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Terminal Maastrichtian ammonites from the Cretaceous–Paleogene Global Stratotype Section and Point, El Kef, Tunisia

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Abstract

Ammonites are described for the first time from the terminal Maastrichtian in the Cretaceous–Paleogene (K/P) Global Stratotype Section and Point at El Kef, Tunisia. A rich assemblage, consisting of at least 17 taxa, occurs in the interval from 7 to 2 m below the K/P boundary. They co-occur with a diverse macrofauna, which also includes rudists. All fossils are pyritic, and the ammonites are all nuclei, mostly <20 mm in diameter. The dominance of *Indoscaphites* suggests open connections with southern India along the southern Tethys. No ammonites have been recovered from the 2-m interval below the K/P boundary in the Tunisian basin, although other macrofossil groups, including some originally aragonitic bivalve taxa, persist up to the boundary and are also present in the basal Paleogene.

Keywords: Tunisia; El Kef GSSP; Terminal Maastrichtian; Ammonites

1. Introduction

At El Kef, the Upper Maastrichtian sequence consists of fully marine greyish marls, forming part of the El Haria Formation of Burollet (1956), which ranges in age from Early Maastrichtian to Early Eocene. The continuous deposition throughout this interval at El Kef led to its selection as the Boundary Stratotype and Global Stratotype Section and Point for the K/P boundary (formerly known as K/T boundary: Minutes IUGS, 1991, p. 23). The GSSP was chosen at the reddish level at the base of the Dark Boundary Clay in a tributary of the Oued Djerfane (the KS locality: see Smit et al., 1997), 1 km south of the road to Hammam Mellegue and approximately 5 km southwest of El Kef town centre (Fig. 1). More recently, Dupuis et al. (2001) defined two members within the El Haria Formation: the Aïn Settara Marls of Late Maastrichtian age and the Sidi Nasseur Marls of Danian age. The boundary between these units corresponds to the base of the Dark Boundary Clay.

Numerous publications have dealt with the El Kef section and its role in understanding end-Cretaceous extinctions (see Dupuis et al., 2001 for an overview). Ammonites, one of the major invertebrate groups that did not survive the K/P boundary events, have been reported from the Upper Maastrichtian of many areas in Tunisia (Pervinquière, 1903, 1907; Solignac, 1927; Berthe, 1949; Arnould-Saget et al., 1951; Eggermont, 1996; Eggermont et al., 1996; Robaszynski et al., 2000),

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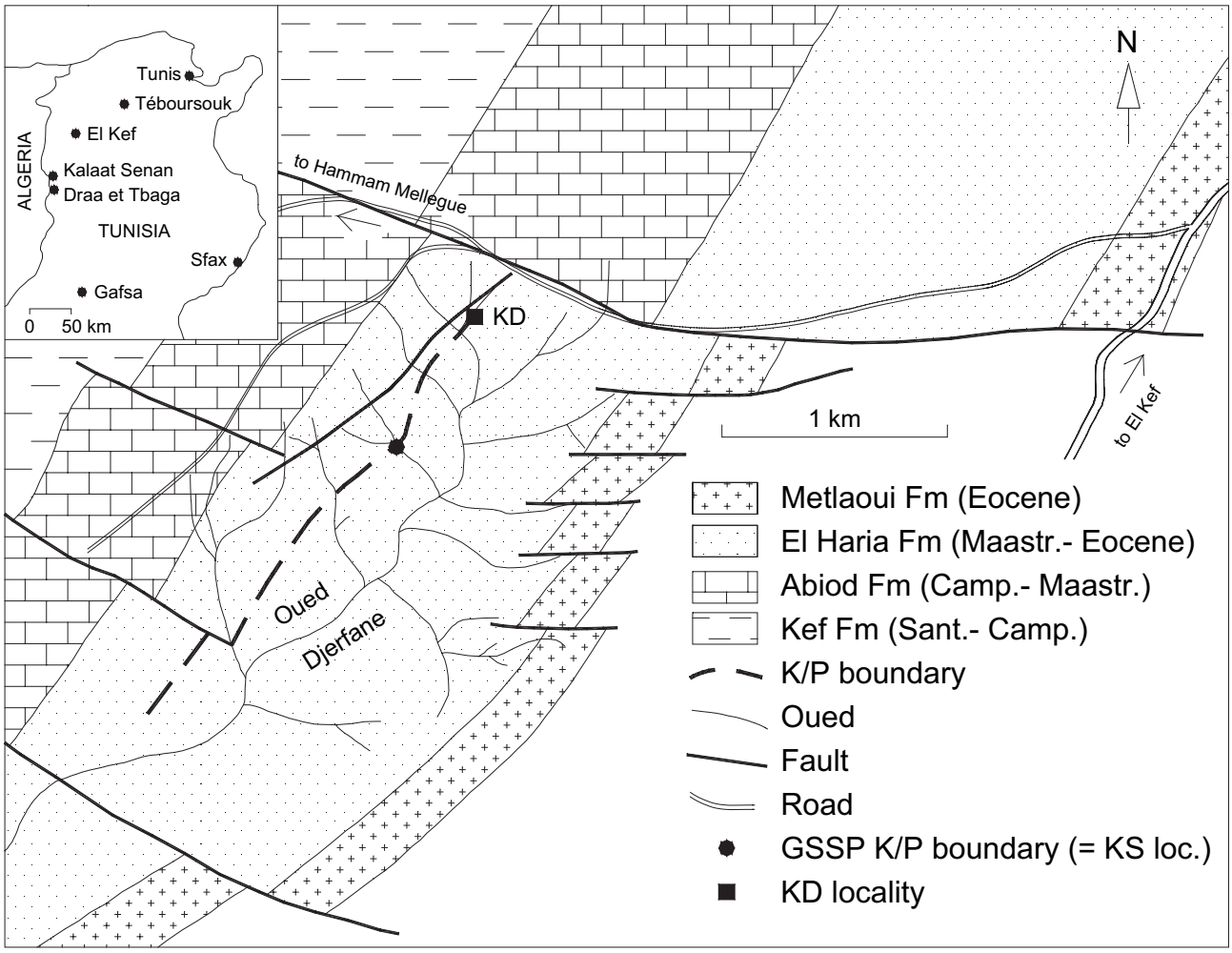

Fig. 1. Detailed geological map of the GSSP and the ammonite-bearing locality (KD) (modified after Smit et al., 1997).

and even close to the K/P boundary in the Kalaat Senan area (Robaszynski et al., 2000). However, except for a short announcement in an abstract by Eggermont et al. (1996) presented at the 1996 K/T conference in Paris and an unpublished thesis (Eggermont, 1996), the presence of ammonites in the K/P boundary GSSP at El Kef has never been discussed in any detail.

In 1995, during a reconnaissance study of the El Kef GSSP, B. Eggermont and C. Dupuis collected 15 ammonite specimens (the Eggermont Collection) at an outcrop of the K/P boundary about 300 m NNE of the GSSP (the KD locality: see Smith et al., 1997 and Fig. 1). In her unpublished thesis, Eggermont (1996) described *Pachydiscus* sp., *Anapachydiscus* sp., *Baculites* sp. type 2, *Hoploscaphites constrictus* type 1 and *Hoploscaphites constrictus* type 3, based on identifications of Prof. P.D. Ward (University of Washington, Seattle, USA). Since that account, 110 more ammonites have been collected at the same locality, by C. Dupuis, E. Steurbaut, M. Hennebert, M. Yahia and S. Goolaerts. These form the basis of the present account. All specimens are pyritic or secondarily limonitised internal moulds and most of them have suffered severe diagenesis and weathering, making species identification difficult in most cases. The present paper gives the first overview of latest Cretaceous ammonite species diversity at El Kef.

2. Material and methods

All specimens, inclusive of those in the Eggermont Collection, were found in an interval between 7 and 2 m below the K/P boundary. The positioning of specimens in Fig. 2 is indicated by an arrow pointing up-section, referring to the fact that all specimens were collected as surface float, and may have moved downslope, although the configuration of the different small outcrops will have allowed only very restricted displacement.

All specimens represent fairly well-preserved internal moulds. A few are crushed, or are unidentifiable on account of pyrite oxidation. The suture line is observable in most specimens. Nearly all are very small (mostly

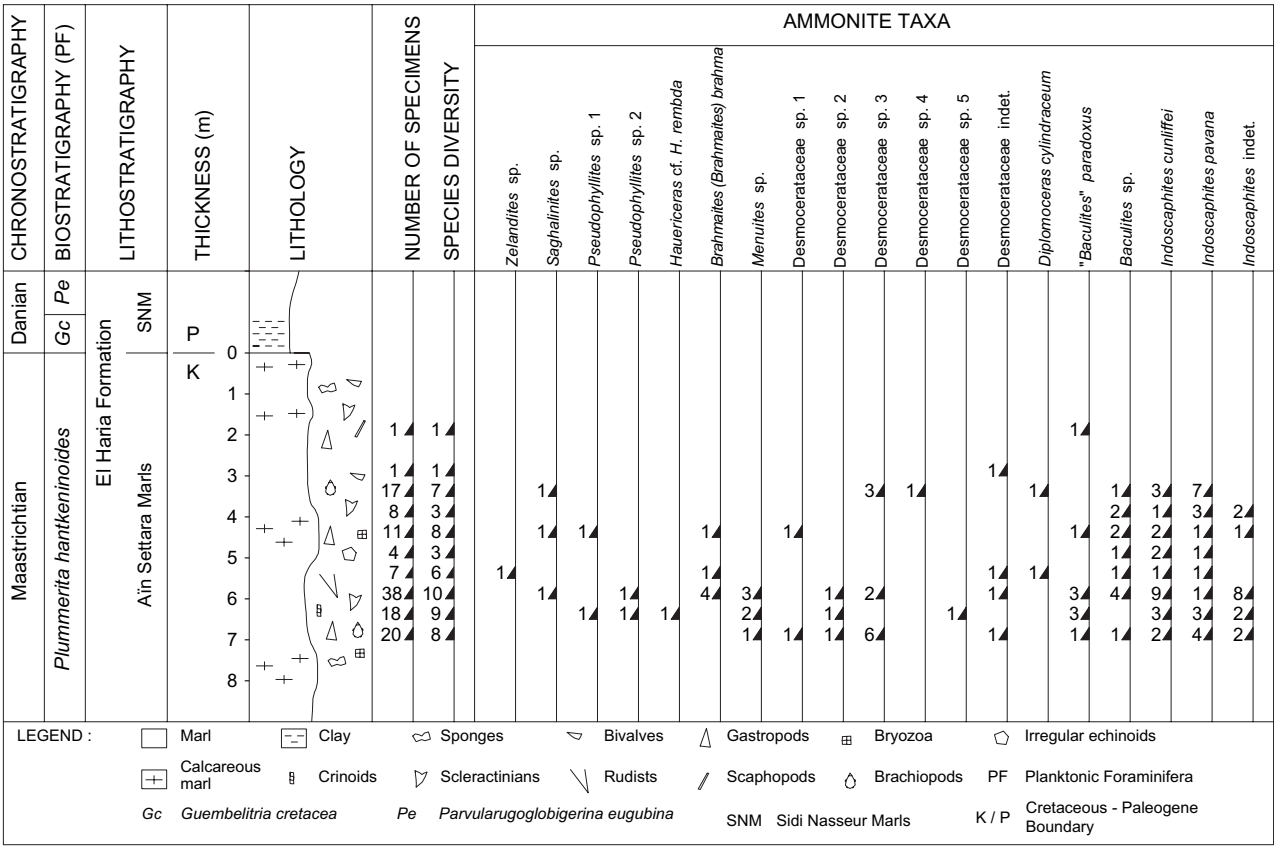

Fig. 2. Vertical distribution of the different ammonite taxa in the El Kef (KD) section. Lithostratigraphy and biostratigraphy (planktonic foraminifera) adapted from Arenillas et al. (2000).

<20 mm), which makes species and even genus identifications difficult in many cases, even impossible, on the basis of the available specimens, especially for those genera and species that are commonly represented by, or have been described on the basis of, much larger specimens, such as members of the superfamily Desmoceratacеae Zittel, 1895 (see also below). However, the presence of diagnostic features in most of the specimens allowed various forms to be distinguished and classified in open nomenclature. Material contained in the Eggermont Collection is also revised here (see below).

In addition to the ammonites, a wide range of other macrofossils was collected, among which are bivalves (including some rudist fragments and originally aragonitic taxa), gastropods, scaphopods, brachiopods, solitary scleractinians, bryozoans and a few crinoid columnals, sponges and fragments of irregular echinoids. Almost all of these macrofossils are pyritized.

3. Systematic palaeontology

The classification used here is that of Wright et al. (1996). Synonymies are provided only in accounts of substantial changes in taxonomy, or to include modifications that have been recently published. We follow the terminology of Arkell (1957) and Wedekind (1916), taking into account the review by Kullmann and Wiedmann (1970).

The specimens are deposited in the collections of the "Koninklijk Belgisch Instituut voor Natuurwetenschappen" (KBIN-IRSNB Brussels, Belgium). The numbers with the prefix IRSNB TC MI refer to the IRSNB Type Collection of Mesozoic Invertebrates. All specimens with the prefix KEFG are from the Goolaerts Collection (IRSNB IG 29944). The numbers with the prefix KEF (IRSNB IG 30032) are those described by Eggermont (1996).

The following abbreviations are used: E, external lobe; L, lateral lobe; U, umbilical lobe; I, internal lobe; D, diameter; Wb, whorl breadth; Wh, whorl height; Ud, umbilical diameter. Dimensions are given in mm. The symbol * is used whenever the dimensions were not measured at maximum diameter; for Diplomoceratidae and Baculitidae this is replaced by the symbol ^{m} when dimensions are measured at the adapical end of the specimen. Length means maximum length of specimen (straight shafts).

Order: Ammonoidea Zittel, 1884
Suborder: Lytoceratina Hyatt, 1889
Superfamily: Tetragonitaceae Hyatt, 1900
Family: Gaudryceratidae Spath, 1927
Genus *Zelandites* Marshall, 1926

Type species. *Zelandites kaiparaensis*, Marshall, 1926, p. 147, pl. 20, fig. 9; pl. 31, figs. 1, 2, by monotypy.

Zelandites sp.
Figs. 3A, 7A, B

Material. One specimen, IRSNB TC MI 10896, from 5.5 m below K/P boundary.

Dimensions. D, 7.75(100); Wb, 2.90(37); Wh, 3.40(44); Ud, 2.50(32).

Description. Early whorls rounded, becoming increasingly compressed as diameter increases. Venter rounded, flanks flattened and slightly converging towards the venter. The umbilical wall is flat, inclined

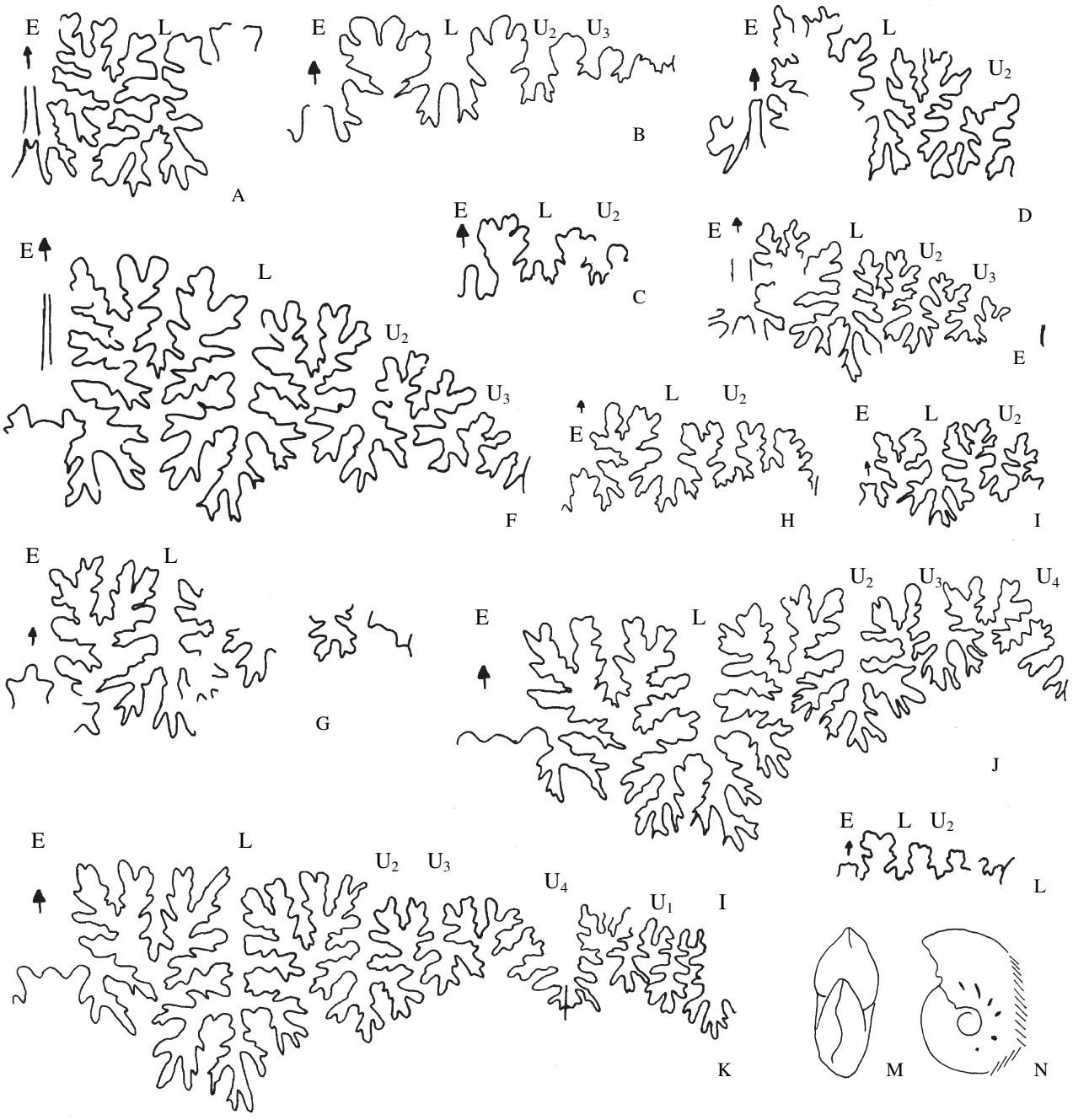

Fig. 3. Sutures and schematic drawings are ×9 and ×3 respectively. A, *Zelandites* sp., IRSNB TC MI 10896. B, C, *Saghalinites* sp., IRSNB TC MI 10898 and 10897 respectively. D, E, *Pseudophyllites* sp. 1, IRSNB TC MI 10899 and 10900 respectively. F, *Menuites* sp., IRSNB TC MI 10905. G, Desmoceratoceae sp. 2, IRSNB TC MI 10909. H, Desmoceratoceae sp. 1, IRSNB TC MI 10907. I–K, Desmoceratoceae sp. 3, IRSNB TC MI 10912, IRSNB TC MI 10934 and 10933 respectively. L, Desmoceratoceae sp. 5, IRSNB TC MI 10915. M, N, Desmoceratoceae sp. 4, IRSNB TC MI 10914.

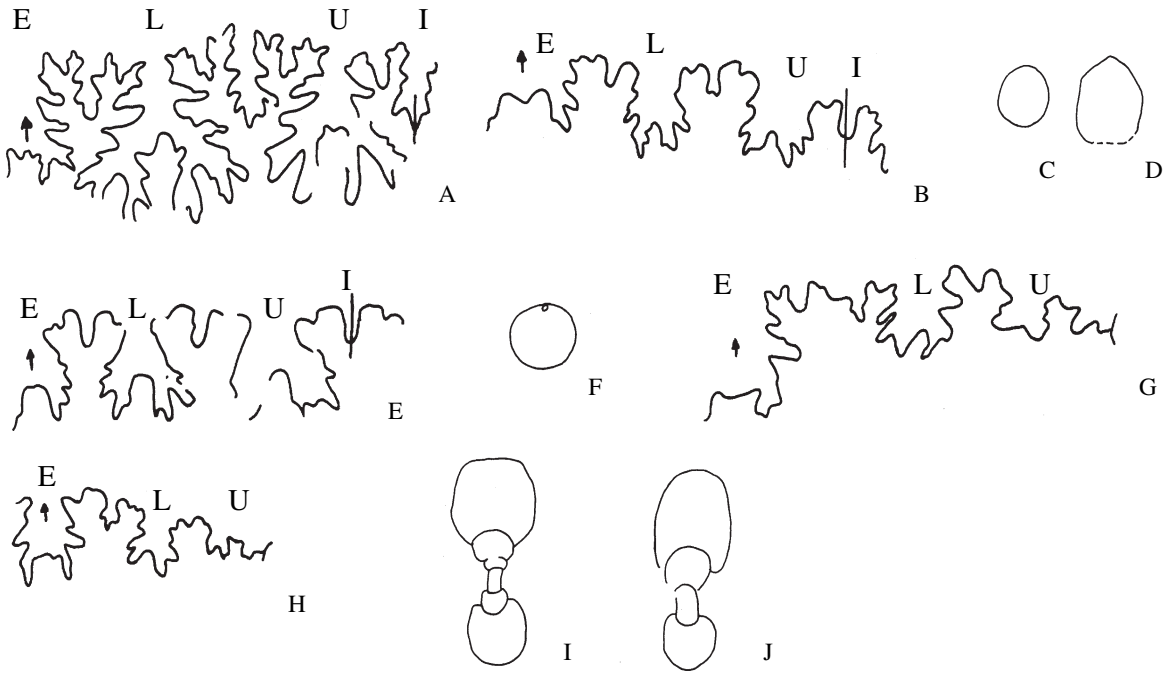

Fig. 4. Sutures and schematic drawings are ×9 and ×3 respectively. A, *Diplomoceras cylindraceum* (Defrance, 1816), IRSNB TC MI 10917. B–D, *Baculites* sp.: B, IRSNB TC MI 10922; C, D, IRSNB TC MI 10921. E, F "*Baculites*" *paradoxus* Pervinquière, 1907, IRSNB TC MI 10918. G, I, *Indoscaphites cunliffei* (Forbes, 1846), IRSNB TC MI 10925 and 10924 respectively. H, M, *Indoscaphites pavana* (Forbes, 1846), IRSNB TC MI 10929 and 10928 respectively.

outwards, making an obtuse angle with the flanks. Umbilical shoulder sharp. The whorl breadth is greatest at the umbilical shoulder. Very weak constrictions appear to be present on the flanks of the last half whorl, one on every chamber. Suture complex, L symmetrical and bifid. Septal lobe large.

Discussion. Overall shell form and suture indicate reference to *Zelandites*.

Family: Tetragonitidae Hyatt, 1900
Subfamily: Tetragonitinae Hyatt, 1900
Genus *Saghalinites* Wright and Matsumoto, 1954

Type species. *Ammonites cala* Forbes, 1846, p. 104, by original designation.

Saghalinites sp.
Figs. 3B, C, 5A, B, 7C, D

Material. Two specimens, IRSNB TC MI 10897 from 3.5 m and 10898 from 4.5 m below K/P boundary.

Dimensions.

	D	Wb	Wh	Ud	Wb:Wh
MI 10897	8.25	–	–	–	–
MI 10897*	6.00(100)	3.00(50)	3.15(53)	2.05(34)	0.95
MI 10898	12.10(100)	–	5.35(44)	2.50(21)	–

Description. Moderately evolute, venter flattened, umbilical wall rather steep, lower and upper flank convex, mid-flank flattened. Oblique, forward-projected constrictions arise on flank and cross venter. No ornament visible on largest specimen. Suture simple, with symmetrical bifid lobes and trifid saddles.

Discussion. The Eggermont Collection contains a specimen of *Saghalinites* sp., from 6 m below the K/P boundary (labelled KEF A5). Eggermont (1996) referred to it as *Anapachydiscus* sp. Constrictions and form of suture indicate *Saghalinites*. Robaszynski et al. (2000, text-fig. 38) cited *Saghalinites* from Upper Maastrichtian deposits in the Kalaat Senan area.

Genus *Pseudophyllites* Kossmat, 1895

Type species. *Ammonites indra* Forbes, 1846, p. 105, by monotypy.

Pseudophyllites sp. 1
Figs. 3D, E, 5C–F

Material. Two specimens, IRSNB TC MI 10899 from 6.5 m and 10900 from 4.5 m below K/P boundary.

Dimensions.

	D	Wb	Wh	Wb:Wh
MI 10899	–	4.60	4.80	0.96
MI 10900	8.75(100)	4.35(50)	4.40(50)	0.99

Description. The specimens are characterised by a moderately involute, smooth shell (with about 45% of the preceding whorl covered) with convex venter. Whorls flattened at mid-flank, outer and inner flank convex. Umbilicus deep and narrow. Whorl breadth/height ratio is about 1, with greatest breadth at mid-flank. Suture complex, L bifid with large and highly incised median element. Septal lobe present.

Discussion. Form of shell and suture indicate reference to *Pseudophyllites*.

Pseudophyllites sp. 2
Figs. 5I, J, 7E, F

Material. Two specimens, IRSNB TC MI 10902 from 6 m and 10901 from 6.5 m below K/P boundary.

Dimensions.

	D	Wb	Wh	Ud	Wb:Wh
MI 10901	7.95(100)	3.45(43)	3.50(44)	–	0.98
MI 10902	23.95(100)	10.25(43)	10.65(45)	5.20(22)	0.96

Description. Early whorls with flat venter, greatest breadth on outer flank; whorl section trapezoidal. Umbilicus wide (40% at D 3.25 mm) and shallow, becoming smaller and deeper as diameter increases (34% at D 6 mm to 22% at D 24 mm). Ornament and constrictions are absent even at diameter of 24 mm (IRSNB TC MI 10902). At this diameter whorl breadth is greater at the upper part of the mid-flank. Ventrolateral region convex, mid-flank flat, umbilical shoulder convex. The venter remains flat, so whorl section becomes angular rather than trapezoidal as in the early stages. Suture simple, with L symmetrical and bifid. Median element of L not incised. E/L and L/U trifid. IRSNB TC MI 10902 shows some ill-preserved septal lobes.

Discussion. The suture is quite similar to specimens referred to as *Saghalinites* sp. above, with some small differences in the median element of E and the incision in L, but the absence of constrictions and overall shell form indicate reference to *Pseudophyllites*.

Suborder: Ammonitina Hyatt, 1889
Superfamily: Desmoceratacea Zittel, 1895
Family: Kossmaticeratidae Spath, 1922
Subfamily: Hauericeratinae Matsumoto, 1938
Genus *Hauericeras* de Grossouvre, 1894

Type species. *Ammonites pseudogardeni* Schlüter, 1872, p. 54, pl. 16, figs. 3–6, by original designation of de Grossouvre (1894, p. 219).

Hauericeras cf. *H. rembda* (Forbes, 1846)
Figs. 5G, H

1846 *Ammonites Rembda* Forbes, p. 111, pl. 7, fig. 3.
1846 *Ammonites Durga* Forbes, p. 104, pl. 7, fig. 11.
1898 *Desmoceras* (*Hauericeras*) *Rembda* Forbes; Kossmat, p. 124 (189), pl. 18 (24), fig. 9.
non 1907 *Hauericeras rembda* Forbes; Pervinquière, p. 167, pl. 7, figs 7–10 = *H. fayoli* (de Grossouvre, 1894).
1992a *Hauericeras rembda* (Forbes, 1846); Kennedy and Henderson, p. 408, pl. 6, figs. 10–24, pl. 17, fig. 1, text-fig. 3h.
1998 *Hauericeras* (*Gardeniceras*) cf. *rembda* (Forbes, 1846); Kennedy and Jagt, p. 157, pl.1, fig. 1.

Type. See Kennedy and Henderson (1992a, p. 408).

Material. One specimen, IRSNB TC MI 10903, from 6.5 m below K/P boundary.

Description. Only two whorls are preserved in this 9.3-mm diameter fragment. Coiling rather evolute with shallow and wide umbilicus and rounded venter. Deeply incised, forward projecting constrictions extend across the flanks, and cross the venter. Only two constrictions are visible, one on the outer whorl, one on the inner. That on the outer whorl appears to be most deeply incised at mid-flank. Suture not visible.

Discussion. Although fragmentary, this specimen may be referred to *H. rembda* on the basis of shape of the constrictions, whorl section and lack of ornament. The absence of the keel, typical for the genus, is a reflection of the small size of the specimen.

Occurrence. Upper Maastrichtian of Tunisia, southern India, Biscay region (France, Spain) and Belgium; Maastrichtian of Madagascar, Zululand (South Africa) and Sumter County, Alabama (USA).

Subfamily: Kossmaticeratinae Spath, 1922
Genus *Brahmaites* Kossmat, 1897
Subgenus *Brahmaites* Kossmat, 1897

Type species. *Ammonites Brahma* Forbes, 1846, p. 100, by original designation.

Brahmaites (*Brahmaites*) *brahma* (Forbes, 1846)
Figs. 5K, L

1846 *Ammonites Brahma* Forbes, p.100, pl. 8, fig. 1.
1897 *Brahmaites Brahma* Forbes; Kossmat (pars), p. 45 (152), non pl. 8 (19), figs. 7, 8 (=*Brahmaites* spp.).
1992a *Brahmaites* (*Brahmaites*) *brahma* (Forbes, 1846); Kennedy and Henderson, p. 410, pl. 7, figs. 1–3; pl. 8, figs. 1–11; pl. 9, figs. 1–4, 8–16; text-fig. 5.

Type. See Kennedy and Henderson (1992a, p. 410).

Material. Six specimens, KEFG A108 from 4 m, A60 from 5.5 m, A43, A44 and IRSNB TC MI 10904 from 6 m and a small fragment, KEFG A48, also from 6 m below K/P boundary.

Description. Coiling very evolute, serpenticone, with broad umbilicus. There are prominent, deeply incised constrictions, with up to six umbilical bullae between consecutive constrictions. The bullae on the largest specimen (IRSNB TC MI 10904) give rise to ribs that extend to the outer flank. Constrictions are preceded by a collar, raised into a bulla on the umbilical shoulder. Tubercles are not yet developed on the smallest specimen (KEFG A60) (D = 4.75 mm), but the constrictions are already present.

Discussion. Robaszynski et al. (2000) reported *B.* (*B.*) *brahma* from the Kalaat Senan region. The six specimens from El Kef substantiate their record, and agree well with the account by Forbes (1846) and the redescription by Kennedy and Henderson (1992a).

Occurrence. Maastrichtian of Tunisia, southern India, France and Spain.

Family: Pachydiscidae Spath, 1922
Genus *Menuites* Spath, 1922

Type species. *Ammonites menu* Forbes, 1846, p. 111, by original designation.

Discussion. Wright et al. (1996) are followed.

Menuites sp.
Figs. 3F, 5M–P

Material. Five specimens, IRSNB TC MI 10905 and KEFG A49 from 6 m, KEFG A29 and IRSNB TC MI 10906 from 6.5 m and KEFG A105 from 7 m below K/P boundary.

Dimensions.

	D	Wb	Wh	Ud	Wb:Wh
MI 10905	13.20(100)	6.95(53)	7.65(58)	–	0.91
KEFG A29	–	6.25	6.10	–	1.02
MI 10906	12.00(100)	6.50(54)	6.10(51)	–	1.06
KEFG A105	5.30(100)	3.90(74)	3.00(57)	1.10(21)	1.30

Description. The specimens are involute, completely smooth, except for KEFG A105 which bears some narrow prorsiradiate ribs on flanks. Shell inflated, with deep and narrow umbilicus. The ventral region is rounded, flanks somewhat compressed, subparallel at mid-flank, but converging towards the ventral region. The umbilical shoulder is convex, the umbilical wall slightly undercut where it meets the preceding whorl. Whorl breadth/height ratio is about 1. Maximum whorl breadth close to the umbilical shoulder. About 80% of the previous whorl is covered. Suture complex.

Discussion. Eggermont (1996, p. 53) referred two El Kef specimens to *Anapachydiscus* sp., both from 6 m below the K/P boundary. As already discussed above, one of these should be referred to *Saghalinites*. The other specimen (D = 7.40 mm; labelled KEF A6) is conspecific with our material. The description of 'specimen III' of *Pachydiscus* sp. indét. by Pervinquière (1907, p. 180, pl. 7, figs. 27, 28) suggests it could also be conspecific with our material, although Pervinquière noted the suture was still rather simple (at the diameter of 6.5 mm). With only these small specimens in hand, species determination is difficult (Fig. 5).

Family: Incertae sedis

A large number of specimens are referred to the superfamily Desmoceratacea without further precision. At least five different taxa are identified. However, on the basis of the specimens available it is not possible to decide if these specimens belong to the Desmoceratidae (subfamilies Puzosiinae and Desmoceratinae) or the Pachydiscidae, because members of both families are not easily distinguishable in the juvenile stage.

Desmoceratacea sp. 1
Figs. 3H, 5Q–S

Material. Two specimens, IRSNB TC MI 10907 from 4.5 m and KEFG A101 from 7 m below K/P boundary.

Dimensions.

	D	Wb	Wh	Ud	Wb:Wh
KEFG A101	6.25(100)	3.25(52)	3.00(48)	–	1.08
MI 10907	6.70	–	–	–	–
MI 10907*	6.00(100)	3.45(58)	3.25(54)	1.75(29)	1.06

Description. Inflated involute form with rounded venter and convex flanks, somewhat flattened at mid-flank. Umbilical shoulder convex. Suture rather simple, with trifid L, U seemingly bifid, auxiliaries retracted. Saddles bifid.

Discussion. Specimen I and II of Pervinquière's *Pachydiscus* sp. indét. (1907, p. 180, pl. 7, figs. 23–26) are very close to our material, which is easily differentiated from the other inflated forms (*Pseudophyllites* sp. and *Menuites* sp.) by its suture line (less complex than *Menuites* sp. and with a trifid L instead of a bifid one as in *Pseudophyllites* sp.). More and better preserved material is needed to make a more precise generic and specific attribution possible.

Desmoceratacea sp. 2
Figs. 3G, 5W–Z

Material. Three specimens, IRSNB TC MI 10909 from 6 m, 10908 from 6.5 m and 10910 from 7 m below K/P boundary.

Dimensions.

	D	Wb	Wh	Ud	Wb:Wh
MI 10908	46.50(100)	19.25(41)	21.25(46)	9.65(21)	0.90
MI 10909	11.25	–	–	–	–
MI 10910	13.90	–	–	–	–

Description. IRSNB TC MI 10908 is a large specimen (D = 46.50 mm) and has a rounded but slightly flattened venter, convex outer flanks and a flattened mid-flank. The umbilical wall is flattened, and inclined towards the flanks. The umbilical shoulder is convex, umbilicus comprises around 21% of the diameter. The greatest breadth is at mid-flank. The whorl overlap is about 70%. IRSNB TC MI 10909 is crushed, as is IRSNB TC MI 10910, with a flat umbilical wall and convex umbilical shoulder. There is no ornament. The suture line is only partly exposed, but complex with trifid L and U. L deeper than E.

Discussion. The two specimens of *Puzosia* (?*Latidorsella*) *snamensis* Pervinquière, 1907 (type series) are very similar to IRSNB TC MI 10909 and 10910.

Assignment to *Pachydiscus* (*Neodesmoceras*) is possible, although not certain in view of the absence of ornament on the largest specimen (IRSNB TC MI 10908).

Desmoceratacеae sp. 3
Figs. 3I–K, 5A, B, T–V, 7G, H

Material. Nine specimens, IRSNB TC MI 10911, 10912 and KEFG A83 from 3.5 m, KEFG A24 from 6 m and IRSNB TC MI 10913, KEFG A95, A96, A97 and A100 from 7 m below K/P boundary.

Dimensions.

	D	Wb	Wh	Ud	Wb:Wh
KEFG A24	7.30(100)	2.30(0.32)	3.35(0.46)	–	0.69
MI 10911	9.45(100)	3.30(35)	4.25(45)	2.20(23)	0.78
MI 10912	8.25(100)	2.80(34)	3.80(46)	2.60(32)	0.73
KEFG A83*	–	6.80	11.60	–	0.58
MI 10913	13.35(100)	3.80(28)	7.20(54)	2.50(19)	0.53
KEFG A95*	–	4.45	6.45	–	0.69
KEFG A96*	–	3.80	3.80	–	1.00
KEFG A97	5.35(100)	1.90(36)	2.20(41)	1.75(33)	0.86
KEFG A100	6.45(100)	2.40(37)	3.15(49)	–	0.76

Description. This taxon is characterised by moderately involute coiling with slightly convex, flattened flanks and narrow venter. The umbilicus is wide, the umbilical wall low, convex and becoming slightly undercut at the umbilical seam. No ornament visible, but KEFG A100 appears to have small constrictions on the flanks. Variation in Wb/Wh ratio is quite high, but specimens become more compressed as D increases. Suture with trifid, slightly asymmetric lobes, with L deeper than E, and retracted auxiliaries. Small specimens are smooth, but the two specimens described by Eggermont (1996, p. 51 and pls. 3, 5a,b), one from 6 m (labelled KEF A7: IRSNB TC MI 10933) and another from 7 m (labelled KEF A12: IRSNB TC MI 10934) below K/P boundary (both referred to *Pachydiscus* sp.), are larger and bear broad umbilical bullae, which give rise to narrow ribs that extend to the outer-flank.

Dimensions.

	D	Wb	Wh	Ud	Wb:Wh
MI 10933	17.75	–	–	–	–
MI 10933*	–	5.10	8.20	–	0.62
MI 10934	20.80	–	–	–	–
MI 10934*	–	5.25	8.45	–	0.62

The sutures of MI 10933 and MI 10934 are shown in Figs. 3J, K.

Discussion. Intraspecific variation is high within this taxon. The presence of umbilical bullae and overall form of whorl section and suture line suggests reference to *Pachydiscus*, but additional and better preserved material is needed to allow a more specific assignment.

Desmoceratacеae sp. 4
Figs. 3M, N, 7I, J

Material. One specimen, IRSNB TC MI 10914, from 3.5 m below K/P boundary.

Dimensions. D, 8.50(100); Wh, 4.80(57); Ud, 1.65(19).

Description. Coiling very involute, with deep and narrow umbilicus (Ud = 19%). The specimen is crushed along the venter, so that the ventral morphology cannot be determined. The whorl breadth is greatest just outside the umbilical shoulder on the last half whorl of the specimen. Low, broad umbilical bullae give rise to small prorsiradiate ribs, restricted to the inner flank. Only six bullae/ribs are present. The umbilical wall is steep and convex, the flanks convex. Suture not well exposed, with trifid L.

Discussion. This specimen resembles *Menuites* sp., but already has ornament at a much smaller diameter; the whorl section also appears different. The post-mortem deformation of the specimen precludes both generic and specific attribution.

Desmoceratacеae sp. 5
Figs. 3L, 7K, L

Material. One specimen, IRSNB TC MI 10915 from 6.5 m below K/P boundary.

Dimensions. D, 7.55; D*, 5.45(100); Wb*, 2.60(48); Wh*, 2.70(50); Ud*, 1.44(27); Wb:Wh, 0.96.

Description. IRSNB TC MI 10915 is characterised by a very involute form with a rounded venter and

a narrow, deep umbilicus. The umbilical wall is steep, convex, and undercut at the umbilical seam. The flanks are flattened at mid-flank. Ornament consists of weak ribs on the flanks. The suture consists of rather simple elements; L and U are trifid.

Discussion. This specimen differs from the other Kef desmoceratacean by its a far less complex suture line, and its overall form and ornament. It bears most resemblance to members of the Kossmaticeratidae.

Desmoceratacean indet.

Material. Four specimens, KEFG A84 from 3 m, A63 from 5.5 m, A14 from 6 m and A98 from 7 m below K/P boundary.

Remarks. These specimens are referred to the Desmoceratacean on the basis of their overall form and suture, but the very poor preservation (crushed, partly eroded, only presenting a small portion of the suture) precludes further identification. They may in part or wholly belong to one of the taxa described above.

Suborder: Ancyloceratina Wiedmann, 1966
Superfamily: Turrilitaceae Gill, 1871
Family: Diplomoceratidae Spath, 1926
Subfamily: Diplomoceratinae Spath, 1926
Genus *Diplomoceras* Hyatt, 1900

Type species. *Baculites cylindracea* Defrance, 1816, p. 160, by original designation of Hyatt, 1900.

Diplomoceras cylindraceum (Defrance, 1816)
Figs. 4A, 6C–E

1816 *Baculites cylindracea* Defrance, p. 160.
1825 *Hamites cylindricus*; de Blainville, p. 382, pl. 23, fig. 1.
1925 *Diplomoceras cylindraceum* Defrance; Diener, p. 74.
1992b *Diplomoceras cylindraceum* (Defrance, 1816); Kennedy and Henderson, p. 704, pl. 6, figs. 1–3, text-figs. 1B, 3.

Type. See Kennedy and Henderson (1992b, p. 706).

Material. Two specimens, IRSNB TC MI 10917 from 3.5 m and 10916 from 5.5 m below K/P boundary.

Dimensions.

	Wb	Wh	Wb:Wh	Length
MI 10917	3.80	3.75	1.01	9.70
MI 10917^{m}	3.35	3.40	0.99	
MI 10916	–	–	–	10.95

Description. Shaft with a circular cross section and fine ribs, which are narrower than the interspaces, stronger on the venter, but slightly effaced on the dorsum. The rib index is 10–11. The crushed specimen is larger (spacing between the ribs already larger). Ribs prorsiradiate, inclined at an oblique angle to the shaft. Suture with bifid L and U, L deeper than E. I trifid and reduced in size relative to L and U, and of similar size to the median auxiliaries of saddles E/L and L/U.

Discussion. Kennedy and Henderson (1992b) regarded almost all *Diplomoceras* of Maastrichtian age as belonging to the widely varying taxon *D. cylindraceum*. Robaszynski et al. (2000) reported *Diplomoceras* sp. fragments from the Kalaat Senan area.

Occurrence. Uppermost Campanian–uppermost Maastrichtian, almost worldwide.

Subfamily: Polyptychoceratinae Matsumoto, 1938
Genus: uncertain

"Baculites" paradoxus Pervinquière, 1907
Figs. 4E, F, 6I

1907 *Baculites paradoxus* Pervinquière, pp. 94–95, pl. 4, figs. 10–11, text-fig. 24.
2001 *Baculites paradoxus* Pervinquière, 1907; Klinger and Kennedy, p. 188.

Type. The species was based on four syntypes. The lectotype, here designated, is the original of Pervinquière 1907, p. 94, pl. 4, figs. 10, 11, from Draa et Tbaga; it and the paralectotypes are housed in the collections of the Sorbonne, now the Université Paris VI (France).

Material. Seven specimens, KEFG A117 from 4.5 m, KEFG A16 and IRSNB TC MI 10918 from 6 m, KEFG A50, A86 and A103 from 6.5 m and KEFG A90 from 7 m below K/P boundary.

Description. All specimens are fragments of straight shafts with a circular cross section; the expansion rate is low, the surface of the mould completely smooth. Suture line with four elements (ELUI): L and U are equal in size and shape, bifid and symmetrical, I reduced to the size of the median incisions of the saddles E/L and L/U, E of same size and very similar to L and U, but with a small incision in the median foliole. When viewed around the whole periphery, the suture appears to consist of five almost equal, symmetrical and triangular-shaped saddles and lobes (E, E/L, L, L/U, U, U/I/U, U, U/L, L, L/E), but this is a reflection of the great reduction of I.

Discussion. Two specimens of "*Baculites*" *paradoxus* from El Kef in the Eggermont Collection, one (labelled KEF A1; from 2 m below K/P boundary) erroneously referred to *Baculites* sp.; a second, unidentified and without label, from 6 m below K/P boundary.

This species remains poorly known in terms of both occurrence and systematic position. Pervinquière (1907)

described four specimens from Draa et Tbaga (central Tunisia; see Fig. 1). Robaszynski et al. (2000, text-fig. 38) reported *Baculites paradoxus* Pervinquière from the Kalaat Senan area. Arnould-Saget et al. (1951) probably referred to this species when they reported *Ptychoceras* sp. from the mountains of Téboursouk, 50 km northeast of El Kef (see Fig. 1). Reeside (1927) was the first to question the assignment of this species to the genus *Baculites*. In their revision of the Baculitidae, Klinger and Kennedy (1997, 2001) noted that *B. paradoxus* should be assigned to the subfamily Polyptychoceratinae Matsumoto, 1938. With only seven fragmentary specimens before us, it is not possible to decide to which genus or subgenus the species should be assigned. However, it certainly belongs to the subfamily Polyptychoceratinae and most probably to a new subgenus of the genus *Polyptychoceras* Yabe, 1927.

Occurrence. Upper Maastrichtian, Tunisia.

Family: Baculitidae Gill, 1871
Genus *Baculites* Lamarck, 1799

Type species. *Baculites vertebralis* Lamarck, 1799, p. 80, by subsequent designation of Meek (1876).

Baculites sp.
Figs. 4B–D, 6F–H, 7M

Material. Ten specimens, IRSNB TC MI 10922 from 3.5 m, KEFG A109 and A110 from 4 m, KEFG A112 and A113 from 4.5, KEFG A69 from 5 m, IRSNB TC MI 10921 from 5.5 m, KEFG A37 and A66 from 6 m and IRSNB TC MI 10923 from 7 m below K/P boundary.

Dimensions.

	Wb	Wh	Wb:Wh	Length
KEFG A37	–	–	–	10.70
MI 10921	2.90	3.70	0.78	11.20
MI 10921^{m}	2.35	2.80	0.84	
KEFG A66	2.50	2.75	0.91	7.50
KEFG A66^{m}	1.85	2.05	0.90	
KEFG A69	1.95	2.35	0.83	5.25
KEFG A69^{m}	1.70	1.85	0.92	
MI 10923	3.30	4.00	0.83	7.20
MI 10923^{m}	2.95	3.65	0.81	
KEFG A109	5.00	6.65	0.75	19.15
KEFG A110	2.95	3.30	0.89	5.70
KEFG A112	1.95	2.35	0.83	4.85
KEFG A112^{m}	1.75	2.10	0.83	
KEFG A113	3.45	4.45	0.76	7.50

Description. The whorl section is rounded, becoming more compressed at larger diameters. The dorsum becomes more tabulate with increasing diameter. The venter is fastigiate (IRSNB TC MI 10921). Weak ribs are limited to the dorsum; they appear at about 2.4 mm whorl height. The flanks are smooth.

Discussion. Eggermont (1996, p. 53) referred three specimens from El Kef to *Baculites* sp. type 2. As discussed above, one of these should be referred to "*Baculites*" *paradoxus*. The other two specimens, both from 6 m below the K/P boundary (and labelled KEF A8 and A10), may be referred to *Baculites* sp.

Species designation remains difficult on the basis of our material, but baculitids have been reported by several authors from the Upper Maastrichtian deposits of Tunisia, including *Baculites vertebralis* Lamarck, 1801 by Pervinquière (1907) and Solignac (1927), and *Baculites* sp. and *Baculites* cf. *anceps* Lamarck, 1822 by Robaszynski et al. (2000).

Superfamily: Scaphitaceae Gill, 1871
Family: Scaphitidae Gill, 1871
Subfamily: Scaphitinae Gill, 1871
Genus *Indoscaphites* Spath, 1953

Type species. *Ammonites cunliffei* Forbes, 1846, p. 109, pl. 8, fig. 2, by original designation.

Indoscaphites cunliffei (Forbes, 1846)
Figs. 4G, I, 6J–L, 7N, O

1846 *Ammonites Cunliffei* Forbes, p. 109, pl. 8, fig. 2.
1898 *Scaphites Cunliffei* Forbes sp., Kossmat, p. 31 (138).
1903 *Ammonites* cf. *Scaphites pavana*; Pervinquière, p. 126.
1907 *Scaphites Cunliffei* Forbes; Pervinquière, p. 124 (pars), pl. 4, figs. 36–40, non figs. 41, 42 [=*I. pavana*]; figs. A–C in the explanation of pl. 4; text-figs. 42–44, non text-fig. 45 [=*I. pavana*].
1911 *Acanthoscaphites Cunliffei* Forbes; Nowak, p. 565.
1916 *Hoploscaphites Cunliffei*; Nowak, p. 66.
1953 *Indoscaphites cunliffei* (Forbes); Spath, p. 14.
1992b *Indoscaphites cunliffei* (Forbes, 1846); Kennedy and Henderson, p. 722, pl. 5, figs. 2, 6–9; pl. 6, figs. 4–6, text-fig. 2A.

Types. See Kennedy and Henderson (1992b), p. 726.

Material. Nineteen specimens, KEFG A72, A122 and A123 from 3.5 m, A28 from 4 m, A115 and A121 from 4.5 m, A61 from 5.5 m, A15, A17, IRSNB TC MI 10924, 10925, KEFG A39, A40 and IRSNB TC MI 10927 from 6 m, KEFG A32, IRSNB TC MI 10926 and KEFG A55 from 6.5 m and KEFG A93 and A104 from 7 m below K/P boundary.

Description. Ornament is visible from a diameter of 6 mm onwards. The ribs are straight to slightly prorsiradiate on the flanks, convex and broad on the venter (but narrowing towards the middle of the venter). All primary ribs bear a ventrolateral horn. Irregular

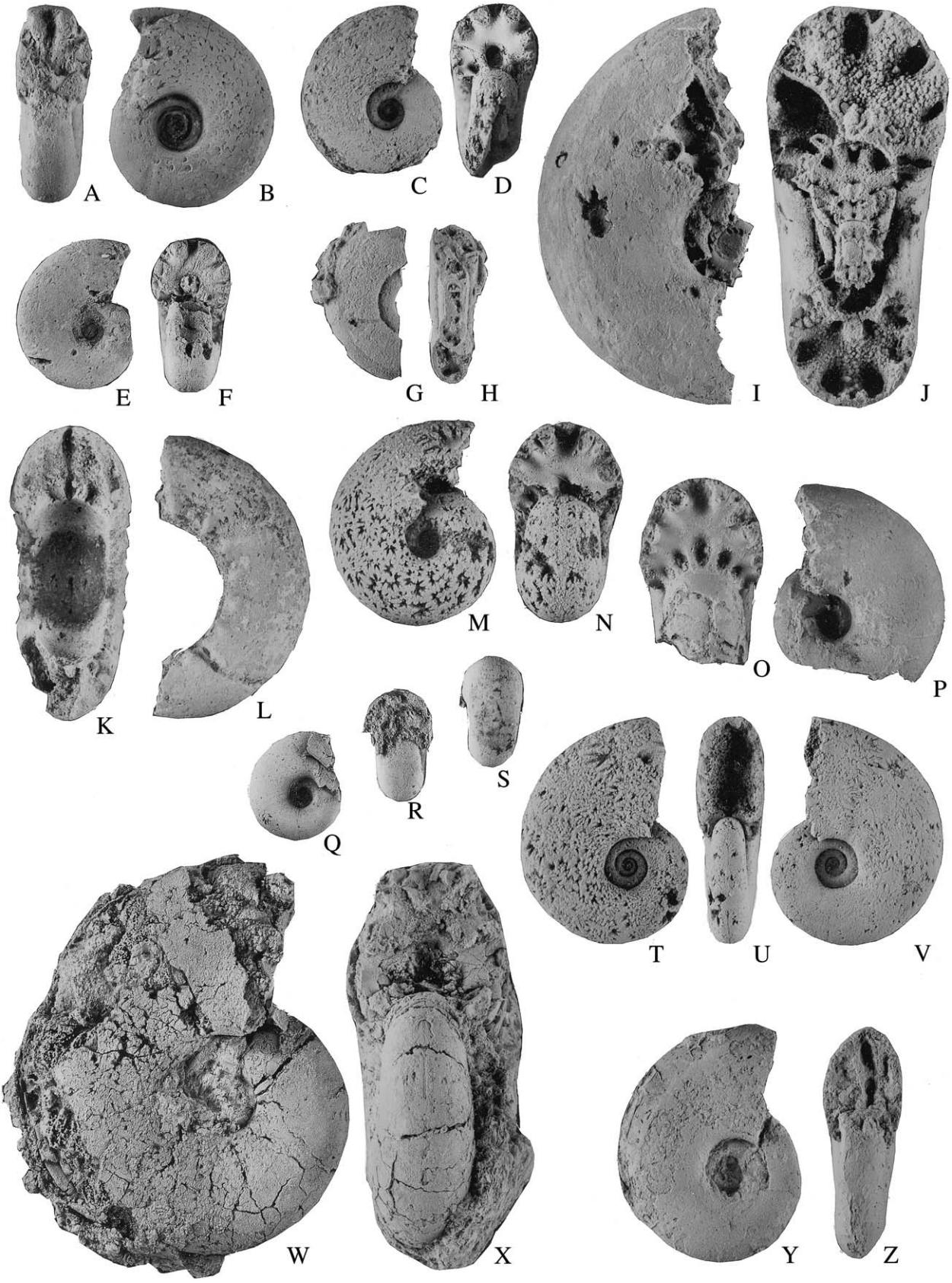

Fig. 5. All specimens coated with NH_4Cl prior to photography; all $\times 3$ except for W, X which are $\times 1.5$. A, B, *Saghalinites* sp., IRSNB TC MI 10898. C–F, *Pseudophyllites* sp. 1: C, D, IRSNB TC MI 10899; E, F, IRSNB TC MI 10900. G, H, *Hauericeras* cf. *H. rembda* (Forbes, 1846), IRSNB TC MI 10903. I, J, *Pseudophyllites* sp. 2, IRSNB TC MI 10902. K, L, *Brahmaites* (*Brahmaites*) *brahma* (Forbes, 1846), IRSNB TC MI 10904. M–P, *Menuites* sp.: M, N, IRSNB TC MI 10906; O, P, IRSNB TC MI 10905. Q–S, Desmoceratoceae sp. 1, IRSNB TC MI 10907. T–V, Desmoceratoceae sp. 3, IRSNB TC MI 10913. W–Z, Desmoceratoceae sp. 2: W, X, IRSNB TC MI 10908; Y, Z, IRSNB TC MI 10910.

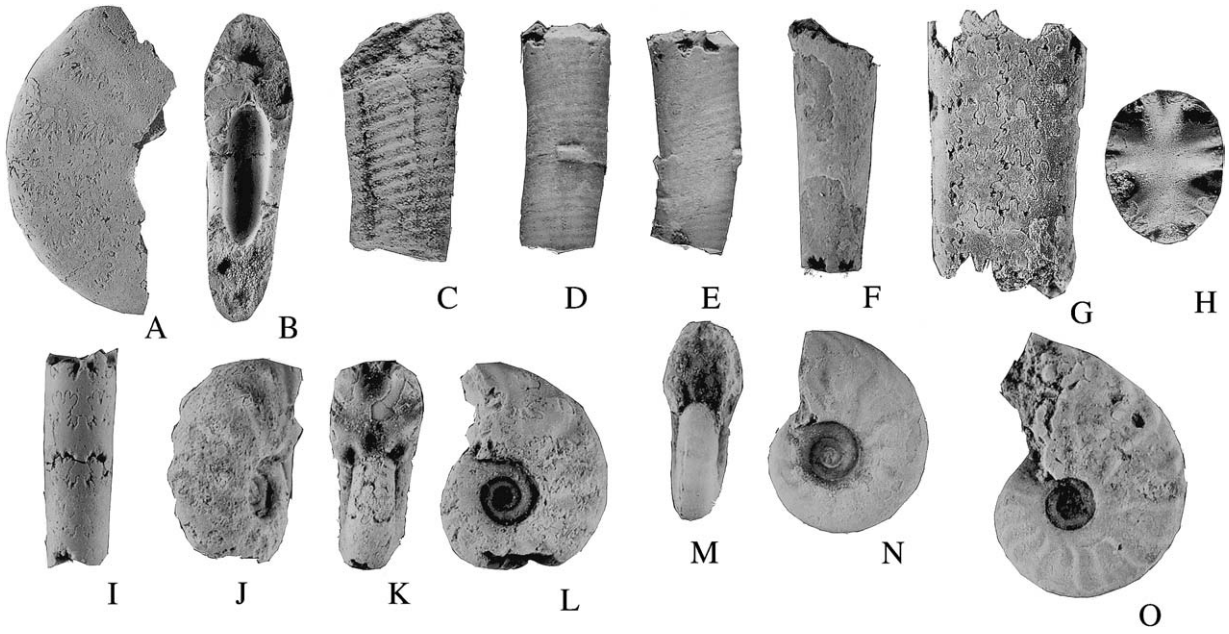

Fig. 6. All specimens coated with NH_4Cl prior to photography; all ×3 except for A, B which are ×2 and for G, H which are ×5. A, B, Desmoceratacеae sp. 3, IRSNB TC MI 10934. C–E, *Diplomoceras cylindraceum* (Defrance, 1816): C, IRSNB TC MI 10916; D, E, IRSNB TC MI 10917. F–H, *Baculites* sp.: F, IRSNB TC MI 10921; G, H, IRSNB TC MI 10923. I, *?Baculites paradoxus* Pervinquière, 1907, IRSNB TC MI 10918. J, L, *Indoscaphites cunliffei* (Forbes, 1846), IRSNB TC MI 10927. M–O, *Indoscaphites pavana* (Forbes, 1846): M, N, IRSNB TC MI 10930; O, IRSNB TC MI 10931.

intercalated ribs arise relatively high on the flanks. The whorl section is rounded in the early stages, and becomes more compressed as diameter increases.

Discussion. Eggermont (1996, p. 58) referred three specimens (KEF A2 and KEF A4, both from 5 m, and KEF A11 from 6 m below K/P boundary) to *Hoploscaphites constrictus* type 1. These three, together with a specimen referred by Eggermont to *Hoploscaphites constrictus* type 3 (from 6 m below K/P boundary), are here reassigned to *Indoscaphites cunliffei*. Pervinquière (1907) noted some differences, such as the absence of umbilical bullae, between the Tunisian specimens and the type material of *I. cunliffei* from southern India. This is related to the smaller size of his material when compared to the types.

Occurrence. Maastrichtian, Tunisia and southern India.

Indoscaphites pavana (Forbes, 1846)
Figs. 4H, M, 6M–O, 7P, Q

1846 *Ammonites Pavana* Forbes, p. 110, pl. 7, fig. 5.
1898 *Scaphites Pavana* Forbes sp.; Kossmat, p. 31 (138).
1907 *Scaphites Cunliffei* var. *Pavana* Forbes; Pervinquière, p. 124 (pars), figs. 41, 42 only; text-fig. 45 only.
1953 *Indoscaphites pavana* (Forbes); Spath, p. 14.
1992b *Indoscaphites pavana* (Forbes, 1846); Kennedy and Henderson, p. 726, pl. 5, figs. 1, 3–5.

Types. See Kennedy and Henderson (1992b, p. 724).

Material. Twenty specimens, KEFG A70, IRSNB TC MI 10930, KEFG A73, A74, IRSNB TC MI 10932, KEFG A82 and A124 from 3.5 m, KEFG A19, IRSNB TC MI 10928 and KEFG A21 from 4 m, KEFG A116 from 4.5 m, KEFG A62 from 5.5 m, IRSNB TC MI 10929 from 6 m, KEFG A35, A54 and A102 from 6.5 m and IRSNB TC MI 10931, KEFG A91, A92 and A99 from 7 m below K/P boundary.

Description. Ribs are convex at mid-flank, concave on the outer flank and prorsiradiate on the ventrolateral shoulder where they bear small clavi. The ribs are convex on the venter. Intercalated ribs arise at mid-flank. The whorl section is rounded in early growth stages, but becomes more compressed and flat-sided at larger diameters.

Discussion. Eggermont (1996, p. 59) referred four specimens to *Hoploscaphites constrictus* type 3. One of these (KEF A3, from 5 m below K/P boundary) is assignable to *Indoscaphites pavana*; the other three should be referred to *Indoscaphites cunliffei* and *Indoscaphites* indet.

Pervinquière (1907) regarded *I. cunliffei* and *I. pavana* as conspecific. We agree with Kennedy and Henderson (1992b), who also studied some material from Tunisia, and considered both species to be valid, but congeneric. When the diameter exceeds 6 mm, *I. pavana* becomes

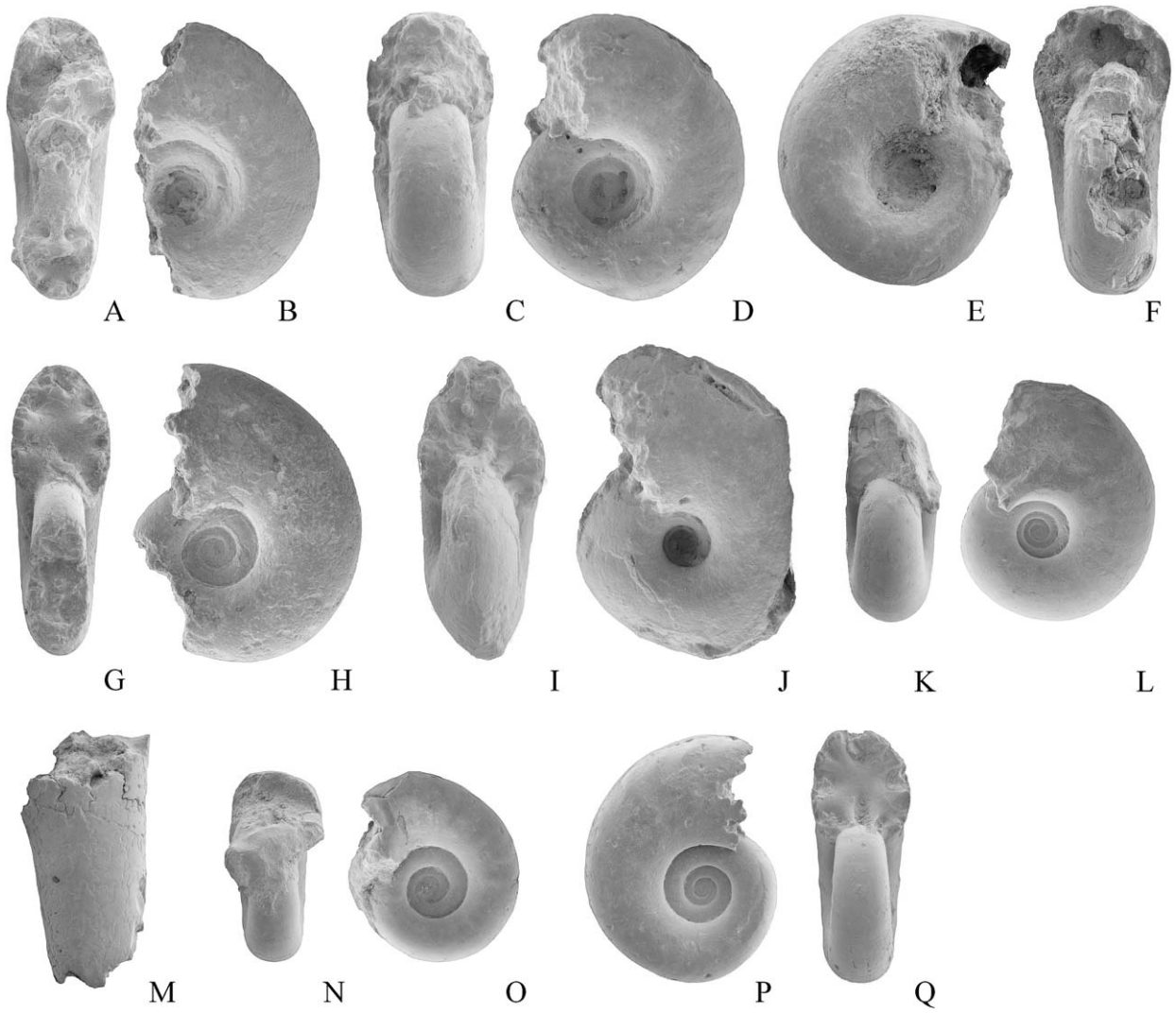

Fig. 7. All specimens coated with gold prior to SEM; all ×5. A, B, *Zelandites* sp., IRSNB TC MI 10896. C, D, *Saghalinites* sp., IRSNB TC MI 10897. E, F, *Pseudophyllites* sp. 2, IRSNB TC MI 10901. G, H, Desmoceratacae sp. 3, IRSNB TC MI 10911. I, J, Desmoceratacae sp. 4, IRSNB TC MI 10914. K, L, Desmoceratacae sp. 5, IRSNB TC MI 10915. M, *Baculites* sp., IRSNB TC MI 10922. N, O, *Indoscaphites cunliffei* (Forbes, 1846), IRSNB TC MI 10926. P, Q, *Indoscaphites pavana* (Forbes, 1846), IRSNB TC MI 10932.

easily distinguishable from *I. cunliffei* by the absence of pronounced ventrolateral horns, more strongly curved ribs and a higher whorl section.

Occurrence. Maastrichtian, Tunisia and southern India.

Indoscaphites indet.

Material. Thirteen specimens, KEFG A26 and A107 from 4 m, A114 from 4.5 m, A18, A23, A25, A45, A47 and A67, from 6 m, A33 and A34 from 6.5 m and A94 and A106 from 7 m below K/P boundary.

Remarks. These specimens are too poorly preserved to allow definite assignment to either *I. cunliffei* or *I. pavana*, described above. Two specimens in the Eggermont Collection, from 6 m below the K/P boundary, referred to *Hoploscaphites constrictus* type 1, are better assigned to *Indoscaphites* sp.

4. Discussion

125 specimens (110 plus 15 from the Eggermont collection) belonging to at least 17 different taxa are described in this paper. Their distribution is shown in Fig. 2. The fauna is numerically dominated by the genus *Indoscaphites* (48% of the collection) and members of the superfamily Desmoceratacae (27%). About 66% and five of the 17 taxa are heteromorphs. A strong connection along the southern Tethys with southern India is suggested by the presence and dominance of the

genus *Indoscaphites* (with both *I. cunliffei* and *I. pavana*), currently known only from Tunisia and southern India.

The stratigraphic position of each ammonite find is indicated in Fig. 2. However, it must be borne in mind that this distribution chart is based on surface collecting and that these specimens had weathered out, and may have moved down-section. The lowest ammonite records are from 7 m below the K/P boundary, the highest from about 2 m below it.

Do the new data clarify the rate (high or low) and the pattern (single-step versus multi-step) of ammonite extinction during the terminal Maastrichtian? The Tunisian ammonites are quite diverse in the highest few metres below the K/P boundary. This interval belongs to the uppermost part of the *Abathomphalus mayaroensis* (planktonic foraminiferal) Zone, also known as the *Plummerita hantkeninoides* Zone, and represent the last 200 ky of the Maastrichtian. This age estimate is based on various published age estimates of the FAD (first appearance datum) of *Pl. hantkeninoides* (300 ky before K/P in Li and Keller, 1998; between 170 and 200 ky in Pardo et al., 1996; and between 230 and 295 ky in Hennebert and Dupuis, 2002, 2003) and on the fact that the base of the *Pl. hantkeninoides* Zone is not reached in the KD section at El Kef (Arenillas et al., 2000).

There is no evidence at present that ammonites persisted up to the K/P boundary in the Tunisian Basin. On the contrary, the topmost 2 m of the Aïn Settara Marls, just below the K/P boundary, are always ammonite-free (2 m at the El Kef section, this paper and 2.5 m at the Aïn Settara section in the Kalaat Senan area, central Tunisia; see Eggermont, 1996, Eggermont et al., 1996, Robaszynski et al., 2000 and Dupuis et al., 2001), although other macrofossils extend up to and above the K/P boundary (this paper; Robaszynski et al., 2000; Dupuis et al., 2001). These include internal moulds of originally aragonitic bivalves (El Kef, this paper). If the latest ammonite indeed disappeared from the Tunisian Basin at the time of the deposition of the −2 m level, this may be the result of true, terminal extinction. It is unlikely to have been the result of differential diagenesis in our view, as other originally aragonitic molluscs, now preserved as moulds (as are the ammonites), occur in the top 2 m interval. What caused this pre-boundary extinction is not clear. However, their exact level of disappearance might suggest links with a major regression (Adatte et al., 2002 and Hennebert and Dupuis, 2003), affecting the Tunisian Basin just before the start of the latest Maastrichtian transgression.

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