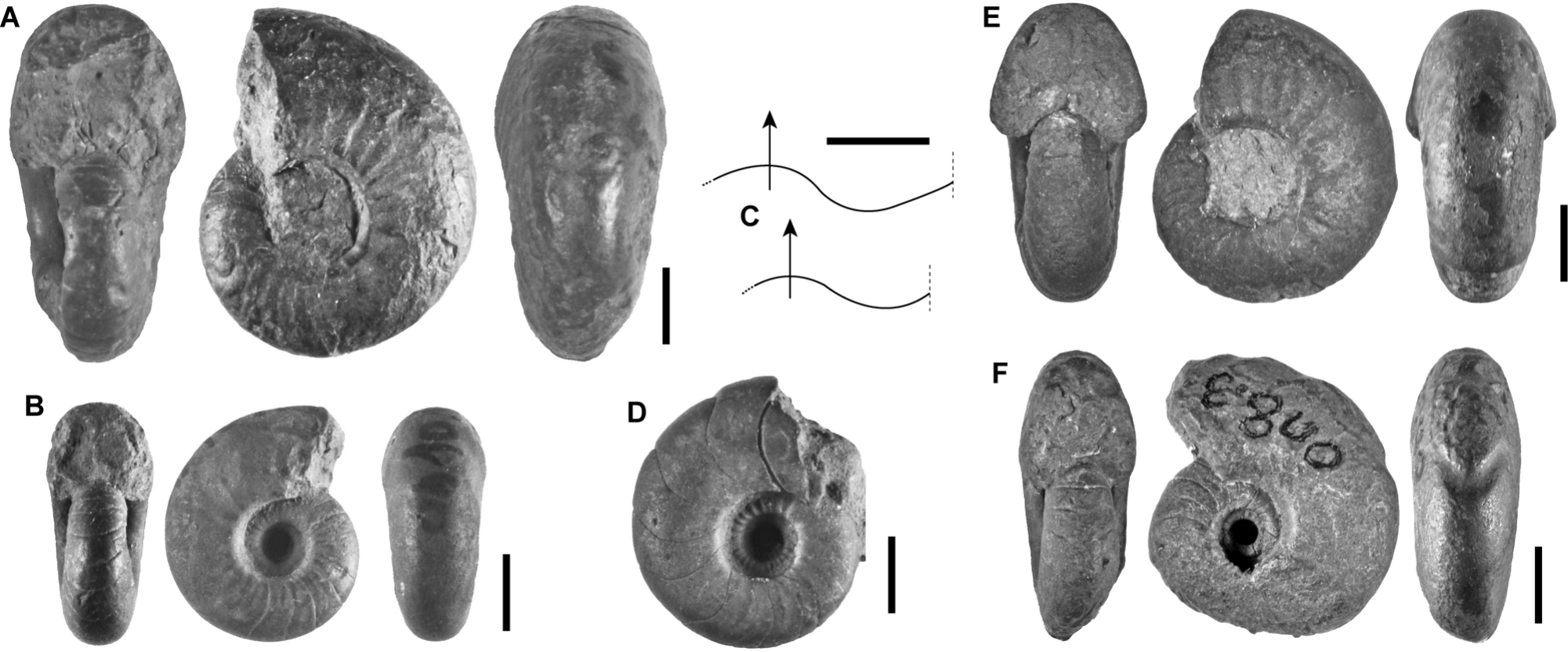
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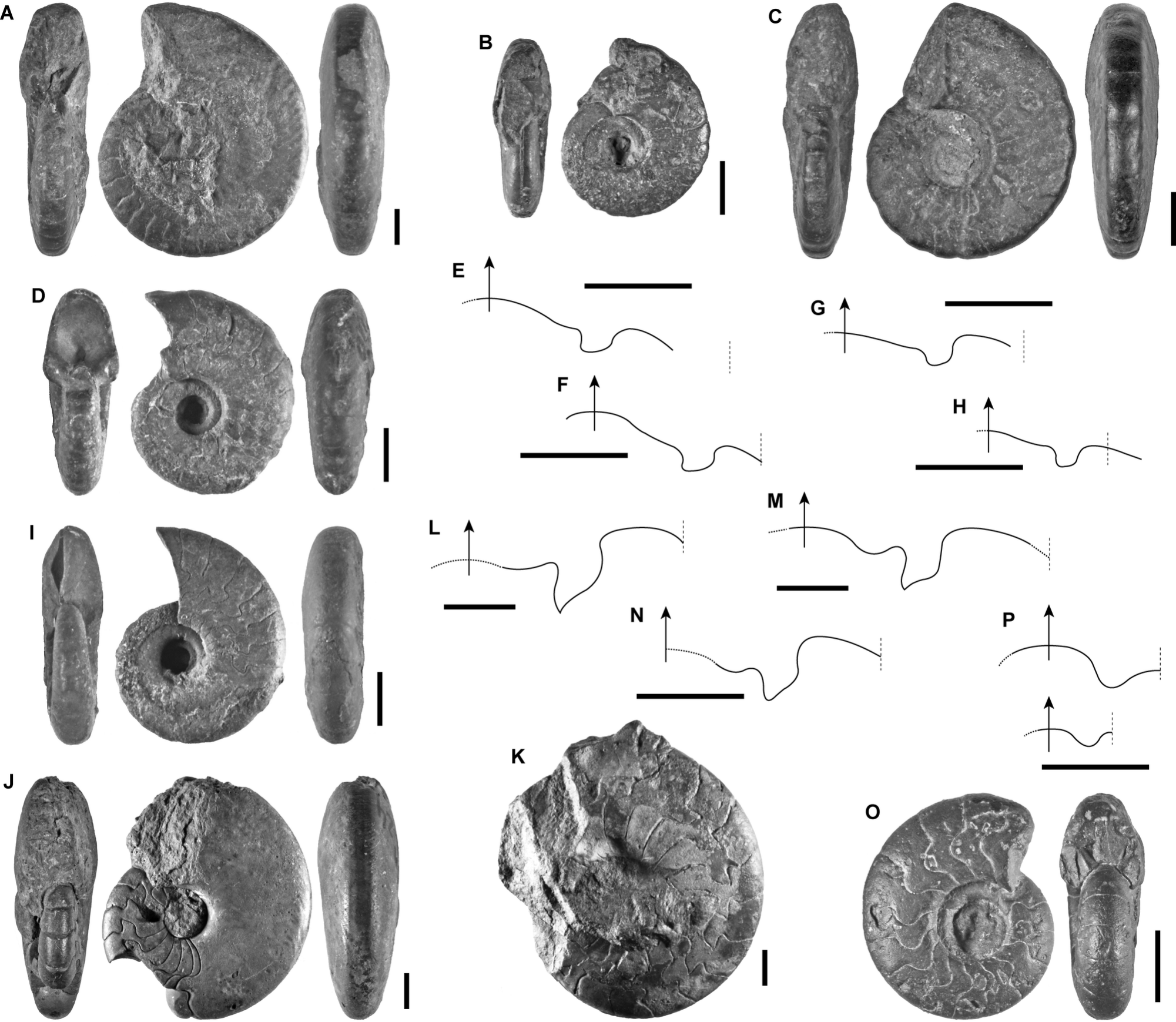
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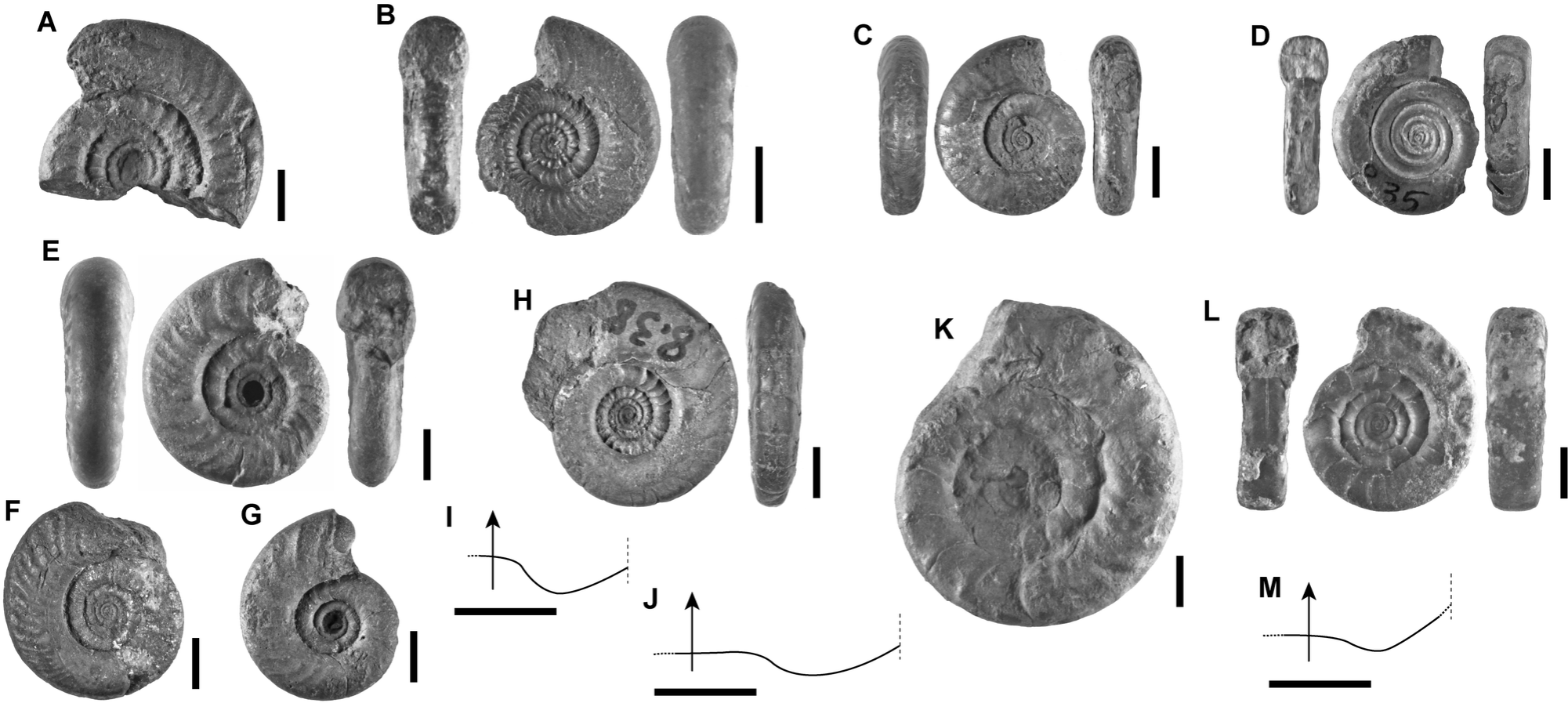
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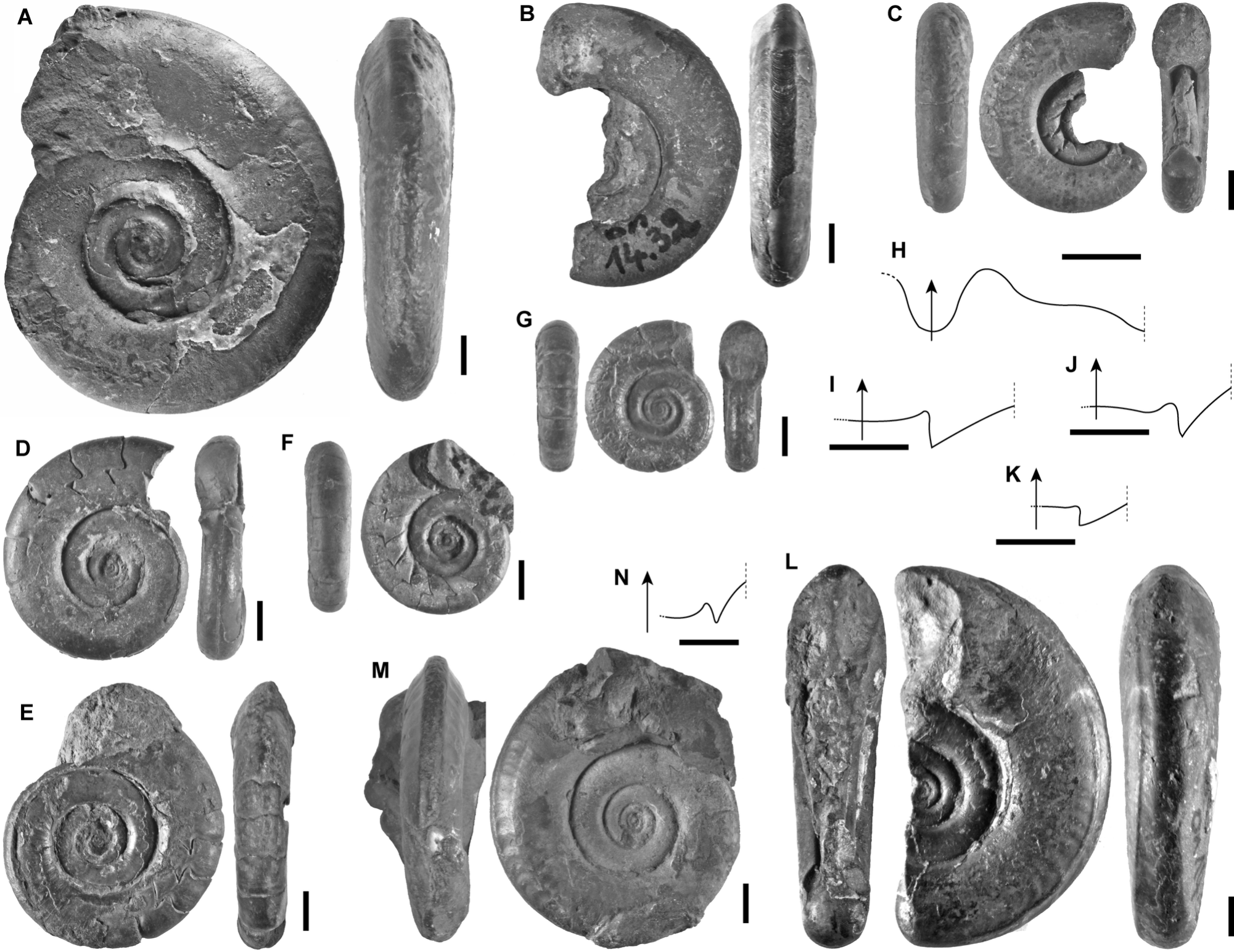
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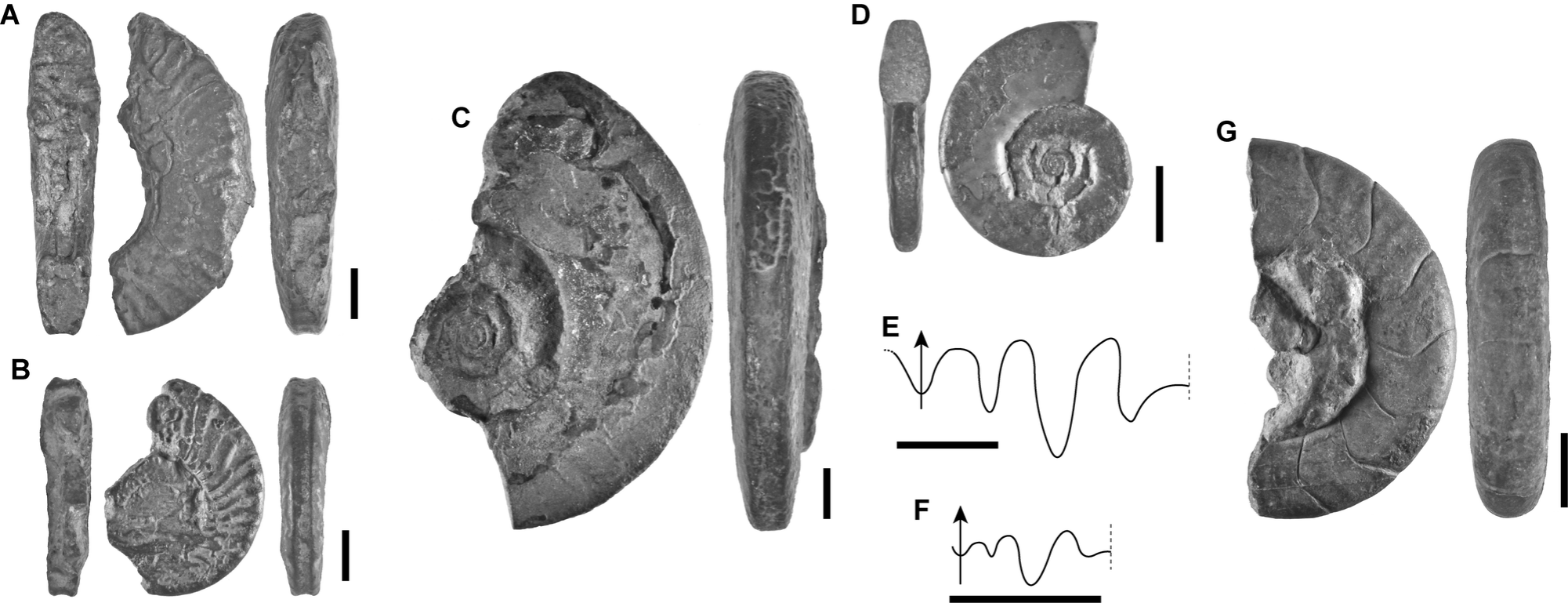
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