

A late Albian ammonite assemblage from the mid-Cretaceous succession at Annopol, Poland

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ABSTRACT:

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A previously unrecorded ammonite assemblage, comprising *Lepthoplites* sp., *Callihoplites tetragonus* (Seeley, 1865), *C. cf. tetragonus*, *Arrhaphoceras cf. substuder* Spath, 1923, *Cantabrigites* sp., *Stoliczkaiella (Stoliczkaiella)* sp., *Hamites cf. duplicatus* Pictet and Campiche, 1861, *H. cf. subvirgulatus* Spath, 1941, and *H. cf. venetianus* Pictet, 1847, is described from the mid-Cretaceous condensed succession at Annopol, Poland. These specimens are preserved as pale phosphates or sandstone moulds in a bed of reworked phosphatic nodules near the top of the Albian. This assemblage has many species in common with the late Albian faunas from condensed deposits of England, Switzerland, and France. The presence of *Callihoplites tetragonus* indicates the lowermost upper Albian *Mortoniceras fallax* Zone. The ammonites studied are the youngest elements in the phosphate bed, which also contains taxa as old as the middle Albian *Hoplites dentatus* Zone. This bed originated through condensation and reworking of nodules and fossils in a period of low net sedimentation rate, being probably a reflection of a sea-level drop at the boundary between the classic ammonite zones of *Mortoniceras inflatum* and *Stoliczkaiella dispar*.

Key words: Ammonites; Albian; Cretaceous; Annopol; Poland; Condensation; Stratigraphy.

INTRODUCTION

The uppermost lower Albian–lower Turonian condensed, phosphorite-bearing succession at Annopol, Poland, is of key importance for the mid-Cretaceous palaeontology, biostratigraphy and palaeobiogeography of this part of Europe (Samsonowicz 1925; Cieśliński 1959; Marcinowski 1980; Marcinowski and Radwański 1983; Marcinowski and Wiedmann 1985, 1990; Walaszczyk 1987). Extensive exploration of this site in recent years has resulted in a series of papers on various aspects of the mid-Cretaceous palaeontology of the succession (Machalski and Kennedy 2013; Machalski and Martill 2013; Popov and Machal-

ski 2014; Machalski and Olszewska-Nejbert 2015; Bardet *et al.* 2015; Fraaije *et al.* 2015; Kapuścińska and Machalski 2015).

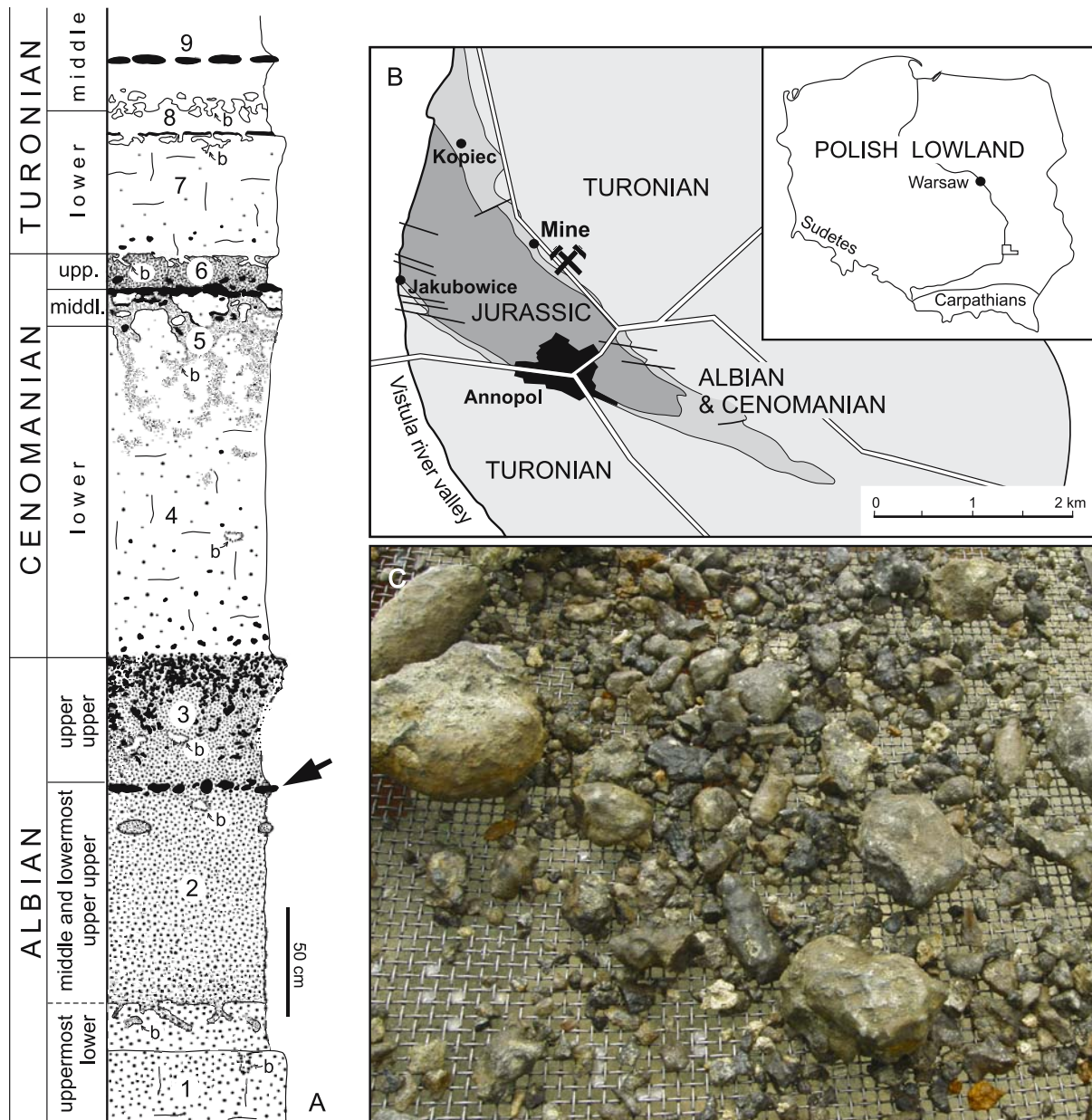
Ammonites are among the most important fossils at Annopol, providing the basis for the biostratigraphic subdivision of the succession (Samsonowicz 1925, 1934; Pożaryski 1947; Cieśliński 1959, Marcinowski 1980; Marcinowski and Wiedmann 1985, 1990; Marcinowski and Radwański 1983, 1989; Marcinowski and Walaszczyk 1985; Machalski and Kennedy 2013; Machalski and Olszewska-Nejbert 2015). Here, we present a description and biostratigraphic discussion of a previously unrecorded ammonite assemblage from Annopol.

PROVENANCE OF THE MATERIAL

The ammonite material studied comes from the top of unit 2 of the Albian portion of the mid-Cretaceous (uppermost lower Albian–lower Turonian) condensed, phosphorite-bearing sedimentary succession exposed along the limbs of the Annapol anticline, central Poland (Text-fig. 1A–C). The Annapol anticline is located on the east bank of the Wisła (Vistula) River, central Poland (Text-fig. 1B). The reader is referred to

Machalski and Kennedy (2013) for the more detailed characteristics of the Annapol succession.

Unit 2 is developed as quartz sands with glauconite and rare ovoid sandstone nodules near the top; the unit is c. 70 cm thick. There is a distinct phosphorite bed, composed of phosphatic nodules and clasts with sandy matrix occurs at the top of unit 2. These phosphates are of variable size, colour and shape, including characteristic spindle-shaped nodules up to 20 cm in length (Walachczyk 1987). The ammonites described in the



Text-fig. 1. **A** – Lithology and stratigraphy of the condensed mid-Cretaceous succession of the Annapol anticline (modified after Machalski and Kennedy 2013, fig. 1); **b** – burrows; arrow indicates a layer of phosphatic nodules and clasts (lower part of the Phosphorite Bed of authors) which yielded the ammonites studied. **B** – Geologic sketch-map of the Annapol anticline (modified after Walachczyk 1987) with location of the Kopiec outcrop (inset: location of the study area in Poland). **C** – Close-up view of the phosphates washed from the ammonite-bearing level at the top of unit 2

present paper are from a finer fraction of these phosphates (Text-fig. 1C). They have been obtained by screen washing of sediment at the locality Kopiec, south of the village of that name, on the northern limb of the anticline (Text-fig. 1B). The phosphatic horizon at the top of unit 2 was referred by previous authors to the lower part of their Phosphorite Bed (e.g., Marcinowski and Radwański 1983, 1989; Marcinowski and Wiedmann 1985, 1990).

The ammonites studied, 41 specimens in total, are preserved as distinctive pale phosphates or fragile un-phosphatised sandstone internal moulds (Text-fig. 2). Most of the specimens are markedly incomplete, being represented by fragments of whorls only; some are worn. There is another ammonite assemblage present in the same phosphatic bed, which is represented by heavily worn fragments of black phosphatic moulds associated with much rarer complete individuals embedded in larger nodules. This hoplitid-dominated assemblage was recognised by early investigators (Samsonowicz 1925, 1934; Pożaryski 1947; Cieśliński 1959). According to Marcinowski and Wiedmann (1985, 1990), it is a mixture of ammonites, ranging from the middle Albian *Hoplites dentatus* Zone to the lower upper Albian *Mortonicerias inflatum* Zone (see table 1 in Machalski and Kennedy 2013 for the ammonite-based subdivision of the Albian). Associated non-ammonite fossils comprise sponges, inoceramids, nautilid mandibles, chimaeroid dental plates, shark and reptile teeth and vertebrae, as well as pieces of conifer driftwood (Samsonowicz 1925, 1934; Marcinowski and Radwański 1983; Popov and Machalski 2014, Bardet *et al.* 2015). Differences in degree of phosphatisation of fossils and nodules, and their common fragmentation and chaotic orientation are indicative of their having been reworked in high-energy conditions (Samsonowicz 1925, 1934; Marcinowski and Radwański 1983, 1989).

The material is stored in the collections of the Institute of Paleobiology of the Polish Academy of Sciences, Warszawa (collection ZPAL Am. 23).

SYSTEMATIC PALAEOLOGY

Superfamily Hoplitoidea H. Douvillé, 1890

Family Hoplitidae H. Douvillé, 1890

Subfamily Anahoplitinae Breistroffer, 1947

Genus *Lepthoplites* Spath, 1925b

Lepthoplites sp.

(Text-fig. 2E, G)

MATERIAL: Five specimens (ZPAL Am. 23/26, 28, 38–40)

DESCRIPTION: These are compressed individuals, the best-preserved (ZPAL Am. 23/26, see Text-fig. 2E) with a whorl height of 9.4 mm. The flanks are feebly convex and converge to the narrowly rounded ventrolateral shoulders, the venter very feebly convex. Small umbilical bullae give rise to pairs of ribs with additional ribs intercalating, the ribs straight on the inner to mid-flank, then flexing forwards and concave on the outer flank, where they link to tiny ventral clavi that alternate in position on either side of the venter and give rise to progressively effacing ventral ribs. This pattern of ventral ornament is well-preserved in specimens ZPAL Am. 23/28 and 38 (28 figured in Text-fig. 2G). Specimen ZPAL Am. 23/40 (not illustrated) has a whorl height of 15.4 mm. Small bullae give rise to up to three flexuous ribs, with additional ribs intercalating. The pattern of ornament, with ribs linking to single ventral clavi suggest *Lepthoplites*, the material resembling that illustrated by Renz (1968, pl. 4, figs 12–15) from the condensed upper Albian of Saint-Croix, Switzerland.

OCCURRENCE: *Lepthoplites* ranges from the *Mortonicerias inflatum* Zone to *M. perinflatum* Zone, is commonest in the *M. fallax* to *M. perinflatum* zones, and is recorded from southern and eastern England, France, and Switzerland.

Subfamily Hoplitinae H. Douvillé, 1890

Genus *Callihoplites* Spath, 1925a

Callihoplites tetragonus (Seely, 1865)

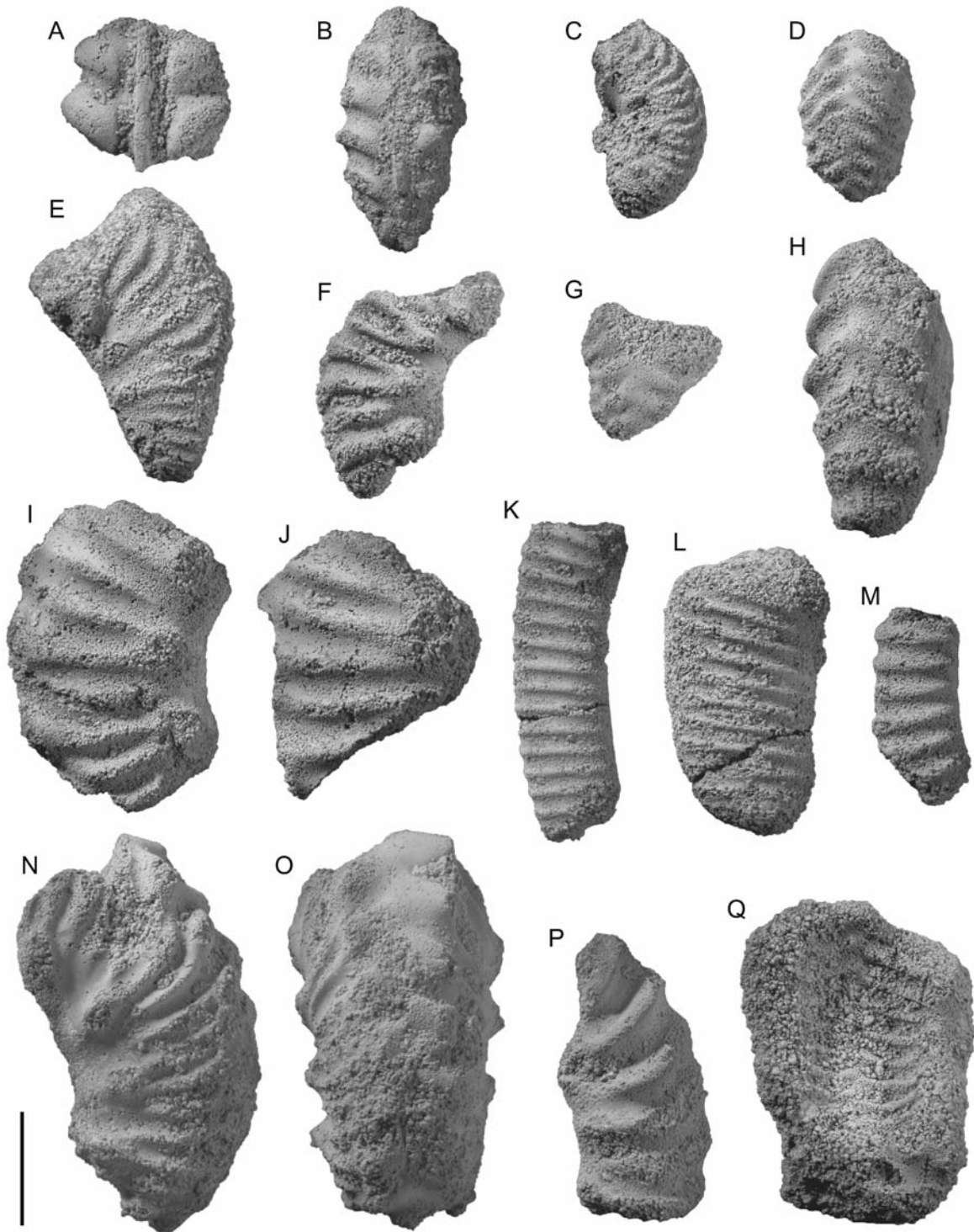
(Text-fig. 2N, O)

1865. *Ammonites raulinianus* var. *tetragonus* Seeley, p. 243.

2008. *Callihoplites tetragonus* (Seeley, 1865); Kennedy *et al.* p. 38, pl. 1, figs 1–18; pl. 2, figs 1–26; pl. 3, figs 1–24; pl. 4, figs 1–5; pl. 5, figs 1–6, 10–17 (with full synonymy)

MATERIAL: A single specimen (ZPAL Am. 23/35).

DESCRIPTION AND DISCUSSION: ZPAL Am. 23/35 (Text-fig. 2N, O) is the largest and best preserved *Callihoplites* in the present material. It is a 120° whorl sector with a maximum preserved whorl height of 16 mm high. There are three well-preserved umbilical bullae on the fragment, and traces of as fourth. The bullae give rise to pairs of ribs, with additional ribs intercalating to give a total of 15–16 on the fragment. They are straight and prorsiradiate on the inner and mid-flank region, flexing forwards and concave on the outer flank, and some, but not all, link in



Text-fig. 2. Upper upper Albian ammonites from the top of unit 2 at Annopol (lower part of the Phosphorite Bed of authors). **A, B** – *Cantabrigites* sp. (A, ZPAL Am. 23/23; B, ZPAL Am. 23/24). **C, D, Q** – *Arrhaphoceras* cf. *substuderi* Spath, 1923 (C, ZPAL Am. 23/25; D, ZPAL Am. 23/41; Q, ZPAL Am. 23/36). **E, G** – *Leptoplites* sp. (E, ZPAL Am. 23/26; G, ZPAL Am. 23/28). **F, H, P** – *Stoliczkaella* (*Stoliczkaella*) sp. (F, ZPAL Am. 23/27; H, P, ZPAL Am. 23/29 in ventral and lateral view, respectively). **I, J** – *Callihoplites* cf. *tetragonus* (Seeley, 1865) (I, ZPAL Am. 23/30; J, ZPAL Am. 23/31). **K** – *Hamites* cf. *subvirgulatus* Spath, 1941, (ZPAL Am. 23/32). **L** – *Hamites* cf. *duplicatus* Pictet and Campiche, 1861 (ZPAL Am. 23/33). **M** – *H.* cf. *venetianus* Pictet, 1847, (ZPAL Am. 23/34). **N, O** – *Callihoplites tetragonus* (Seeley, 1865) (ZPAL Am. 23/35 in lateral and ventral view, respectively). Scale bar 1 cm

in pairs at strong ventrolateral clavi, of which four are preserved. A low, broad rib zig-zags between the clavi on the venter (Text-fig. 2O). The specimen matches well with some individuals of variable *Callihoplites tetragonus* (Seeley, 1865) from the Bracquegnies Formation at Strépy-Thieu (Hainaut, Southern Belgium) as interpreted by Kennedy *et al.* (2008), for example the specimens in their pl. 3, figs 1–6.

OCCURRENCE: *Callihoplites tetragonus* is recorded from the lowest upper upper Albian *Mortoniceras fallax* Zone of eastern England, southern Belgium, France.

Callihoplites cf. tetragonus (Seeley, 1865)
(Text-fig. 2I, J)

Compare:

1865. *Ammonites raulinianus* var. *tetragonus* Seeley, p. 243.
2008. *Callihoplites tetragonus* (Seeley, 1865); Kennedy *et al.* p. 38, pl. 1, figs 1–18; pl. 2, figs 1–26; pl. 3, figs 1–24; pl. 4, figs 1–5; pl. 5, figs 1–6, 10–17 (with full synonymy)

MATERIAL: Three specimens (ZPAL Am. 23/30, 31, 37).

DESCRIPTION AND DISCUSSION: Specimen ZPAL Am. 23/37 (not illustrated) is a tiny fragment with an apparently compressed whorl section, the maximum preserved whorl height 10.3 mm. One relatively large umbilical bulla is preserved. It gives rise to three ribs that are straight on the inner flank and concave on the outer flank, sweeping forwards to join in pairs at ventral clavi. Specimen ZPAL Am. 23/30 (Text-fig. 2I) is a larger fragment of body chamber with a maximum preserved whorl height of 18 mm. The umbilicus is shallow. Three relatively large umbilical bullae are preserved on the fragment. They give rise to two or three ribs that are straight and prorsiradiate on the inner flank, flexing forwards and linking in pairs at large ventral clavi. Specimen ZPAL Am. 23/31 (Text-fig. 2J) is a flank fragment of an individual of comparable size. The distinctive feature of all these fragments is the linking of ribs in pairs at ventral clavi, which distinguishes them from material referred to *Lepthoplites*, above. These specimens differs in no significant respects from some individuals referred to *Callihoplites tetragonus* (Seeley, 1865) from the Bracquegnies Formation at Strépy-Thieu (see above).

OCCURRENCE: as for *Callihoplites tetragonus* (above).

Genus *Arrhaphoceras* Whitehouse, 1927
Arrhaphoceras cf. substuderi Spath, 1923
(Text-fig. 2C, D, Q)

Compare:

1968. *Arrhaphoceras substuderi* Spath; Renz, p. 31, pl. 2, figs 20–22; text-figs 11b, 12f (with full synonymy).

MATERIAL: Three specimens (ZPAL Am. 23/25, 36, 41).

DESCRIPTION AND DISCUSSION: The most complete individual is ZPAL Am. 23/25 (Text-fig. 2C), a half whorl with a maximum preserved diameter of 16.8 mm. Coiling is relatively involute, the umbilicus small and deep, the umbilical wall outward-inclined, the whorl section slightly depressed ovoid. Four relatively strong umbilical bullae are preserved on the fragment. They give rise to groups of up to three ribs, whilst additional ribs intercalate. The ribs are narrow, crowded, markedly concave on the flanks, sweeping forwards and weakening across the ventrolateral shoulder and strongly prorsiradiate on the venter. They extend to the mid-line of the venter, where they alternate in position, rather than meeting in a symmetrical chevron. Specimen ZPAL Am. 23/41 (Text-fig. 2D) is the well-preserved ventral region of a somewhat larger specimen, with comparable fine, crowded ventral ornament, the ends of the ribs strengthened and alternating in position at the mid-line of the venter. Specimen ZPAL Am. 23/36 (Text-fig. 2Q) is a mould of the dorsum of a much larger specimen with the same pattern of ornament. These specimens are much smaller than most *Arrhaphoceras* illustrated in the literature. The closest comparison is between ZPAL Am. 23/36 and specimens referred to *Arrhaphoceras substuderi* by Renz (1968, p. 31, pl. 2, figs 21, 22).

OCCURRENCE: *Arrhaphoceras substuderi* is recorded from the *Mortoniceras fallax* Zone of southern and eastern England and Switzerland, and the *M. perinflatum* Zone of southern England and southeastern France.

Superfamily Acanthoceratoidea de Grossouvre, 1894
Family Brancoceratidae Spath, 1934 (1900)
Subfamily Mortoniceratinae H. Douvillé, 1912
Genus *Cantabrigites* Spath, 1933
Cantabrigites sp.
(Text-fig. 2A, B)

MATERIAL: Three specimens (ZPAL Am. 23/23, 24, 41).

DESCRIPTION: Specimen ZPAL Am. 23/23 (Text-fig. 2A) is a fragment of part of the venter, 14 mm wide. The venter is flat, with a strong siphonal keel. Two coarse, strongly prorsiradiate ribs are preserved, strengthened into bullae that do not extend to the keel. Specimen ZPAL Am. 23/24 (Text-fig. 2B) is a comparable fragment, 10.6 mm wide and 20.8 mm long, with comparable keel and ribbing, here with better differentiated ventrolateral tubercles. Specimen ZPAL Am. 23/41 (not illustrated), 12.5 mm long, preserves part of the flank, with three coarse, prorsiradiate ribs with variably developed umbilical bullae, and inner ventrolateral tubercles.

DISCUSSION: The combination of ribbing, tuberculation, keel, and flat venter suggest *Cantabrigites*, although the material is specifically indeterminate. It compares well with that figured by Spath (1933, pl. 41, figs 1, 2; text-fig. 152), Renz (1968, pl. 10, figs 10–29), and Scholz (1979, pl. 30).

OCCURRENCE: *Cantabrigites* species are known from the *Mortoniceras fallax* Zone to the *M. perinflatum* Zone. There are records from southern and eastern England, France, Switzerland, and Hungary.

Family Lyelliceratidae Spath, 1921

Subfamily Stoliczkaeiellinae Cooper, 2012, 1921

(*nom. nov. pro* Stoliczkaünae Breistroffer, 1953)

Genus and subgenus *Stoliczkaeiella* Cooper, 2012

Stoliczkaeiella (Stoliczkaeiella) sp.

(Text-fig. 2F, H, P)

MATERIAL: Three specimens (ZPAL Am. 23/27, 29, 62)

DESCRIPTION: ZPAL Am. 23/27 (Text-fig. 2F) is a body chamber fragment with a maximum preserved whorl height of an estimated 24 mm. The umbilicus appears to have been of moderate depth, the umbilical wall broadly rounded. Relatively strong umbilical bullae give rise to two or three relatively coarse ribs that are straight on the inner flank and sweep forwards and are concave on the outer flank; the venter is abraded. Specimen ZPAL Am. 23/29 (Text-fig. 2H, P) is a fragment of the body chamber of a slightly larger individual, lacking the umbilical margin. The ribs are relatively coarse, strengthening markedly and concave on the outer flanks and ventrolateral shoulder and sweeping forwards across the venter without weaken-

ing, to form an obtuse ventral chevron. A third specimen, ZPAL Am. 23/62 (not illustrated) is a fragment of one flank with comparable ornament.

DISCUSSION: The very coarse ribbing and strong, symmetrical ventral chevron separate these fragments from species of *Arrhaphoceras*. The closest comparable material seems to be amongst the *Stoliczkaeiellinae*. The ribbing style and ventral ornament compare well with that of *Stoliczkaia (Lamnayella) worthense* (Adkins, 1920), in particular the original of Böse 1928, pl. 18, figs 15, 17 (*pars*) (refigured by Kennedy 2004, text-fig. 19b–e), from the upper Albian Pawpaw Shale of northeast Texas. There are also similarities to species of the subgenus *Stoliczkaeiella (Shumarinaia)*, such as *S. (S.) africana* Pervinquier, 1907 (p. 388, *pars*, pl. 12, fig. 9 only, see revision in Wright and Kennedy 1994, p. 578, text-figs 3d–h, l–n, r–w; 11c–g), but the ventral chevron of the present species is distinctive. The material may represent a new species, but more and better material is needed to fully characterise it.

Suborder Ancyloceratina Wiedmann, 1966

Superfamily Turrilitoidea Gill, 1871

Family Hamitidae Gill, 1871

Genus *Hamites* Parkinson, 1811

Hamites spp.

(Text-fig. 2K–M)

MATERIAL: Twenty three specimens (ZPAL Am. 23/32–34, 42–61).

DESCRIPTION: The material, all fragments, the largest 25 mm long, varies in both rib density and whorl section. The limits of intraspecific variation amongst upper Albian *Hamites* is uncertain. Renz (1968) recorded 12 species from the condensed upper Albian of la Vraconne, Switzerland, and Spath 10 species from the reworked and condensed fauna of the Cambridge Greensand of eastern England. In terms of these authors, the present material can be compared as below.

Specimens such as ZPAL Am. 23/33 (Text-fig. 2L) have a compressed oval whorl section with a whorl breadth to height ratio of 0.8 approximately. The rib index is seven, the ribs effaced across the dorso lateral, strengthening across the dorsolateral margin, straight and prorsiradiate across the flanks, and transverse over the venter. These can be compared to *Hamites duplicatus* Pictet and Campiche, 1861, as interpreted by Wright and Kennedy (1995, p. 298, pl. 87, figs 1, 2, 7, 8, 10; pl. 88, figs 2, 4).

Coarser ribbed fragments such as ZPAL Am. 23/32 (Text-fig. 2K) have whorl heights of up to 8.7 mm, a

compressed oval whorl section with a whorl breadth to height ratio of 0.8 and a rib index of five, the ribs weakened on the dorsum, strengthening across the dorsolateral margin, near-transverse to very feebly prorsiradiate on the flanks, and straight and transverse across the venter. They compare with specimens referred to *Hamites subvirgulatus* Spath, 1941, from the condensed *fallax* Zone of the Cambridge Greensand of eastern England and the *perinflatum* Zone ammonite bed of the Dorset coast in southern England (Spath 1941, p. 645, text-fig. 234).

The coarsest ribbed fragment, ZPAL Am. 23/34 (Text-fig. 2M), is 17.7 mm long, with a whorl breadth to height ratio of 0.83. It has a rib index of 4, the ribs weak on the dorsum, strengthening progressively, prorsiradiate and feebly convex across the flanks, before strengthening further over the venter where they are very coarse, transverse, and wider than the interspaces. This fragment corresponds to *Hamites venetianus* Pictet, 1847, as illustrated from the Cambridge Greensand of eastern England by Spath (1941, pl. 71, figs 11–13; text-fig. 231) and from la Vraconne by Renz (1968, pl. 11, figs 9–11).

OCCURRENCE: Species with which the present material is compared range from the *Mortoniceras fallax* Zone to *M. perinflatum* Zone in western Europe, with *H. duplicostatus* extending into the upper Cenomanian.

AGE OF THE AMMONITE ASSEMBLAGE

Ammonites ranging from the middle Albian *Hoplites dentatus* Zone to the lower upper Albian *Mortoniceras inflatum* Zone, preserved as black phosphates, were described from the phosphatic level at the top of unit 2 by previous authors (e.g., Marcinowski and Wiedmann 1990). We have additional material in this preservation, age-range and lithologic provenance in our recent collections.

The ammonite specimens described here are distinctive by their preservation as pale phosphates or friable, unphosphatised sandstone moulds. These are: *Lepthoplites* sp., *Callihoplites tetragonus*, *Callihoplites* cf. *tetragonus*, *Arrhaphoceras* cf. *substuderi*, *Cantabrigites* sp., *Stoliczkaiella (Stoliczkaiella)* sp., *Hamites* cf. *duplicatus*, *H.* cf. *subvirgulatus*, and *H.* cf. *venetianus*. This is an upper upper Albian association, with many species in common with faunas from condensed deposits such as the Cambridge Greensand of eastern England (Spath 1923–43), and those from the *Mortoniceras perinflatum* Zone ammonite bed on the Dorset coast of southern England (Wright in Arkell 1947), la

Vraconne, Switzerland (Renz 1968) and Salazac in Gard, southeastern France (Breistroffer 1940; Latil 1995). These faunas belong to the classic *Stoliczkaiella dispar* Zone of authors, and to the *M. fallax* Zone (Cambridge Greensand, Salazac), or *M. perinflatum* Zone (*perinflatum* Zone Ammonite bed, la Vraconne in part) in contemporary terms (see Machalski and Kennedy 2013, table 1). The only taxon of precise biostratigraphic significance in the present material is *Callihoplites tetragonus*, which dates the assemblage to the lowest upper upper Albian *Mortoniceras fallax* Zone. This assignment is supported by the presence of the oyster-bioimmured ammonites of the *M. rostratum* or *M. perinflatum* zones at a higher level in the Annapol sequence: the phosphates forming the upper part of unit 3 (Text-fig. 1A) (Machalski and Kennedy 2013).

The ammonite assemblage described here is the youngest amongst the mixed ammonite faunas known from the phosphate layer at the top of unit 2. In view of our assignment of this assemblage to the *Mortoniceras fallax* Zone, this layer may be correlated with condensed beds at the base of the “Vraconnian” (*sensu* Amédéo 2002) sedimentary cycle in various parts of Europe, e.g., the Bed XII of the Gault Clay succession at Folkestone. These beds often contain an admixture of the older faunal elements, derived from the underlying strata (Amédéo 2002). Their origin may be ascribed to condensation and reworking of nodules and fossils in a period of low net sedimentation rate, probably linked to a regressive sea-level trough at the boundary between the classic ammonite zones of *Mortoniceras inflatum* and *Stoliczkaiella dispar* (see Hancock 1990, fig. 11).

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