LOWER KIMERIDGIAN AMMONITES FROM THE DRIFT OF LINCOLNSHIRE

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ABSTRACT. A collection of ammonites is described from the drift of Lincolnshire; they are of Lower Kimeridgian age, Mutabilis Zone. Almost all of the specimens belong to the genera *Rasenia* and *Aulacostephanus*, and include several new species which are grouped into two new subgenera of *Aulacostephanus*: *Xenostephanus* and *Xenostephanoides*. These new forms have only recently been found *in situ* in England, and are known from the Kimeridge Clay of both east and west Scotland.

THIS paper describes a collection of ammonites made mostly by Dr. R. G. Thurrell while mapping in the Lower Cretaceous of north Lincolnshire, and now deposited in the Sedgwick Museum, Cambridge. The material is all from the drift, and hence does not provide primary stratigraphic evidence; its publication seems of interest, however, for a number of reasons. The various forms were found in such intimate admixture, often in the same block of stone, that there can be little doubt that they give a fairly representative picture of a closely contemporaneous population. Their age is Lower Kimeridgian, Mutabilis Zone. The material is in rock-facies and only slightly crushed, whereas the known exposures in the outcrop of the shales of the Mutabilis Zone in this country yield, mostly, only wholly flattened shells, which have not attracted collectors in the past. Our knowledge of the fauna of the Mutabilis Zone is therefore scanty.

The fauna consists overwhelmingly of forms of the perisphinctid subfamily Aulacostephaninae at the stage where *Rasenia* changes to *Aulacostephanus*, and includes several new and previously little-known forms of great interest. The classification of the genus *Rasenia* is at present still in a state of confusion, but a revision of *Aulacostephanus* has been published by Ziegler (1962). New names will therefore be mostly confined here to the forms being described.

In referring to specimens the following abbreviations will be used:

R. MS. SW: Thurrell collection, material from Ranby, Market Stainton, and South Willingham (Lincolnshire) respectively.
BM: British Museum (Natural History).
SM: Sedgwick Museum, Cambridge.

We wish to thank Dr. R. G. Thurrell for making his material available to us for description; Dr. B. Ziegler for discussions and criticisms, and for very kindly allowing us to see the manuscript of his monograph on *Aulacostephanus*; and Mr. A. G. Brighton (Sedgwick Museum), Dr. M. K. Howarth (British Museum), and Mr. R. B. Wilson (Geological Survey, Edinburgh) for help with material in collections in their custody.

[1] This paper is based in part on a provisional manuscript prepared by Dr. Arkell shortly before his illness in 1956. I am grateful to Mr. A. G. Brighton for passing the manuscript on to me for completion after Dr. Arkell's death in 1958. J. H. C.

[Palaeontology, Vol. 6, Part 2, 1963, pp. 219–45, pls. 27–33.]

SYSTEMATIC DESCRIPTIONS

Family PERISPHINCTIDAE Steinmann 1890
Subfamily AULACOSTEPHANINAE Spath 1924 (= RASENIINAE Schindewolf 1925)

This subfamily encompasses a well-defined offshoot of the main perisphinctid tree. It leads back to such typically perisphinctid forms as *Pictonia* in the basal Lower Kimeridgian, with evolute coiling, round whorl-section, and smooth, regular ribbing which passes over the venter without interruption. It terminates in end-forms of *Aulacostephanus* which are of quite different appearance, with compressed, angular whorl-section, smooth tabulate or grooved venter, and strong straight ribbing reminiscent in style of the Cretaceous genus *Hoplites*. Between these extremes, further wide variations in coiling and novel forms of ornamentation occurred, so that the whole subfamily, although in itself closely delimited, covers an unusually wide range of forms. Attempts at classification have usually started from a broad division of the subfamily into two parts: an earlier part grouped around the genus *Rasenia*, leading to the later forms grouped around *Aulacostephanus*. Besides these, there has, however, sprung into existence a large number of other generic names created often on the basis of insufficient material and stratigraphy, inadequate type specimens, and the requirements of phylogenetic theory. The resulting confusion cannot be fully analysed here, but, in order to justify the classification which will be adopted in this paper, a number of points have to be discussed.

(*a*) *Generic classification.* It seems sufficient to divide the subfamily into only two genera: *Rasenia* and *Aulacostephanus*. Further grouping according to sculpture can be conveniently incorporated at subgeneric level.

(*b*) *Dimorphism.* In common with apparently most other perisphinctids, the Aulacostephaninae seem to have been dimorphic, and it is possible to classify most of the shells as macroconchs or microconchs (for full discussion, see Callomon 1957, 1963). As elsewhere, it seems helpful to incorporate this distinction at subgeneric level.

(*c*) *The* Rasenia–Aulacostephanus *boundary.* The transition between these genera is so gradual that, in drawing a dividing-line, many difficulties arise. Development occurred in more than one character of the sculpture, and the breaks in the development of different characters occurred at different times. If the development of a single character were made the sole criterion, an unnatural classification would result. Thus, for example, the presence or absence of a ventral smooth band alone might seem a tempting distinction to use as criterion; but, as is in fact seen in the material being here described, among a collection of shells which in most other respects are clearly conspecific, some have a ventral smooth band, others not. Moreover, many have it at one stage of their ontogeny, but not throughout. The best approach seems to be to group specimens of a contemporaneous population according to species, taking all their characters into account. A particular arrangement of species into genera is then of lesser importance. The arrangement of borderline species used here has been chosen to accord fairly closely with the one used by Dr. Ziegler in his monograph of the genus *Aulacostephanus*, but no claims are made for its uniqueness. It serves also to bring out resemblances between the Lincolnshire material and the fauna of the Mutabilis Zone farther south.

Genus RASENIA Salfeld 1913

Type species. Rasenia involuta (Salfeld MS) Spath 1935, designated by ICZN Opinion 426.

Microconchs. The following subgenera may be recognized, arranged in order of decreasing coarseness of ribbing.

1. PRORASENIA Schindewolf 1925. Type species: *P. quenstedti* Schindewolf, figured 1926, pl. xix, fig. 1. (Synonym *Desmosphinctes* Schindewolf 1925, type species: *Perisphinctes mniovnikensis* Nikitin 1884, p. 30, pl. ii, figs. 11, 12.) Small, strongly ribbed species with lappets. Its special character is the presence of strong triplicate ribbing on the inner whorls, reverting to biplicate perisphinctoid on the final body-chamber. Spath (1935, pl. 14, 15) has figured and named three species from England, and Waterston (1951, pl. 2) records them from Scotland.

2. RASENIA sensu stricto. Salfeld attached the manuscript name *involuta* to a number of specimens in the British Museum, of which Spath selected and figured only one. As, however, Spath is formally the author of the species, this specimen is holotype of *involuta* Spath rather than lectotype of *involuta* Salfeld, and both species and genus have to be interpreted by Spath's figured specimen. This is broken and slightly incomplete, and, in the absence of the last few sutures and peristome, it is impossible to tell conclusively whether the specimen is adult or not. All of the preserved last three-quarters whorl is, however, body-chamber, and it gives the impression near the end of slight contraction indicating maturity. There exist in the collections other specimens (e.g. Geol. Survey Coll. 25550–1) which agree with the holotype closely in all respects including size, and which, although also without peristomes, carry similar amounts of body-chamber. A complete adult from Scotland has been figured by Waterston (1951, pl. ii, fig. 8*a*, *b*). Its final diameter is 40 mm., and the body-chamber is terminated by a final constriction. The peristome shows the stump of a lappet. It seems certain, therefore, that *Rasenia* s.s. was fully grown at *c.* 40 mm. diameter with strong unmodified ribbing maintained to the end, and hence microconch; and it seems probable that it carried at least short lappets. Its special character is the differentiation of strong, sinuous primary and fine, fasciculate secondary ribbing. Inner whorls are always well covered, involute and inflated.

In a recent revision of the genus Geyer (1961, p. 86), rather than re-examine the type specimen of *involuta* Spath himself, quotes Spath's statement describing it as 'small, inner whorls . . .', which, whatever significance one may attach to size in taxonomy, it is not; and interprets *Rasenia* sensu stricto as covering large, typically macroconch forms. *Rasenia* s.s. is now capable of precise interpretation, and it is hoped that the confusion of the past has found an end.

Geyer does point out that, if *Rasenia* sensu lato is taken to include *Involuticeras* Salfeld as a subgenus (see below), *involuta* Spath 1935 is junior homonym of *involuta* (Quenstedt 1849), and proposes *Rasenia anglica* nom. nov. = *involuta* Spath non Quenstedt.

3. RASENIOIDES Schindewolf 1925, p. 335. Type species by original designation: *Nautilus striolaris* Reinecke 1818, which Schindewolf states should be interpreted by *Am. striolaris* Quenstedt pars 1888, pl. 124, fig. 8, non Reinecke. Reinecke's specimen seems to be lost, but his figure represents recognizable characters which seem to differ considerably from

those shown by Quenstedt's figure, notably in whorl-section and coiling. There is nothing in Reinecke's description to indicate a smooth venter, which, in this case, puts Quenstedt's specimen in *Aulacostephanus*; and, as small 'striolarian' Rasenids of the *thermarum* group are common in the Mutabilis Zone (see below), *Rasenioides* fills a useful role, interpreted here as microconch subgenus characterized by very fine, dense fasciculate ribbing. Lappets proper are not known, although some specimens carry a slightly raised sinuous collar on the mouth-border.

(PRORASENIOIDES Schindewolf 1925, p. 338; type species by original designation: *P. transitorius* Schindewolf, which is nom. nov. for *Am. striolaris* Quenstedt pars 1888, pl. 107, figs. 12, 13, non Reinecke, with additional specimens figured by Schindewolf 1926, p. 507, pl. xix, figs. 3–5, resembles *R. striolaris* Reinecke more than *Am. striolaris* Quenstedt 1888, pl. 124, fig. 8. However, as the latter is not strictly the type species of *Rasenioides* whereas, according to the Rules, the former is, *Prorasenioides* and *Rasenioides* are here regarded as synonymous.)

Macroconchs

4. ZONOVIA Sasonov 1960. Type species by original designation: *Amm. uralensis* d'Orbigny 1845. Large, evolute, coarse-ribbed forms with smooth apertures.

5. EURASENIA Geyer 1961, p. 87, 90. Type species: *Amm. Rolandi* Oppel 1863. Large, coarsely ribbed forms intermediate between *Zonovia* and *Involuticeras*.

6. INVOLUTICERAS Salfeld 1913. Type species by monotypy (Salfeld 1914, p. 175) or subsequent designation (Spath 1931): *Amm. involutus* Quenstedt 1849. Large, involute, compressed forms, finely ribbed on inner whorls, becoming smooth.

7. ?SEMIRASENIA Geyer 1961, p. 87, 92. Type species: *Amm. Möschi* Oppel 1863. The holotype of *möschi* is 45 mm. in diameter, and if Oppel's statement in the legend to his figure, that the suture-line shown is the last, is to be believed, it carries three-quarters whorl body-chamber and is hence nearly complete. Geyer states the final size to be 'probably about 70 mm.' without giving reasons based either on Oppel's specimen, which he refigures but does not redescribe, or additional material, of which he cites only one additional, even smaller specimen. The peristome remains unknown, and maximum size and ontogeny of mature examples in doubt.

The only other species included by Geyer in *Semirasenia* is *Amm. thermarum* Oppel. The holotype of this species seems to us to fit equally well into *Rasenioides*, however.

Subgenus RASENIA s.s. Salfeld

1. *Rasenia* (*Rasenia*) sp. ind.

cf. *Rasenia evoluta* (Salfeld MS), Spath 1935, pp. 48–49, pl. 14, fig. 6*a*, *b*.

Material. One (MS 128).

Description. Diameter 17 mm., sutures invisible, but at least half the outer whorl appears to be body-chamber. Coiling moderately evolute; ribbing straight, coarse and strong, modifying on the last quarter-whorl to typically rasenid fasciculate style, passing uninterruptedly over the venter.

Spath assumed that *R. evoluta* was a large species (1935, p. 49, footnote). Like *R. involuta*, however, he figured only a single specimen (BM C.8046 from Market Rasen), which is therefore holotype. It is a wholly septate nucleus, maximum diameter only 24 mm., and on comparing the actual specimen with the type of *R. involuta* (which is broken and shows the inner whorls well) at similar diameters, it is hard to detect even the minutest differences between them. Whatever else Spath may have had in mind, *R. involuta* and *R. evoluta* as defined by the monotypes are the same, and the latter name may be dropped with little regret.

Subgenus RASENIOIDES Schindewolf (= PRORASENIOIDES Schindewolf)

1. *Rasenia* (*Rasenioides*) cf. *transitoria* (Schindewolf)

Plate 33, fig. 2

Ammonites striolaris Quenstedt 1888 pars, pl. 107, figs. 12, 13.
Prorasenioides transitorius Schindewolf 1925, p. 338.

Material. One (MS 80a).

Description. The specimen is crushed, but agrees well with Quenstedt's figures. The ribbing passes uninterruptedly over the venter where visible. Sutures and peristome are missing, but at the maximum diameter of 32 mm. at least some of the outer whorl appears to be body-chamber. The umbilical seam uncoils slightly near the end, indicating maturity.

2. *Rasenia* (*Rasenioides*) cf. and aff. *lepidula* (Oppel)

Plate 32, figs. 19–21

cf. *Ammonites lepidulus* Oppel 1863, p. 242, pl. 67, fig. 4*a*, *b*.

Material. Five, more or less fragmentary (MS 1, 33–35, 53).

Description and comparisons. Oppel's figured type specimen was wholly inadequate to form the basis of a new species, only the final quarter-whorl being recognizable. Fortunately, this shows the specimen to have been a complete adult, and the name is used here for forms of the *R. thermarum* group which are rather larger and more evolute than *R. thermarum*, and in which the secondary ribs cross the round venter with perhaps some weakening but without actual interruption.

Agreement is best between Oppel's figure and the terminal fragment shown in Plate 32, fig. 21. This shows the peristome: the aperture is sinuous, preceded by a broad, shallow constriction and provided with a raised collar, as in *R. thermarum*, with no lappets; whereas Oppel's specimen was armed with lappets.

Oppel's species is very close to *Rasenia eulepida* Schneid (see below). This, however, has a prominent smooth band on the venter (*teste* Dr. Ziegler), but whether this serves to distinguish it from *R. lepidula* it is impossible to say in the absence of more information on the inner whorls of the latter. Schneid also stated that the distinguishing feature of *R. lepidula* was the persistence of the characteristic sheaves of multiple secondaries arising from each primary rib right to the end, whereas in *R. eulepida* near the aperture the ribbing reverts to simple bi- or triplication.

3. *Rasenia* (*Rasenioides*) *thermarum* (Oppel)

Plate 32, figs. 13–18

Ammonites thermarum Oppel 1863, p. 243, pl. 65, fig. 5*a*, *b*.
Rasenia (*Semirasenia*) *thermarum* Geyer 1961, p. 106, pl. 8, fig. 9, (? 10).

Material. Eight, and fragments (MS 9, 14, 31–32, 36, 64, 78, 118; R 20).

Description. All of the specimens seem to carry some body-chamber, and in one (Pl. 32, fig. 14) the peristome is preserved on one side. The impression that they are fully grown and nearly complete is supported by lack of remains of similar shells of larger ammonites. The average size of the eight specimens is 19·5 mm.: Oppel's holotype is 20 mm. in diameter, with nearly complete body-chamber, and he says: 'All the specimens found so far possess a nearly complete body-chamber. The partly visible peristome appears to be straight, without showing the formation of lappets.' The peristome observed here is also without lappet, but is sinuous and bears a slightly raised collar; it is preceded by a broad shallow constriction.

The Lincolnshire material therefore agrees well with Oppel's specimens and differs only in being slightly less inflated than the holotype. On some specimens the secondaries weaken on the venter, which is round, but they are not fully interrupted. Geyer considers *R. thermarum* to be a somewhat larger species, up to 40 mm. in diameter, effectively reinterpreting it on the basis of a specimen previously figured by de Loriol (1878, pl. xiii, fig. 5), which is variocostate like *Aulacostephanus möschi*. The total material available to him was only three specimens, however, including the holotype; and as there is no reason to believe that the holotype is in any way imperfect, incomplete, or untypical, but in fact representative of a readily recognizable group as shown by the Lincolnshire material, we prefer to continue to interpret *R. thermarum* as closely defined by Oppel's type, and retain it in *Rasenioides*.

4. *Rasenia* (*Rasenioides*) cf. *striolaris* (Reinecke)

Plate 31, figs. 6*a*, *b*

Nautilus striolaris Reinecke 1818, p. 77, figs. 52, 53.
cf. *Rasenia* (*Rasenioides*) *striolaris* Geyer 1961, p. 10.

Material. Two (MS 29, figured; MS 141).

Description. The figured specimen is only 16·5 mm. in diameter but carries half a whorl body-chamber. The umbilicus is only some 20 per cent. of the diameter, and inner whorls are almost wholly concealed. The second specimen is crushed, but similar.

Reinecke did not state the magnification of his figure, and his specimen seems to be lost. The present material agrees well with it, if we assume that his figure was about natural size. Geyer has designated and figured a neotype (1961, pl. 21, fig. 3) without, however, an adequate description. Thus, there is no mention of whether it, or supporting material, carries any body-chamber; there is no ventral view; and no indication of the form of the peristome. Moreover, the specimen differs considerably from Reinecke's figure in being much more evolute with very little inclusion of inner whorls, quite unlike both Reinecke's side-view and section.

Subgenus ZONOVIA Sasonov 1960

1. *Rasenia* (*Zonovia*) sp. ind.

Plate 33, fig. 3*a*, *b*

Material. One fragment (R 2).

Description. The specimen consists only of a quarter of two contiguous wholly septate whorls, corresponding to a diameter of about 45 mm. The whorl-section is round, inflated, depressed; the ribbing blunt, subdued, coarse. Short, straight bullate primaries trifurcate into strong secondaries, which cross the venter with sight weakening but no interruption.

Genus AULACOSTEPHANUS Sutner and Pompeckj in Tornquist 1896

Type species. Ammonites mutabilis d'Orbigny non Sowerby = *Ammonites pseudomutabilis* de Loriol 1874, designated by ICZN Opinion 302. A lectotype from the d'Orbigny collection has been figured by Ziegler (1962, pl. 15, fig. 8).

The boundary between *Rasenia* and *Aulacostephanus* is here being drawn such that most forms assigned to the latter have a smooth band on the venter in at least one stage of their ontogeny. Simultaneously, the whorl-section becomes more compressed and quadrate, the venter tending to flatten; and inner whorls are markedly more evolute and serpenticone than in *Rasenia* so that the secondary ribs on them are often partly exposed. The umbilici are in consequence also usually shallow, with often characteristically smooth, gently sloping or even barely perceptible walls. These features together allow a fairly sharp line to be drawn between the two genera.

The material from Lincolnshire falls into four subgenera: two pairs each consisting of a microconch and a macroconch. One of these pairs of subgenera, *Aulacostephanites* and *Aulacostephanoides*, differs but little from *Rasenia* and includes the forms well known from the Mutabilis Zone elsewhere. The other pair of subgenera, *Xenostephanoides* and *Xenostephanus*, is new. A few specimens have been known previously, but the presence of a considerable number in the material under consideration gives it a peculiar stamp of great interest.

Microconchs

1. AULACOSTEPHANITES Ziegler 1962. Type species: *Rasenia eulepida* Schneid 1939, p. 146, pl. v, figs. 13, 13*a*. Small, evolute forms with lappets; ornament similar to that of *Rasenioides*. Smooth band on venter, at least on inner whorls. In crushed material from the typical Mutabilis Zone shales in the south of England *Rasenioides* and *Aulacostephanites* may be indistinguishable.

2. XENOSTEPHANOIDES subgen. nov. Type species: *Aulacostephanus* (*Xenostephanoides*) *thurrelli* sp. nov. (see below). Small species (*c.* 40–50 mm.); coiling evolute, particularly on inner whorls; whorl-section rounded quadrate. Ribbing strong; short bullate primaries with sheaves of strong, straight secondaries often separated from the primaries by a smooth band on the whorl-side. The style of the ribbing is already much more like the 'hoplitid' of the later aulacostephanoids than the sinuous one of the rasenids. On the final body-chamber it may revert to simple biplication, as in *Prorasenia*. The

venter carries a smooth band, sometimes accentuated by a groove. Peristomes with oblique final constrictions and short lateral projections not really long enough to call lappets.

Macroconchs

3. AULACOSTEPHANOIDES Schindewolf 1925. Type species, by original designation: *Amm. desmonotus* Oppel. The type specimen of Oppel's species (1863, p. 241, pl. 67, fig. 1*a*, *b*) seems to have been lost during the war. His figure establishes the style of ribbing, coiling, and umbilicus well, and shows clearly a smooth band on the venter. Oppel stated, however, that no sutures were visible anywhere, and that the peristome was unknown; and it is therefore impossible to say whether the specimen (the only one known to Oppel) was fully grown and complete, or merely the nucleus of a much larger form. This makes the species a highly unsuitable one on which to found a genus, and interpretations have been correspondingly varied. Dr. Ziegler has redescribed the species on the basis of additional material. Among this is one specimen (Ziegler 1962, pl. 2, fig. 14) which resembles the lost holotype extraordinarily closely, with unfortunately the same shortcomings. Others lead from this to more or less complete adults, which are large and nearly smooth with simple peristomes. We follow this interpretation of *A. desmonotus*, which is thus a macroconch.

The subgeneric characters of *Aulacostephanoides* are therefore: macroconch; rasenid ornamentation on the inner whorls which fades, becoming smooth on the final body-chamber; ventral smooth band on at least the inner whorls; simple peristomes. From general experience involuteness of coiling seems of lesser importance, and Dr. Ziegler shows that *Aulacostephanoides* can usefully accommodate a gradation of forms ranging from the discoidal *A. linealis* (Quenstedt) to the true evolute *A. mutabilis* (Sowerby). Several species of the subgenus differ but little from forms still included in *Rasenia*, the dividing-line from which is arbitrary, as discussed above.

4. XENOSTEPHANUS subgen. nov. Type species: *Aulacostephanus* (*Xenostephanus*) *ranbyensis* sp. nov. (see below). Large species (*c.* 120 mm.); coiling stout, depressed, and evolute—particularly on the inner whorls. Primary and secondary ribbing well differentiated on inner and middle whorls, the former tending to extreme bullae or tubercles on the umbilical margin, the latter characteristically strong, triplicate, with intercalatories, fusing into the primaries or sometimes separated from them by a narrow smooth band on the whorl sides. Venter flat on inner whorls, with smooth band, sometimes accentuated by a groove. On the body-chamber the ribbing becomes subdued and degenerates to more perisphinctid form: primary ribs biplicate smoothly or become merely single widely spaced ridges. The whorl-section becomes round, and ribbing passes over the venter without interruption. Peristomes simple.

Inner and intermediate whorls in some species are almost fully homeomorphic with the quite unrelated earlier genus *Reineckeia*; outer whorls are as in *Rasenia* (*Zonovia*), especially *R. uralensis* (d'Orbigny).

Xenostephanus and *Xenostephanoides* form a typical macroconch and microconch pair, and it would be difficult to find a clearer demonstration of the dimorphism among the perisphinctids. The inner whorls are so similar that it would be hard to sort them out in immature, incomplete, or fragmentary material.

Subgenus AULACOSTEPHANITES Ziegler 1962

1. *Aulacostephanus* (*Aulacostephanites*) cf. *eulepidus* (Schneid)

Plate 32, figs. 1–8

Rasenia eulepida Schneid 1939, p. 146, pl. v, figs. 13, 13*a*.
Aulacostephanus (*Aulacostephanites*) *eulepidus* Ziegler 1962, p. 44, pl. 341, figs. 2–7, 8 *partim*, ? 11, 14.

Material. Twenty-five (24 from MS; and R 5), and fragments.

Description and remarks. The Lincolnshire material seems to be consistently somewhat smaller than the type (33 mm.), for the average diameter of seventeen complete adults is 25 mm. (standard deviation 3·9 mm. = 15·5 per cent.). The style of ribbing, however, is the same, including the degeneration of the ribbing near the end, which Schneid cited as diagnostic compared with *Am. lepidulus* Oppel. Peristomes are preserved in several specimens. There is usually a slight terminal constriction and a raised mouth-border. Lateral extensions may be short (Pl. 32, figs. 3, 5), or long enough to qualify as lappets (figs. 2, 10). Smooth bands on the venters are generally present, but narrow and inconspicuous, and they die out on the last half-whorl of body-chamber.

The question of the generic position of the specimens here described raises in its most acute form the difficulty attending attempts to divide *Aulacostephanus* from *Rasenia*. The ventral smooth band is undoubtedly much less prominent here than in the type of *A. eulepidus* and other south German material, and the Lincolnshire forms might, on this account, rest more comfortably in *Rasenia* (*Rasenioides*), with possibly gradations to *R. thermarum* (Oppel). On the other hand, the style of coiling and ribbing resembles *A. eulepidus* much more closely than *R. thermarum* or any other *Rasenioides* so far described (with the possible exception of *R. lepidula* (Oppel), which we exclude from consideration because of the imperfection of the type); and there is gradation to the forms described as *A. ebrayoides* below, which have quite prominent smooth bands on the venter.

It seems therefore that we are here sampling the *Rasenia–Aulacostephanus* boundary at a slightly different stage from that observed in central Europe. There the distinction between *Rasenioides thermarum* and *Aulacostephanus eulepidus* is clear, and the latter grades into more coarsely ribbed forms which nevertheless retain the rasenid (fasciculate) style of secondary ribbing, and which Ziegler designates *A. peregrinus* nov. In contrast, these forms appear to be absent in the Lincolnshire material, which, instead, shows more or less gradation from *A. ebrayoides* (unknown in central Europe), via *A. eulepidus*, to *R. thermarum*. Whether these differences reflect slight differences in ages, or ecological factors (geographic subspeciation), it is at present hard to say.

A. eulepidus is also found in the Mutabilis Zone of Mull (cf. Pl. 33, figs. 4–6).

2. *Aulacostephanus* (*Aulacostephanites*) *ebrayoides* sp. nov.

Plate 30, figs. 14–18

Material. Nine (eight from MS, and R 16), and fragments.

Description. The holotype, MS 5 (Pl. 30, fig. 14) is 26 mm. in diameter, with half-whorl body-chamber preserved. The remaining material is of similar size. Coiling is evolute, the whorl-section quadrate. Ribbing is dense, but strong and sharp, straight, triplicate

or biplicate with intercalatories; the furcation point is very low on the whorl-side, so that the primaries (about twenty-two on the outer whorl) are reduced to short ridges on the umbilical margins. There is a distinct smooth band on the venter on inner whorls, fading somewhat on the body-chamber.

Comparisons. The species differs from *A. eulepidus* through the reduced contrast between primary and secondary ribbing, and the straightness and coarseness of the latter. Its name reflects the close homeomorphism with the Bathonian genus *Ebrayiceras* Buckman (Morphoceratidae), e.g. *E. pseudo-anceps* (Ebray) (see Arkell 1955, pl. xvii, figs. 7–11).

There are occasional specimens with more flexuous, but still coarse, secondary ribbing (Pl. 32, figs. 9, 10, with short lappets), which may link *A. ebrayoides* with *A. eulepidus*. These coarse forms of *Aulacostephanites* occur also in Mull (Pl. 33, fig. 7).

Quenstedt's *Amm.* cf. *striolaris* pars, 1888, pl. 107, fig. 18 seems to resemble *A. ebrayoides* closely in its ribbing, but differs in having a much more prominent ventral smooth band, and a deep terminal constriction (which may, however, have only varietal significance.)

3. *Aulacostephanus* (*Aulacostephanites*) sp. aff. *desmonotus* (Oppel)

Plate 32, figs. 11, 12

cf. *Ammonites desmonotus* Oppel 1863, p. 241, pl. 67, figs. 1*a*, *b*.

Material. Three (MS 76, 115; R 17).

Description and comparisons. All three specimens attain between 20 and 23 mm. and appear to carry some body-chamber. They resemble the other specimens described here under *Rasenia thermarum* in ornament, but are distinctly more compressed, have prominent ventral smooth bands and the characteristic shallow umbilicus of Oppel's *Amm. desmonotus*. The latter, however, probably attained a large size (see discussion above).

4. *Aulacostephanus* (*Aulacostephanites*) sp. aff. *möschi* (Oppel)

Plate 32, figs. 22–24

cf. *Ammonites möschi* Oppel 1863, p. 240, pl. 65, fig. 2*a*, *b*.
Ammonites cf. *striolaris* Quenstedt pars 1888, p. 969, pl. 107, fig. 17.

Material. Eleven (MS, ten; R 1), and fragments (MS).

Description and comparisons. These specimens are characterized by the absence of primary ribbing on the inner whorls, which carry only very dense, fine secondary ribbing. The whorl-section is compressed, umbilicus shallow, and there is a ventral smooth band. Agreement with Oppel's figure is fairly close, except that *A. möschi* shows no trace of a ventral smooth band, is bigger, and has the primary ribs, when they appear, lower on the whorl-side. The best agreement is with Quenstedt's specimen.

EXPLANATION OF PLATE 27

Fig. 1*a–c*, *Aulacostephanus* (*Xenostephanus*) *ranbyensis* sp. nov. var. *elshamensis* var. nov. Adult, with half a whorl body-chamber. BM C.47908, T. B. Parks coll., from Elsham, Lincs. All natural size.

Subgenus AULACOSTEPHANOIDES Schindewolf, emend. Ziegler

1. *Aulacostephanus* (*Aulacostephanoides*) *mutabilis* (J. de C. Sowerby)

Plate 31, fig. 3

Ammonites mutabilis J. de C. Sowerby 1823, **4**, p. 145, pl. 405, fig. 1.
Rasenia mutabilis Salfeld 1913, p. 129.
Pararasenia mutabilis Arkell 1933, p. 612, pl. xxxix, figs. 5, 5*a* (holotype refigured).
Rasenia mutabilis Arkell 1951, p. 188.
Aulacostephanus (*Aulacostephanoides*) *mutabilis* Ziegler 1962, p. 62, figures and plates.

Material. One (MS 80).

Description. The specimen, half an ammonite, is somewhat crushed; maximum diameter 175 mm., wholly septate, the last few septa approximated and degenerate. The complete shell must have attained some 210 mm. Inner whorls are evolute; the whorl-section is at all stages compressed with barely perceptible umbilical walls. Well-differentiated, fine, dense, secondary ribbing is visible to at least 60 mm. with occasional feeble constrictions and flared ribs; primary ribs persist to 90 mm. Thereafter the shell is wholly smooth. Venter on inner whorls not visible.

Remarks. There has been confusion in the past in interpreting this species, largely as a result of Sowerby's poor illustration. The holotype (BM 43934) has a maximum diameter of 71 mm. and is wholly septate, with none of the degeneration and approximation of the last sutures rather typical of adults of this species. Despite the sudden end of primary ribbing at a shallow constriction at 52 mm., it seems certain that the holotype is the inner part of what was a much larger shell. The secondary ribbing on the venter is interrupted by a distinct smooth band. The whorl-section is compressed and angular. All these points are exemplified in another specimen figured here (Pl. 31, fig. 3, from Cambridgeshire) which resembles the holotype very closely, and is also wholly septate to 105 mm. It also shows something of the inner whorls, invisible in the holotype, which are evolute, exposed, and densely ribbed.

As for the generic position of the species, the style of ribbing on middle whorls is that of *Rasenia*; but the compressed whorl-section, evolute inner whorls, shallow umbilical walls, and ventral smooth band place it firmly in *Aulacostephanus*. [This view is contrary to that expressed previously by Dr. Arkell (1951, p. 188); but on re-examining both the holotype and supporting material, and in the light of Dr. Ziegler's study of the whole genus *Aulacostephanus* it seems the only possible one. J. H. C.]

2. *Aulacostephanus* (*Aulacostephanoides*) sp. nov.?, aff. *mutabilis* (Sowerby)

Plate 31, figs. 1, 2

Material. Two, and fragments (MS 37, 102; R 5).

Description. This species resembles *A. mutabilis* in all respects, but seems to be much smaller. Thus the specimen figured in Plate 31, fig. 1 is apparently adult, and complete with peristome at the same size (110 mm.) at which *A. mutabilis* itself (Pl. 31, fig. 3) is still septate. The same specimen is rather more evolute than *A. mutabilis*, and all ribbing has disappeared at 60 mm. The specimen shown in Plate 31, fig. 2 has inner whorls which are evolute and densely ribbed as in *A. mutabilis*; likewise the imprint of the flat

venter of the penultimate whorls in the outer (body-chamber) whorls shows the secondary ribbing to be dense, with occasional feeble constrictions and slightly flared ribs, and interrupted by a smooth band.

Similarly, small forms (for macroconchs) are known from the Kimeridge Clay of Cromarty (Scotland). They are to be described by Dr. Ziegler, who proposes the name *R. askepta* for them. They differ from those described here, however, in having oval whorl-section, involute inner whorls, and secondary ribbing uninterrupted on the venter, i.e. belong still to *Rasenia*. Their precise age is not known.

3. *Aulacostephanus* (*Aulacostephanoides*) *circumplicatus* (Quenstedt)

Plate 31, figs. 4, 5; Plate 33, figs. 9–11

Ammonites circumplicatus Quenstedt 1888, p. 978, pl. 107, fig. 19.
Ammonites cf. *trifurcatus* Quenstedt 1888, p. 971, pl. 107, fig. 21.
Tobolia pseudotrifurcata Sasonov 1960, p. 156, pl. v, fig. 4 (= nom. nov. for, and reproduction of original figure of *Amm.* cf. *trifurcatus* Quenstedt, cited above).

Material. One, and two fragments (MS 51, 120; R 19).

Description. The specimen shown in Plate 31, fig. 4 is septate to only 55 mm., and if adult, could not have exceeded 80 mm. complete. The whorl-section is slightly compressed, and in both figured specimens the secondary ribbing is weakened over the venter, but not actually interrupted.

Remarks and comparisons. The present material agrees with *A. circumplicatus* in size and style of ribbing; but the holotype has an exceptionally prominent and broad smooth ventral band. This is, however, in part due to a deformity, and, according to Dr. Ziegler, the ventral smooth band is unusually variable in the species, some specimens being practically without.

There is a considerable resemblance to *Rasenia gemmata* Schneid (1939, p. 147, pl. v (ix), figs. 9, 9*a*), which, however, differs in being inflated, with depressed whorl-section, and is more involute.

The species is common in the Kimeridgian exposure on Mull (Pl. 33, figs. 9–11), and some of the specimens have a clearly defined ventral smooth band.

Subgenus XENOSTEPHANOIDES nov.

1. *Aulacostephanus* (*Xenostephanoides*) *thurrelli* sp. nov.

Plate 30, figs. 1–3

Material. Eight, and fragments (R, five; MS, two; SW, eleven).

Description. The holotype (R 11; Pl. 30, fig. 1) is 44 mm. in diameter; septate to 40 mm.,

EXPLANATION OF PLATE 28

Fig. 1*a–e*, *Aulacostephanus* (*Xenostephanus*) *ranbyensis* sp. nov. Holotype; adult, with five-eighth whorl body-chamber preserved (1*a*). Suture-line at *s* shown in fig. 1*e*, × 2. Thurrell coll. R 6, from Ranby, Lincs.

Fig. 2, *Aulacostephanus* (*Xenostephanus*) cf. *ranbyensis* sp. nov. Body-chamber fragment, showing the peristome. Thurrell coll. SW 23, from South Willingham, Lincs.

All natural size, except fig. 1*e*.

with a quarter-whorl body-chamber preserved. The last three septa are approximated, with some degeneration. The coiling is extremely evolute, and the dimensions (between and through ribs or tubercles) at 45 mm. are: 24·5–26·5, 25·5–31, 49. Primary ribs are in the form of tubercles on the umbilical margin (20 per whorl at 45 mm.; 21 at 30 mm.); secondaries are trifid or bifid with frequent intercalatories, separated from the primaries by a nearly smooth lateral spiral band. On the last half-whorl, the secondaries revert to widely spaced, very coarse bifid without intercalatories indicating, together with septal approximation, that the specimen was adult. The secondary ribbing is extremely strong and coarse, resembling that of *A. undorae* (Pavlow) of the Eudoxus Zone, but is quite different on the venter. In *A. thurrelli* it is interrupted by a deep narrow smooth band, accentuated by a groove, with no tendency to form ventro-lateral tubercles.

The paratype R 25 (Pl. 30, fig. 2) resembles the holotype closely. It is septate to only 34 mm., but shows the complete body-chamber of five-eighth whorl with peristome at 50 mm. The ribbing reverts to strictly biplicate on the last quarter whorl; an oblique constriction follows an isolated triplicate rib. The lip of the aperture is flared into a collar on the venter, and has a slight lateral projection too short to be called a lappet proper.

Presumed inner whorls are shown in Plate 30, fig. 3, although no septa are visible.

The species or a close ally seems to be present in the Kimeridgian of Mull (cf. Pl. 33, fig. 8) to judge by inner whorls; but the imprint of the outer whorls is too badly distorted to be certain. There is also a specimen from the Cromarty coast (Royal Scottish Museum, Edinburgh, Hugh Miller coll.).

2. *Aulacostephanus* (*Xenostephanoides*) *lindensis* sp. nov.

Plate 30, figs. 4–13

Derivation. Lindum is the Roman name for Lincoln.

Material. Twenty-seven (SW, twenty-one; R, three; MS, four), and fragments.

Description. The material is plentiful but poorly preserved, and no single specimen is complete. It is with some hesitation, therefore, that we select the specimen MS 13 (Pl. 30, fig. 10) only formally as holotype and designate the other nine figured specimens (Pl. 30, figs. 4–9, 11–13) paratypes, although for purposes of description it would be best to regard all ten as syntypes.

Sutures are rarely visible, but from the difference in preservation between outer and inner whorls (which are usually flattened) it seems probable that most of the specimens carry some body-chamber. The holotype itself definitely does, and was presumably complete at about 30 mm. diameter. Another fragment (SW 59) shows the final peristome with oblique constriction, flared collar, and short incipient lappet (just as in *A. thurrelli*) at a final diameter of *c.* 40 mm. The species is thus small.

The coiling is moderately involute, the whorl-section stouter than in *A. thurrelli*. Ribbing is dense and moderately strong, with three, sometimes four, secondaries per primary, separated, as in *A. thurrelli*, by a lateral smooth band. The venter is flat, broad, with a narrow smooth band but no groove. Inner whorls are shown in Plate 30, fig. 13.

Comparison. The species most closely resembles *Aulacostephanus thurrelli* although the stouter, more involute coiling and finer ribbing appear to be consistently distinct. It stands, like *A. thurrelli*, apart from all other contemporaneous aulacostephanids; but,

in its resemblance to some later forms of the *A. eudoxus* group, it heralds the future development of the genus.

A. lindensis has also been found in the drift of Norfolk (SM J48657, one specimen, Baden-Powell coll.).

For completeness it is convenient to mention here another form which belongs to this group.

3. *Aulacostephanus* (*Xenostephanoides*) *scoticus* nom. nov. = *Aulacostephanus* cf. *autissiodorensis* (Cotteau) Spath 1935, p. 49, pl. 13, figs. 8*a*, *b* (BM C13216)

Remarks. The specimen figured by Spath from Culgower, eastern Scotland, seems unique. It carries some body-chamber on which the otherwise trifid ribbing reverts to biplication, indicating maturity, as in *A. thurrelli*; *A. scoticus* is therefore a small species and not a young specimen of giant forms like *Rasenia borealis* Spath, as Spath supposed. Its evoluteness and style of ribbing, particularly on the inner whorls, are typical of *Xenostephanoides*. It differs from *A.* (*X.*) *thurrelli* principally in having rather more inflated inner whorls, about nine more ribs per whorl, and a less-pronounced ventral smooth band, the ventral ribbing on the inner whorls being weakened without actual interruption. The exact horizon is unknown, although there are other Mutabilis Zone faunas from the same area.

Subgenus XENOSTEPHANUS nov.

1. *Aulacostephanus* (*Xenostephanus*) *ranbyensis* sp. nov.

Plate 28, figs. 1*a–e*, 2; Plate 29, fig. 4

Material. Two (R 6; BM C.47909), and fragments (SW).

Description. The holotype (R 6) is a splendidly preserved internal cast of 120 mm. maximum diameter, septate to 81 mm., with the last three sutures approximated and simplified. The body-chamber is broken, but, to judge from the highly degenerate last few visible ribs, represented very nearly up to the peristome and hence occupying five-eighths of a whorl.

Dimensions: at 115 mm.: 23, *c.* 26, 48.
80 mm.: 25–27, 30–33, 54.
55 mm.: 25–27, 29–31, 55.
Ribs: at 40–50 mm.: 19 per whorl; 70–90 mm.: 22; 115 mm.: *c.* 25.

EXPLANATION OF PLATE 29

Fig. 1*a*, *b*, *Aulacostephanus* (*Xenostephanus*) *anceps* sp. nov. Holotype; adult, with one-quarter whorl body-chamber preserved, and umbilical suture indicating former extent to five-eighths of a whorl. BM 50761, old collection, no history.

Fig. 2*a*, *b*, *Aulacostephanus* (*Xenostephanus*) *staintonensis* sp. nov. Syntype I; the cross marks what appears to be the last septum. Thurrell coll. MS 142, from Market Stainton, Lincs.

Fig. 3, *Aulacostephanus* (*Xenostephanus*) *staintonensis* sp. nov. Syntype II; wholly septate, last few septa approximated. SW 2/35, from South Willingham, Lincs.

Fig. 4, *Aulacostephanus* (*Xenostephanus*) cf. *ranbyensis* sp. nov. Fragment at commencement of the body-chamber. SW 34.

All natural size.

In the umbilicus nothing is visible before a diameter of 20 mm. Thereafter the primary ribbing consists of conspicuous dorsolateral tubercles, only slightly bullate, and separated from the strong rectiradiate ribs that spring from them by a lateral smooth band. The ribs are bifid with regular intercalatories, which, on the last septate whorl, tend to join up to form trifid bundles, while fresh intercalatories come in. On the body-chamber the ribbing weakens, the primaries degenerate to bullae and triplicate, finally biplicate, ribs. The last few ribs are single, coarse and irregular, indicating the end of growth. The peristome is not preserved. The venter, where it emerges, has a groove, but no tubercles. The groove fades to a mere smooth band before septation ceases, this coming about as the ribbing loses relief, and persists to the end even when the ventral ribbing is barely perceptible. The whorl-section on inner whorls is quadrate, angular, and becomes rounded towards the end. The suture-line is a typically perisphinctid one, with slender widely spaced lobes on a straight base-line.

The peristome is preserved on another fragment (Pl. 28, fig. 2). It is straight and simple, with slight forward sweep at the umbilical seam.

There is another specimen in the British Museum (C47909, T. B. Parks coll., from Elsham, Lincs., only 72 mm. in diameter, wholly septate, somewhat crushed, which agrees with the holotype in all details, including matrix. The species has also been found in the drift of Norfolk (SM J48657, Baden-Powell coll., one specimen).

Remarks. Inner whorls are practically indistinguishable from *A.* (*X.*) *thurrelli*, and, as remarked previously, it would be hard to find a clearer demonstration of ammonoid dimorphism. Also remarkable is the close homeomorphism between *Xenostephanus* and *Reineckeia* s.s. of the Callovian, yet another instance showing the tendency of ammonites to evolve repeatedly through similar forms.

1a. *A.* (*X.*) *ranbyensis* var. *elshamensis* var. nov.

Plate 27, fig. 1*a–c*

Material. One (BM C.47908, T. B. Parks coll., from Elsham, N. Lincs.).

Description. Size *c.* 130 mm. (slight distortion), septate to 103 mm. with approximation and degeneration, half a whorl of body-chamber preserved with indications of former extent to three-quarters of a whorl, so that the maximum size of the complete shell must have been 150 mm.

Dimensions: at 100 mm.: 25, 29–34, 57.
Ribs: at 130 mm.: 25 per whorl; 120: 23; 100: 22; 80: 20; 60: 19; 40: 19; 30: 20.

The primary ribs are bullate, triplicate with low furcation point up to 80 mm.; they then revert to biplicate, perisphinctid ridges to 120 mm., and single simple ribs thereafter. The secondaries are strong, in regular triplicate sheaves, to about 80 mm., then rapidly weaken and become biplicate at high furcation points, and finally fade altogether. They show some weakening in the middle of the venter where first visible, although there is no fully smooth band, and after about 90 mm. pass over the venter with no interruption.

Comparison. Agreement with the holotype of *A. ranbyensis* is close in proportions and rib-count. The variety differs in becoming bigger, with a more inflated body-chamber,

and having less differentiation between primary and secondary ribbing so that a lateral smooth band is present only on the innermost whorls.

2. *Aulacostephanus* (*Xenostephanus*) *staintonensis* sp. nov.

Plate 29, figs. 2, 3

Material. Two (MS 142, SW 2), and fragments (SW).

Description. Neither specimen is really sufficiently complete to serve as sole basis of the species, and the two figured specimens are syntypes.

Syntype I (Pl. 29, fig. 2): maximum diameter 57 mm., apparently septate to only 35 mm. with five-eighths whorl body-chamber. Neither ribbing nor coiling, where last visible, show any signs of modification whatever, and the specimen seems to be genuinely immature.

Dimensions: at 55 mm.: 32, *c.* 33, 45.
Ribs: at 60 mm.: 22 per whorl; 50: 21; 40–20: 20.

Inner whorls evolute, becoming more inflated. Primary ribs moderately bullate, trifid on inner whorls, changing to regular triplicate. Strong secondaries with ventral smooth band, fading at the end.

Syntype II (Pl. 29, fig. 3): maximum diameter 115 mm., wholly septate (details of sutures invisible), flattened through crushing.

Ribs: at 115 mm.: *c.* 30 per whorl; 70: *c.* 27 (counts based on half-whorls).

Ribs on inner whorls triplicate or biplicate with intercalatories; sharp bullate primaries, no lateral smooth band; ventral smooth band. Ribbing has started to modify a 90 mm. to perisphinctid style; and at 115 mm. only straight primaries of low relief remain. The ventral smooth band persists until the entire venter is smooth.

Comparisons. The species differs from *A. ranbyensis* in being markedly more densely ribbed and involute. The primary and secondary ribbing are less well differentiated, so that there is no lateral smooth band even on inner whorls, which are less openly exposed. In this sense the species stands in the same relation to *A. ranbyensis* as *A. lindensis*

EXPLANATION OF PLATE 30

Figs. 1–3, *Aulacostephanus* (*Xenostephanoides*) *thurrelli* sp. nov. 1*a*, *b*, Holotype; adult, with one-quarter whorl body-chamber preserved. Thurrell coll. R 11, from Ranby, Lincs. 2*a*, *b*, Fragmentary but complete adult, with peristome showing slight lappet. R 19/25. 3*a*, *b*, Inner whorls, no sutures visible. SW 39.

Figs. 4–13, *Aulacostephanus* (*Xenostephanoides*) *lindensis* sp. nov. 4, SW 31, no sutures visible but probably one-half whorl body-chamber. 5, SW 29, last third whorl body-chamber. 6*a*, *b*, SW 33, no sutures visible, but probably at least one-half whorl body-chamber. 7, SW 26, ditto. 8*a*, *b*, SW 60, ditto. 9*a*, *b*, SW 9, ditto. 10*a*, *b*, Holotype, MS 13, seven-tenths whorl body-chamber. 11, SW 53, remarks as 6. 12*a*, *b*, MS 38, ditto. 13*a*, *b*, MS 18, wholly septate. All Thurrell coll.

Figs. 14–18, *Aulacostephanus* (*Aulacostephanites*) *ebrayoides* sp. nov. 14, Holotype; last half whorl body-chamber; MS 5. 15, MS 56, half whorl body-chamber. 16*a–c*, MS 57, ditto. 17*a–c*, MS 45, eight-tenths whorl body-chamber. 18*a–c*, MS 71, six-tenths whorl body-chamber; perhaps transitional to *A.* (*A.*) *eulepidus* (Schneid). All Thurrell coll.

All natural size.

stands to *A. thurrelli*. An example of this species has also been found in the drift of Norfolk (SM J48658, a double mould, Baden-Powell coll.).

3. *Aulacostephanus* (*Xenostephanus*) *anceps* sp. nov.

Plate 29, fig. 1

Material. One (the holotype, BM no. 50761).

Description. Maximum size 95 mm., septate to 85 mm. with severe approximation and degeneration of the last (and only visible) sutures, and a quarter whorl body-chamber. The umbilical suture indicates a former extent of the final body-chamber to five-eighths whorl, so that the complete shell attained a maximum diameter of *c.* 110 mm.

Dimensions: at 90 mm.: 27, 29–33, 51 (cast).
at 75 mm.: 27, 36–43, 52 (test).
Ribs: at 100–80 mm.: 21 per whorl; 60–50: 20; 40: 19; 30–20: 18.

This is the most inflated of the species described here, with a whorl-section at 75 mm. depressed almost to the point of being coronate. In contrast, the body-chamber contracts and reverts to normal perisphinctid dimensions. Similarly, the ribbing, which is characterized by very high, sharp bullate primaries on the umbilico-lateral margin giving rise to regular sheaves of very coarse triplicate secondaries, modifies to rather widely spaced and in part biplicate ribs of low relief on the body-chamber. The secondaries show only the faintest weakening on the round venter where first visible (at 60 mm.); they smooth out altogether on the body-chamber.

Affinities and remarks. A. anceps bears undeniably close resemblance to various species of *Rasenia* from the Cymodoce Zone of Market Rasen, including *R. uralensis* (d'Orb.), and, in the absence of a ventral smooth band, to place it in any but this genus might seem unnatural. Its inner whorls, however, are quite different: evolute, with flat whorl sides and the differentiation, with lateral smooth band, of primary and secondary ribbing characteristic of *Xenostephanus*. The aulacostephanid characters of angular whorl-section and ventral smooth band seem here to make their first appearance in *Xenostephanus* proterogenetically.

The specimen has the test preserved on all but the last half whorl, and it is therefore conceivable that an internal cast might show a ventral smooth band not visible on the outside; and that the difference in this respect between *A.* (*X.*) *anceps* and the other forms of *Xenostephanus* described here, mostly casts, might only be apparent and attributable to differences of preservation. This seems unlikely, however, for a specimen of *A.* (*X.*) *ranbyensis* from Norfolk (SM J48657) shows the same ventral smooth band on both internal cast and external mould of the same part of the body-chamber at 60 mm. diameter.

The holotype was presented to the British Museum by Prof. J. Morris in 1867; there is no other recorded history. Its preservation and matrix are, however, so precisely similar to the other material here described that there can be little doubt that it came from a similar source. It seems to have been one of the specimens which Salfeld included in his MS species *evoluta*; but its inner whorls are quite different from those of the specimen Spath selected as type for his species (see above). Besides oysters, the matrix carries an imprint of *Rasenia* cf. *thermarum* (Oppel).

Xenostephanus seems to occur in the Kimeridgian of Skye. A single specimen of *A.* (*X.*) cf. or aff. *anceps* (Pl. 33, fig. 1) was collected by Mr. W. G. Cordey at Kildorais, Trotternish, in the spring of 1961, and we thank him for presenting it to us. It is crushed, in clay, and encrusted with an oyster on the inner whorls. Neither septa nor venter are discernible, but the ornament is typically that of *Xenostephanus*, and enough is visible of the inner whorls to show that they are evolute just as in *A. anceps*. The Skye specimen differs in having rather fewer ribs on the middle and outer whorls: at 85 mm.: 17 per whorl; 70: 16; 50: 15; 30: *c.* 18. The specimen was unfortunately found without any supporting fauna.

For completeness, we include here:

4. *Aulacostephanus* (*? Xenostephanus*) sp. indet. = *Ammonites* cf. *trifurcatus* Quenstedt 1888, p. 971, pl. 107, fig. 24

Remarks: Quenstedt's figure shows an extremely evolute shell, maximum size *c.* 85 mm., with ornament typical of *Xenostephanus*: well-spaced bullate primary ribs leading to triplicate, strong secondaries with intercalatories. Unfortunately neither venter nor sutures are anywhere visible. At 85 mm. there are 18 ribs per whorl; at 60: 17; at 40: 15. The species differs from *A. ranbyensis* therefore in being less densely ribbed; also, in having the primaries half-way up the whorl-side rather than on the umbilico-lateral margin.

Nautilus trifurcatus Reinecke (1818, p. 75, pl. v, fig. 49) is quite different: inflated, involute, with barely bullate primary ribbing. Spath (1935, p. 49, footnote) thought Quenstedt's specimen belonged to *Rasenia evoluta* Salfeld MS, and in the sense that the specimen described above as *A.* (*X.*) *anceps* appears to have been a syntype of Salfeld's unpublished manuscript species he was probably correct. It is unfortunate that he chose to publish the name on the basis of only a small nucleus (see above).

If the above identification is correct, Quenstedt's specimen seems to be the only representative of these early aulacostephanitids so far known from more southerly regions. It was found in a volcanic erratic at Floriansberg, and ascribed to White Jura δ.

There are a number of other boreal forms intermediate between *Rasenia* and *Aulacostephanus* proper which, when more is known about them, may turn out to be closely related to *Xenostephanus*.

Aulacostephanus groenlandicus Ravn (1912, p. 492, pl. xxxvii, fig. 3*a–c*, from Koldewey Island, 76° N.; Frebold 1930, p. ix, fig. 4, from Spitsbergen) has the evolute coiling and indications of a ventral smooth band, but is densely ribbed and lacks the tuberculate

EXPLANATION OF PLATE 31

Figs. 1, 2, *Aulacostephanus* (*Aulacostephanoides*) sp. nov. ? aff. *mutabilis* (J. de C. Sowerby). 1, Complete adult, with seven-tenths whorl body-chamber, and peristome transposed unto the figured side (white dotted line) as it is developed on the reverse side. Thurrell coll. MS 37. 2, MS 102; the outer whorl is body-chamber.

Fig. 3, *Aulacostephanus* (*Aulacostephanoides*) *mutabilis* (J. de C. Sowerby). Wholly septate example, from a nodule-bed in Kimeridge Clay near Haddenham Station, Cambridgeshire. SM J.29157.

Figs. 4, 5, *Aulacostephanus* (*Aulacostephanoides*) *circumplicatus* (Quenstedt). 4, MS 120, with some body-chamber. 5*a*, *b*, MS 51b, outer whorl body-chamber.

Fig. 6*a*, *b*, *Rasenia* (*Rasenioides*) cf. *striolaris* (Reinecke). MS 29, with half whorl body-chamber.

All natural size.

primaries. Precise age unknown, but Kimeridgian of *mutabilis* age is known to be present in east Greenland (J. H. C. 1957).

Aulacostephanus Pischmae Khudyaev 1932 (p. 646, text-fig. 2, pl. 1 fig. 1, from Petchoraland) seems to be very close to *Xenostephanus*, if not actually to belong to it. Khudyaev's text-fig. 2 shows the whorl-section of inner whorls to be depressed with tuberculate or bullate ribbing of high relief, as in *A.* (*X.*) *anceps*. Unfortunately the plate shows only the outer whorl—body-chamber—which has perisphinctid bi- and triplicate ribbing with subtriangular, compressed whorl-section, and, in the absence of better material, affinity with *Xenostephanus* must remain in doubt. *A. pischmae* seems equally close to some of the large, coarsely, but bluntly, ribbed forms like *A. quenstedti* Durand, which Dr. Ziegler places in *Pararasenia* Spath.

A. pischmae is type species by monotypy of the genus *Sarygulia* Khudyaev, proposed in the legend of text-fig. 2 (p. 647) only. The type species comes from the Timan, Petchora, north Russia, whereas Sary-goul (Saragula) is in the southern Urals, where, to judge by Pavlow's plates (1886), the group does not occur. Possibly Khudyaev withdrew the name on account of this but forgot to remove it also from the underline of the text-figure. The original name is invalid, having been proposed after 1931 without diagnosis or citation of a type species. It has been revived by Sasonov (1960, p. 157), who has formally designated *A. pischmae* as type species. He figures no additional material, however, and so *Sarygulia* Sasonov 1960, though valid, will continue to be regarded here as synonymous with *Pararasenia* Spath, emend. Ziegler.

Pomerania ilovaiskyi Sasonov 1960 (p. 162, pl. 3, figs. 1, 1*a*, pl. iv, figs. 2, 2*a*, *b*). This species resembles *Xenostephanus* in having evolute inner whorls; a clear ventral smooth band without tubercles; in its size; and in the extreme degeneration of the ribbing on the body-chamber. It differs in being somewhat more compressed than any of the species here described, and much more densely ribbed: at 50 mm. it has twenty-six ribs per whorl. The primary ribs in consequence never attain the highly differentiated tuberculate character of those in, for example, *ranbyensis*, or even *A.* (*Xenostephanoides*) *scoticus*, which is similarly densely ribbed. There are also prominent constrictions which *Xenostephanoides* does not have. Sasonov's material came from the Sosva basin, on the eastern side of the northern Urals.

Family CARDIOCERATIDAE Siemiradzki 1891
Subfamily CARDIOCERATINAE Siemiradzki 1891
Genus AMOEBOCERAS Hyatt 1900

Type species. Ammonites alternans von Buch 1832.

Subgenus AMOEBITES Buckman 1925

Type species. Amoebites akanthophorus Buckman 1925.

1. *Amoeboceras* (*Amoebites*) cf. *kitchini* (Salfeld)

Plate 32, fig. 26*a*, *b*

Cardioceras Kitchini Salfeld 1913, p. 423.
Cardioceras Kitchini Salfeld 1914, p. 129.
Cardioceras Kitchini Salfeld 1915, p. 189, pl. xix, figs. 8–17; pl. xx, figs. 15, 16.
Amoeboceras (*Amoebites*) *kitchini* Spath 1935, pp. 30–31 (neotype designated); pl. 1, fig. 9*a*, *b*.

Amoeboceras (*Amoebites*) *kitchini* Waterston 1951, p. 42, pl. ii, fig. 4*a*, *b*.
Amoeboceras (*Amoebites*) aff. *rasenense* Waterston 1951, pl. ii, fig. 1.

Material. One (MS 48).

Description. The specimen is 29 mm. in diameter; septate to 20 mm., the last sutures show none of the degeneration or approximation otherwise almost invariably found in adults of the Cardioceratidae, so that the specimen seems to have been immature. It agrees well, as far as it goes, with the neotype (Salfeld 1915, pl. xx, fig. 16), although it does not, and could not at that size, show any of the looped ribbing or ventro-lateral clavi of the adult *A. kitchini*.

Remarks: Salfeld, in his English paper (Oct. 1913), based the species on a drawing in Woodward, 1895, but in his German paper (1914) he compared Woodward's figure with another in de Loriol (1876), which he queried in his monograph (1915). It is possible to interpret the species only as from the 1915 monograph, when photographs were published, including that of the Scottish neotype. Unfortunately, even the latter does not fix the species unambiguously, being itself incomplete and recognizable only up to 27 mm.; and both the neotype of *A. kitchini* and the specimen described here might be hard to distinguish from inner whorls of larger specimens differing in their outer whorls and described under various names, e.g. *A. akanthophorus* Buckman, *A. salfeldi* Spath (nom. nov. for *Card. pinguis* Salfeld pars, 1915 pl. xx, fig. 14), or *A. rasenense* Spath (1935, pl. 1, fig. 6*a*, *b*).

The amoeboceratids of the Lower Kimeridgian are as yet scarcely known. The tuberculate forms of *Amoebites* are of particular interest. Most of those hitherto published are of the *A. kitchini* group, from the Baylei–Cymodoce Zones, and so we take the

EXPLANATION OF PLATE 32

Figs. 1–8, *Aulacostephanus* (*Aulacostephanites*) cf. *eulepidus* (Schneid). 1*a*, *b*, MS 112, eight-tenths whorl body-chamber with lappet on reverse side. 2*a*, *b*, MS 69, with lappet. 3*a*, *b*, MS 27, with short lappet. 4*a*, *b*, MS 77, nine-tenths whorl body-chamber. 5*a*, *b*, MS 58, no sutures visible, but peristome preserved with lappet and collar. 6*a*, *b*, MS 66, no sutures visible. 7*a–c*, R 5, with onset of lappet. 8*a*, *b*, MS 72, outer whorl body-chamber.

Figs. 9, 10, *Aulacostephanus* (*Aulacostephanites*) *ebrayoides* sp. nov., transitional to *A.* (*A.*) cf. *eulepidus* (Schneid). 9*a–c*, MS 8, with lappet. 10*a*, *b*, MS 10 with lappet.

Figs. 11, 12, *Aulacostephanus* (*Aulacostephanites*) aff. *desmonotus* (Oppel). 11*a*, *b*, R 17, no sutures visible, but probably part of the outer whorl is body-chamber. 12*a*, *b*, MS 115, ditto.

Figs. 13–18, *Rasenia* (*Rasenioides*) *thermarum* (Oppel). 13*a*, *b*, MS 14, with probably some body-chamber. 14*a*, *b*, MS 118, with eight-tenths whorl body-chamber, peristome, and slight lappet. 15*a–c*, MS 9, nine-tenths whorl body-chamber. 16*a–c*, MS 32, remarks as 11. 17*a*, *b*, MS 36, ditto. 18*a*, *b*, R 20, ditto.

Figs. 19–21, *Rasenia* (*Rasenioides*) cf. *lepidula* (Oppel). 19*a*, *b*, MS 34, eight-tenths of last whorl body-chamber. 20*a*, *b*, MS 53, a fragment with outer whorl body-chamber. 21*a*, *b*, MS 35, body-chamber with peristome.

Figs. 22–24, *Aulacostephanus* (*Aulacostephanites*) sp. aff. *möschi* (Oppel). 22, MS 136, body-chamber fragment. 23*a*, *b*, MS 24, with eight-tenths whorl body-chamber. 24*a*, *b*, MS 19, no sutures visible.

Fig. 25*a–c*, *Amoeboceras* (*Amoebites*) *cricki* (Salfeld). MS 111, outer whorl body-chamber with peristome.

Fig. 26*a*, *b*, *Amoeboceras* (*Amoebites*) *kitchini* (Salfeld). MS 48, with half whorl body-chamber.

All natural size.

opportunity to illustrate two examples of *A.* (*Amoebites*) *salfeldi* Spath from the Mutabilis Zone of Mull (Pl. 33, figs. 12, 13). Development via the ventro-lateral clavi of *A. kitchini* to the fully looped ribs with tubercles of *A. salfeldi* seems systematic and may be of help in dating beds in regions, e.g. east Greenland, in which rasenids are absent.

2. *Amoeboceras* (*Amoebites*) cf. *cricki* (Salfeld)

Plate 32, fig. 25*a–c*

Cardioceras Cricki Salfeld 1914, p. 129.
Cardioceras Cricki Salfeld 1915, p. 191, pl. xix, figs. 2–6.
Cardioceras Kapffi Salfeld pars (non Oppel) 1915, pl. xix, fig. 7*a–c*.

Material. One (MS 111), and two fragments (MS).

Description. The figured specimen is about 22 mm. in diameter. The last half-whorl is body-chamber and the peristome is preserved, with ventral rostrum. The whorl-section is quadrate, compressed, with sharp shoulders and flat venter.

Remarks. The history of the name is similar to that of *kitchini* and interpretation is possible only as from the 1915 monograph. Salfeld's best figured specimen (pl. xix, fig. 2) attains 25 mm., and is slightly more densely ribbed than the one described here. The species seems to stay small and not to develop the modified ribbing characteristic of the *A. kitchini* group.

ORIGIN AND AGE OF THE FAUNA

The Lincolnshire material has been collected at four localities (from north to south): Elsham, 9 miles east of Scunthorpe and 15 miles north-north-west of Market Rasen; South Willingham, 6½ miles south-east of Market Rasen; Market Stainton, 9½ miles south-east of Market Rasen; and Ranby, ½ mile south of Market Stainton.

Elsham. The material in the British Museum (T. B. Parks coll.) came from 'huge boulders in sand' found in a small pit on the Chalk Wolds ¼ mile from Elsham chalk-pit. The ammonites were briefly mentioned by Spath (1954), who described them as 'probably new and undescribed species of *Rasenia*'.

South Willingham. The following are extracts from notes kindly supplied by Dr. Thurrell.

'Specimens labelled SW were collected from the village at a point 250 yards east of the church where a water-main trench intercepted the boulders within the Chalky Boulder Clay.'

Market Stainton. 'Specimens labelled MS were collected from two massive boulders (each about 3 feet across) in the corner of a large field 500 yards south-east of the church.'

Ranby. 'Specimens labelled R were collected on the roadside 600 yards east of Ranby church.

'The MS and R specimens are from blocks which are only 725 yards apart, but it is quite obvious that the blocks have been dumped. Enquiries failed to locate their exact origin, except that the MS blocks came from the centre of the field in the corner of which they lie.

'It seems certain that all the blocks come from—or are likely to occur in—the lowest levels in the Boulder Clay spread and one might presume also that they are of fairly local origin. Mapping of the boulder-clay suggests ice-movement from north to south over the existing Jurassic clay vale, the stream being confined by the Chalk Wolds escarpment not a mile to the east of Market Stainton. Evidence of possible derivation from the North Sea basin is lacking.'

The matrix and preservation of all the material is very similar: fine grey siltstone, some pieces crowded with fossils including, besides the ammonites, small gastropoda, pectens, oysters, and *Astarte*. There is no known outcrop of Lower Kimeridgian in such facies in England, nor has any been found in borings. The origin of the material must remain conjectural. Some of it has found its way to Norfolk, although for boulders of the size of those found in Lincolnshire transport over such distances seems improbable. The Kimeridgian is known to thin rapidly towards the Market Weighton axis, only some 30 miles north of Market Rasen, which influenced sedimentation in Jurassic times; and a more sandy development in its immediate vicinity, perhaps under chalk cover or even some way out to sea, would not be unexpected.

The question arises: do all these boulders contain identical faunas and hence are they, geologically speaking, all of the same age? The distribution of the material among the various localities is shown in Table 1, counting only identifiable specimens (some unnumbered fragments are indicated '+'). The species of Aulacostephaninae can be divided into two groups: those known elsewhere from the Mutabilis Zone—group (A); and species of the subgenera *Xenostephanus* and *Xenostephanoides* peculiar to the present collection (B). Whereas species of the second group (B) were found at all the localities, those of the first (A) occurred only at Ranby and Market Stainton, and not at South Willingham. There exist boulders, therefore, which contain exclusively the *Xenostephanus–Xenostephanoides* fauna. This leads to two possibilities for the age of the latter.

Firstly, if segregation is not general, and there also exist boulders containing both groups of species, then these have the same age which is Mutabilis Zone *sensu stricto*. The segregation of species in some parts of a 'contemporaneous' deposit would require explanation, but cases of this have been observed in other deposits of dogger facies.

EXPLANATION OF PLATE 33

Fig. 1, *Aulacostephanus* (*Xenostephanus*) aff. *anceps* sp. nov. Kildorais, Trotternish, Skye. W. G. Cordey coll.

Fig. 2, *Rasenia* (*Rasenioides*) cf. *transitoria* (Schindewolf). MS 80a, Thurrell coll., with probably some body-chamber.

Fig. 3*a*, *b*, *Rasenia* (*Zonovia*) sp. ind. R 2, wholly septate.

Figs. 4–6, *Aulacostephanus* (*Aulacostephanites*) *eulepidus* (Schneid). Latex casts of crushed impressions from Kimeridgian shales of Mull (Geol. Surv. Scotland, nos. M4512i, T4734c, T1981d).

Fig. 7, *Aulacostephanus* (*Aulacostephanites*) *spp.* aff. *eulepidus* (Schneid) or *ebrayoides* sp. nov. As above, from Mull (T1970d).

Fig. 8, *Aulacostephanus* (*Xenostephanoides*) aff. *thurrelli* sp. nov. or *scoticus* sp. nov. Mull (M4525i).

Figs. 9–11, *Aulacostephanus* (*Aulacostephanoides*) *circumplicatus* (Quenstedt). 9, Imprint of smooth band on the venter shown at 'v'. 10, Imprint of venter of *Amoeboceras* in the umbilicus. Mull (M4516i, T4732c, T4733c).

Figs. 12–13, *Amoeboceras* (*Amoebites*) *salfeldi* Spath. Mull (T1991d, T4721c).

All natural size. Figs. 4–13 are photographs under oblique lighting of latex moulds coated with magnesium oxide.

The fossils occur notably in isolated pockets, the chance remains of accumulations through wave-action at different moments over considerable periods of time in shifting, unconsolidated sandbanks whose relics we must consider to be geologically of uniform age. Segregation in such pockets might then be a reflection of ecology, particularly if the remains are those of organisms that were gregareous.

TABLE 1. Summary of distribution of species in the Lincolnshire Drift

	R	MS	SW	E
A. *Rasenia* (*Rasenia*) *sp.*		1		
(*Rasenioides*) *transitoria*		1		
cf. & aff. *lepidula*		5		
thermarum	1	8		
cf. *striolaris*		2		
(*Zonovia*) *sp.*	1			
Aulacostephanus				
(*Aulacostephanites*) *eulepidus*	1	24		
ebrayoides	1	8		
aff. *desmonotus*	1	2		
aff. *möschi*	1	10		
(*Aulacostephanoides*) *mutabilis*		1		
aff. *mutabilis*	1	2		
circumplicatus	1	2		
B. (*Xenostephanoides*) *thurrelli*	5	2	11	
lindensis	3	4	21	
(*Xenostephanus*) *ranbyensis*	1		1+	1
—var. *elshamensis*				1
staintonensis		1	1+	
anceps				
Amoeboceras				
(*Amoebites*) cf. *kitchini*		1		
cf. *cricki*		3		
Totals	17	77	34+	2

E = Elsham.

Alternatively, if the segregation of species is rigorous, we must deduce differences of age. This could not have been large, for on zoological grounds *Xenostephanus* and *Xenostephanoides* would fit into the faunal succession best as descendants of at least the earliest of the well-known rasenids of the Cymodoce Zone, and certainly as precursors of the aulacostephanids of the Eudoxus Zone (the lower part of the former Pseudomutabilis Zone *sensu lato*—for revision, see Ziegler 1961). On geological grounds it would also seem unlikely to have a selection of faunas of two zones, 1 and 3, with no trace of the intermediate zone 2. At most, therefore, it seems possible that *Xenostephanus* and *Xenostephanoides* mark a separate subdivision or subzone of the Mutabilis Zone.

The two alternatives above can only be resolved by further collecting, and careful attention should be paid to analysis of new material boulder by boulder.

Note added in proof (1 February 1963). The pit at Elsham which yielded *Xenostephanus* has been recently re-examined by P. E. Kent and R. Casey (*Proc. Geol. Soc., London,*

1605, 1963). They report that the sands and doggers exposed there are in fact *in situ*, showing the presence of a local sandy development of Lower Kimeridgian immediately under the Chalk. This had previously been mapped as Spilsby Sandstone (Neocomian).

The *Xenostephanus* fauna has also been found in drift at Miningsby, 4 miles west of Spilsby, at the southernmost end of the Wolds. Two specimens are figured by Ziegler (1962, pl. 22, figs. 5–6, 13–14; University of Nottingham Collection).

COMPARISON WITH OTHER AREAS

East Scotland. Lower Kimeridgian is exposed at two places: Eathie, on the Moray Firth, south of Cromarty; and the Brora–Helmsdale strip in Sutherlandshire.

The Eathie exposure seems to lie mainly in the Baylei–Cymodoce Zones (Waterston 1951), although nodules washed up on the beach indicate some higher beds offshore. The Lincolnshire fauna does not appear to be represented among them.

A more complete section is to be found in Sutherlandshire. The collections contain material from all the zones of the Lower Kimeridgian, but there seems to be no systematically collected succession (for summary, see Bailey and Weir 1932). The specimens that have found their way into the museums have tended to be the well-preserved ones out of mudstone nodules, often found loose on the shore; among them is *A.* (*Xenostephanoides*) *scoticus* sp. nov. (see above). Of the crushed ammonites from the rest of the great thickness of shales making up most of the succession there is little record.

Some of the lower of these shales—the Loth River Shales—are highly fossiliferous. The following section was recorded during a brief visit (J. H. C. 1956), in the river gorge south of Loth station, just east of the railway bridge on the north bank of the river. From above:

Loth River Shales

	ft.	in.
6. Black paper shales with sandy intercalations and seams; to below rail-level at the north end of the bridge.	seen *c.* 15	0
5. Soft yellow sandstone or sand, cross-bedded, with large doggers; variable	*c.* 6	0
4. Black varved paper shales with sandy white layers; many crushed ammonites, especially 2 ft. from the top: *Amoeboceras* (*Amoebites*) *beaugrandi* (? Sauvage) Spath (1935, pl. 5, fig. 4). *A.* (*A.*) *sp.* aff. *kitchini* (Salfeld). *Rasenia*? cf. *möschi* (Oppel). *Aulacostephanus* (*Xenostephanoides*?) cf. *lindensis* sp. nov. also profuse plant remains, and *Aucella sp.*	6	0
3. Sandstone, doggery, cross-bedded, barren	2 to 8	0
2. Black paper shales, as above, with sandy layers	10 to 15	0

Allt na Cuile Sandstone

1. Sandstone, white, massive, weathering black	seen 15	0

This section was not recorded in connexion with the present work, and only a few specimens from bed 4 were brought back. There seems little doubt about the *Aulacostephanus*, however, and more careful collecting from this section might settle the precise age of the Lincolnshire material.

West Scotland. There are indications of the Lincolnshire fauna from two localities: Kildorais, northern Skye, and Duart Bay, eastern Mull (see Arkell 1933, p. 114, fig. 19).

The only description of the Skye section so far published is by MacGregor (1934, p. 400), although it seems to be one of the most complete and fossiliferous successions from Lower Oxfordian to Lower Kimeridgian in Britain (J. H. C. 1961). The Pseudocordata Zone (uppermost Oxfordian), with profuse *Ringsteadia*, and Baylei Zone (Lower Kimeridgian) with typical *Pictonia* are thick and easily recognizable. Higher beds are present, but much less fossiliferous and badly covered by beach material: from one of these Mr. W. G. Cordey obtained the *Xenostephanus* shown in Plate 33, fig. 1. MacGregor submitted his material to Spath for identification, and in a more detailed account in a thesis (1931) mentions '*Pararasenia pseudomutabilis*' in text. Illustrations show nothing identifiable of post-*baylei* age, and search has failed to find the material. Thus there is so far no unconfirmed material which could throw light on the age of the single *Xenostephanus* mentioned above.

The occurrence in Mull is in a tiny faulted patch of baked blue shale on the right bank of the stream flowing into Duart Bay (Lee and Bailey 1925). The identification of the ammonites has had a varied history. They were first reported by Buckman to be Callovian *Kosmoceras* and *Reineckeia*. This was corrected by Spath (1932, p. 149) and Arkell (1933, p. 371), who identified them as *Amoeboceras* and *Rasenia*; but their precise age was not mentioned and none of them has so far been described. They are in fact from the Mutabilis Zone and the following species can be recognized in the collections of the Scottish Geological Survey:

Aulacostephanus (*Aulacostephanites*) *eulepidus* (Schneid) (Pl. 33, figs. 4–6).
— — cf. *ebrayoides* sp. nov.
— — aff. *möschi* (Oppel).
— (*Aulacostephanoides*) *mutabilis* (Sow.).
— — *circumplicatus* (Quen.) (Pl. 33, figs. 9–11).
— — *linealis* (Quenstedt).
— (*Xenostephanoides*) cf. *thurrelli* sp. nov. (Pl. 33, fig. 7).
— (*Xenostephanus*) aff. *ranbyensis* sp. nov.
Amoeboceras (*Amoebites*) *beaugrandi* (Sauvage).
— — *beaugrandi* Spath (non Sauvage).
— — *cricki* (Salfeld).
— — *kitchini* (Salfeld).
— — *salfeldi* Spath (Pl. 33, figs. 12, 13).
— (*Euprionoceras*) cf. *sokolovi* Sokolov and Bodylevsky.

Thus there is considerable similarity with the Lincolnshire fauna. The *Xenostephanus* resembles the one from Skye, but is too poorly preserved to be worth figuring. *Amoeboceras* predominates (this seems to apply to most Scottish Lower Kimeridgian), and the small fine-ribbed rasenids seem to be rare or absent. This further suggests that the Mutabilis Zone may be capable of subdivision.

England. Nowhere between Yorkshire and Dorset does the Mutabilis Zone appear to exceed a few feet in thickness, and very little is known about it in detail. Locally it is condensed or absent. Once again the museum material is largely that from nodules, found in many of the small brick-pits which have now all vanished. Such material from Lincolnshire is fairly abundant, but contains no *Xenostephanus*. This, too, may indicate that these forms occur at a somewhat different level from the rest of the Mutabilis fauna. Otherwise, if the Lincolnshire drift boulders are of relatively local origin, there would have to be a very sharp ecological boundary in the neighbourhood of the Humber.

South Germany. Due largely to the work of recent years the faunal successions are now known in considerable detail. The fauna of the Mutabilis Zone seems to be confined to the White Jura δ 1–2 (Ziegler 1962) (Tenuilobatum Zone *partim*, Badener Schichten of Switzerland), but constitutes only a minor part of the whole fauna. It seems unlikely therefore to become the type area for subdivisions of the Mutabilis Zone. Only one specimen of *? Xenostephanus* has so far been found (see above) and that not in place. This confirms the impression that this group is primarily characteristic of the boreal faunal realm.

REFERENCES

ARKELL, W. J. 1933. *The Jurassic System in Great Britain*. Oxford.

—— 1951. Proposed use of the plenary powers to designate the type species of the genus 'Aulacostephanus' Tornquist, 1896 (Class Cephalopoda, Order Ammonoidea) (Jurassic). *Bull. Zool. Nomenel.* **2,** 188–90.

—— 1955. Monograph of the English Bathonian Ammonites, Pt. v. *Palaeont. Soc. Monogr.*

BAILEY, E. B. and WEIR, J. 1932. Submarine Faulting in Kimmeridgian Times in East Sutherland. *Trans. roy. Soc. Edinb.* **57,** 429–67, pl. 1–3.

CALLOMON, J. H. 1957. Field Meeting in the Oxford Clay of Calvert and Woodham Brick Pits, Buckinghamshire. *Proc. Geol. Ass.* **68,** 61–64.

—— 1963. Sexual dimorphism in Jurassic ammonites. *Trans. Leicester lit. phil. Soc.*, **57** (In press).

FREBOLD, H. 1930. Verbreitung und Ausbildung des Mesozoikums in Spitzbergen. *Skrifter om Svalbard og Ishavet*, no. 31.

GEYER, O. F. 1961. Monographie der Perisphinctidae des unteren Unterkimeridgium (Weisser Jura γ, Badenerschichten) im süddeutschen Jura. *Palaeontographica*, A **117,** 1–157, pl. 1–22.

KHUDYAEV, I. 1932. The fauna of the Upper Kimmeridgian deposits of Timan. *Bull. Geol. Serv. U.S.S.R.* **51,** 645–53, pl. 1.

LEE, G. W. and BAILEY, E. B. 1925. The pre-Tertiary geology of Mull, Loch Aline and Oban. *Mem. Geol. Surv. Scotland.*

LORIOL, P. DE. 1874. In LORIOL, P. DE and PELLAT, E. Monographie paléontologique et géologique des étages supérieures de la formation jurassique des environs de Boulogne-sur-Mer. *Mém. Soc. phys. Genève*, **23,** 253–407, pl. 1–10.

—— 1876. Monographie paléontologique des couches de la zone à Ammonites tenuilobatus (Badener Schichten) de Baden (Argovie). *Mém. Soc. pal. Suisse*, **3,** (pt. I), 1–32, pl. 1–4.

—— 1878. Ibid. (pt. III), 77–200, pl. 13–22.

MACGREGOR, M. 1931. An account of the sedimentary rocks of north Trotternish, Isle of Skye. *Thesis*, University of London (unpublished).

—— 1934. The sedimentary rocks of North Trotternish, Isle of Skye. *Proc. Geol. Ass.* **45,** 389–413.

NIKITIN, S. N. 1885. Die Cephalopodenfauna der Jurabildungen des Gouvernements Kostroma. *Verh. russ.-kais. Min. Ges. St. Petersburg*, **20,** 13–86, pl. 1–8. (Also published at the same time in Russian, *Mém. Comm. géol. St. Petersbourg*, **2,** no. 1.)

OPPEL, A. 1863. Über jurassische Cephalopoden. *Pal. Mitth. Mus. bayer. Staates*, **3,** 163–266, pl. 51–74.

ORBIGNY, A. D'. 1845. In MURCHISON, R. I., VERNEUIL, E. DE, and KEYSERLING, A. DE. *Géologie de la Russie d'Europe et des Montagnes de l'Oural*. Vol. II: Paléontologie. Système Jurassique: Mollosques. London and Paris.

PAVLOW, A. 1886. Les ammonites de la zone à *Aspidoceras acanthicum* de l'est de la Russie. *Mém. Comm. géol. St. Petersbourg*, **2,** 1–91, pl. 1–10.

QUENSTEDT, F. A. 1887–8. *Die Ammoniten des Schwäbischen Jura*. Band 3: *Der Weisse Jura*. 818–944, pl. 91–102 (1887); 945–1140, pl. 103–26 (1888). Stuttgart.

RAVN, J. P. J. 1912. On Jurassic and Cretaceous fossils from N.E. Greenland. *Medd. om Grønl.* **45,** 10, 433–500, pl. 32–38.

REINECKE, J. C. M. 1818. *Maris protogaei Nautilos et Argonautas vulgo Cornua Ammonis in Agro Coburgi et vicino reperiundos*. . . . Coburg.

SALFELD, H. 1913. Certain Upper Jurassic Strata of England. *Quart. J. geol. Soc. Lond.* **69,** 423–30.
—— 1914. Die Gliederung des oberen Jura in Nordwesteuropa. *Neues Jb. Miner.*, Beil. Bd. **37,** 125–246.
—— 1915. Monographie der Gattung *Cardioceras* Neumayr und Uhlig, Teil I. Die Cardioceratiden des oberen Oxford und Kimmeridge. *Z. deutsch. Geol. Ges.* **67,** 149–204, pl. 16–20.
SASONOV, N. T. 1960. Novye dannye ob Oksfordskikh i kimeridjskikh ammonitakh. *Paleontologicheskyi Sbornik*, Leningrad, **3,** Trudyi, Vyipusk *xvi*, 133–61, pl. 1–6. (English translation: Nat. Lend. Lib. RTS 2019, D.S.I.R., London.)
SCHINDEWOLF, O. H. 1925. Entwurf einer Systematik der Perisphincten. *Neues Jb. Miner.*, Beil. Bd. **B 52,** 309–43.
—— 1926. Zur Systematik der Perisphincten. *Neues Jb. Miner.*, Beil. Bd. **B 55,** 495–517, pl. 19.
SCHNEID, T. 1939. Über Raseniiden, Ringsteadiiden und Pictoniiden des nördlichen Frankenjura. *Palaeontographica*, A **89,** 117–86, pl. 1–14.
SOWERBY, J. and SOWERBY, J. DE C. 1812–46. *The Mineral Conchology of Great Britain.* London. 7 vols.
SPATH, L. F. 1931. Revision of the Jurassic Cephalopod Fauna of Kachh (Cutch). *Pal. Indica*, N.S. **9,** mem. 2, part iv, 279–550, pl. 48–102.
—— 1932. The invertebrate faunas of the Bathonian-Callovian deposits of Jameson Land (East Greenland). *Medd. om Gronl.* **87,** no. 7.
—— 1935. The Upper Jurassic invertebrate faunas of Cape Leslie, Milne Land. I. Oxfordian and Lower Kimmeridgian. Ibid. **99,** no. 2.
—— 1954. In DENNISON, V. D. and PARKS, T. B. Geology. *Trans. Lincs. Nats. Union*, **13,** 191–3.
TORNQUIST, A. 1896. Die degenerierten Perisphinctiden des Kimmeridge von Le Havre. *Abh. schweiz. paläont. Ges.* **23,** 1–43, pl. 1–8.
WATERSTON, C. D. 1951. The stratigraphy and palaeontology of the Jurassic rocks of Eathie (Cromarty). *Trans. Roy. Soc. Edinb.* **53,** 33–51, pl. 1, 2.
WOODWARD, H. B. 1895. The Jurassic Rocks of Britain. V. The Middle and Upper Oolites of England (Yorkshire excepted). *Mem. Geol. Surv. Gt. Brit.*
ZIEGLER, B. 1961. Stratigraphische und zoogeographische Beobachtungen an Aulacostephanus (Ammonoidea — Oberjura). *Paläont. Z.* **35,** 79–89.
—— 1962. Die Ammonitengattung Aulacostephanus im Oberjura (Taxionomie, Stratigraphie, Biologie). *Palaeontographica*, A **119,** 1–172, pl. 1–22.

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Manuscript received 21 November 1961

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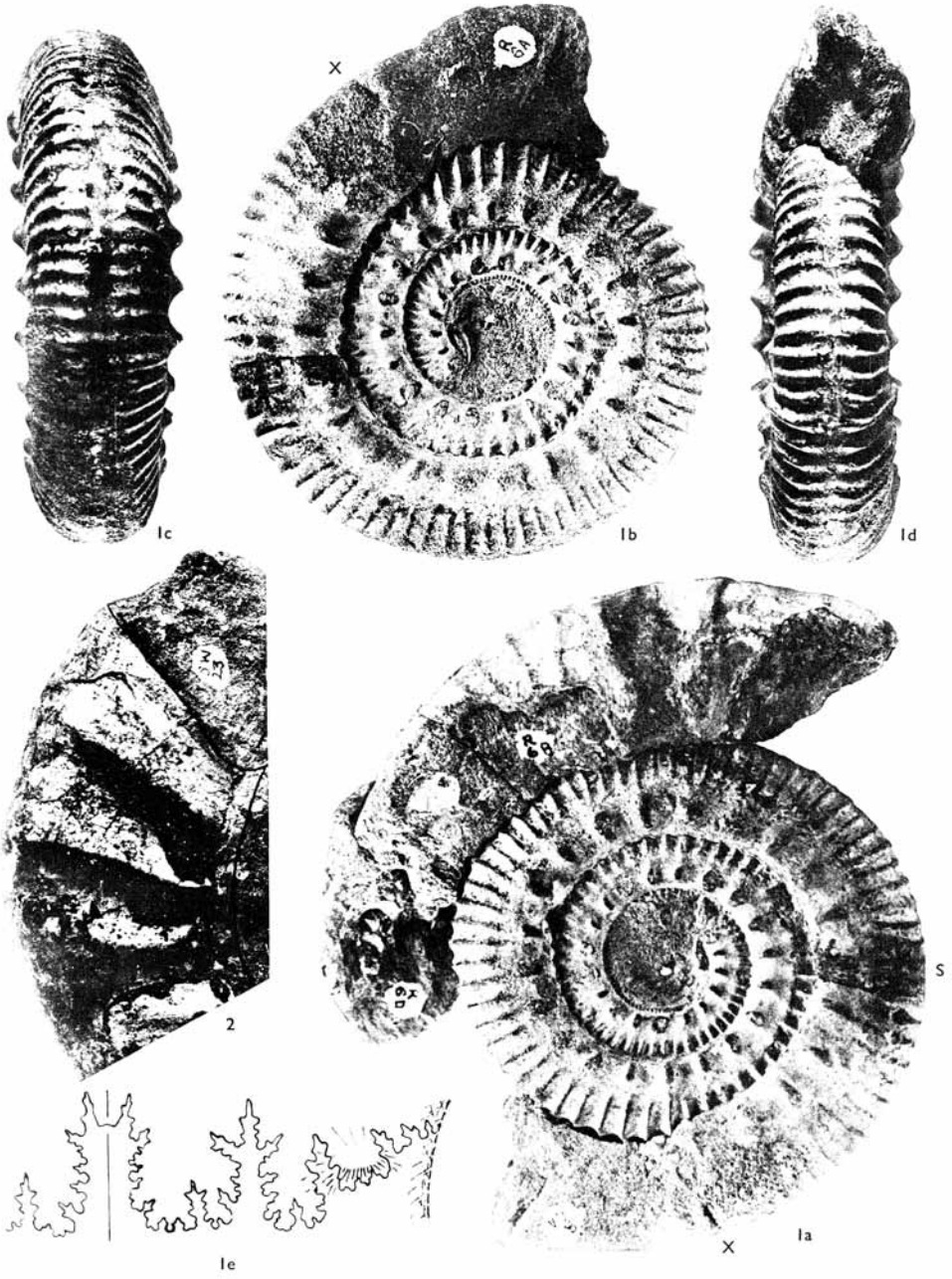

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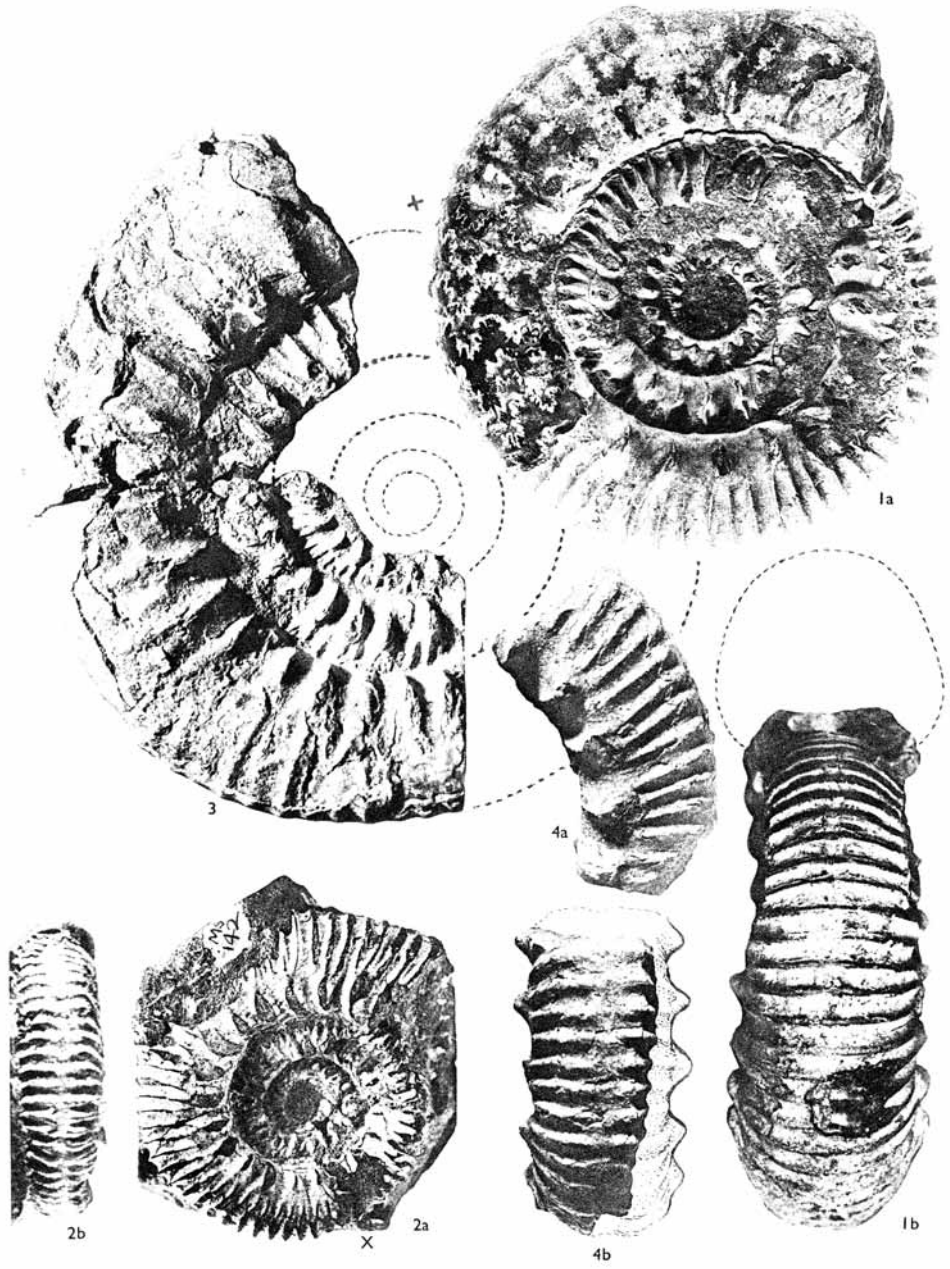

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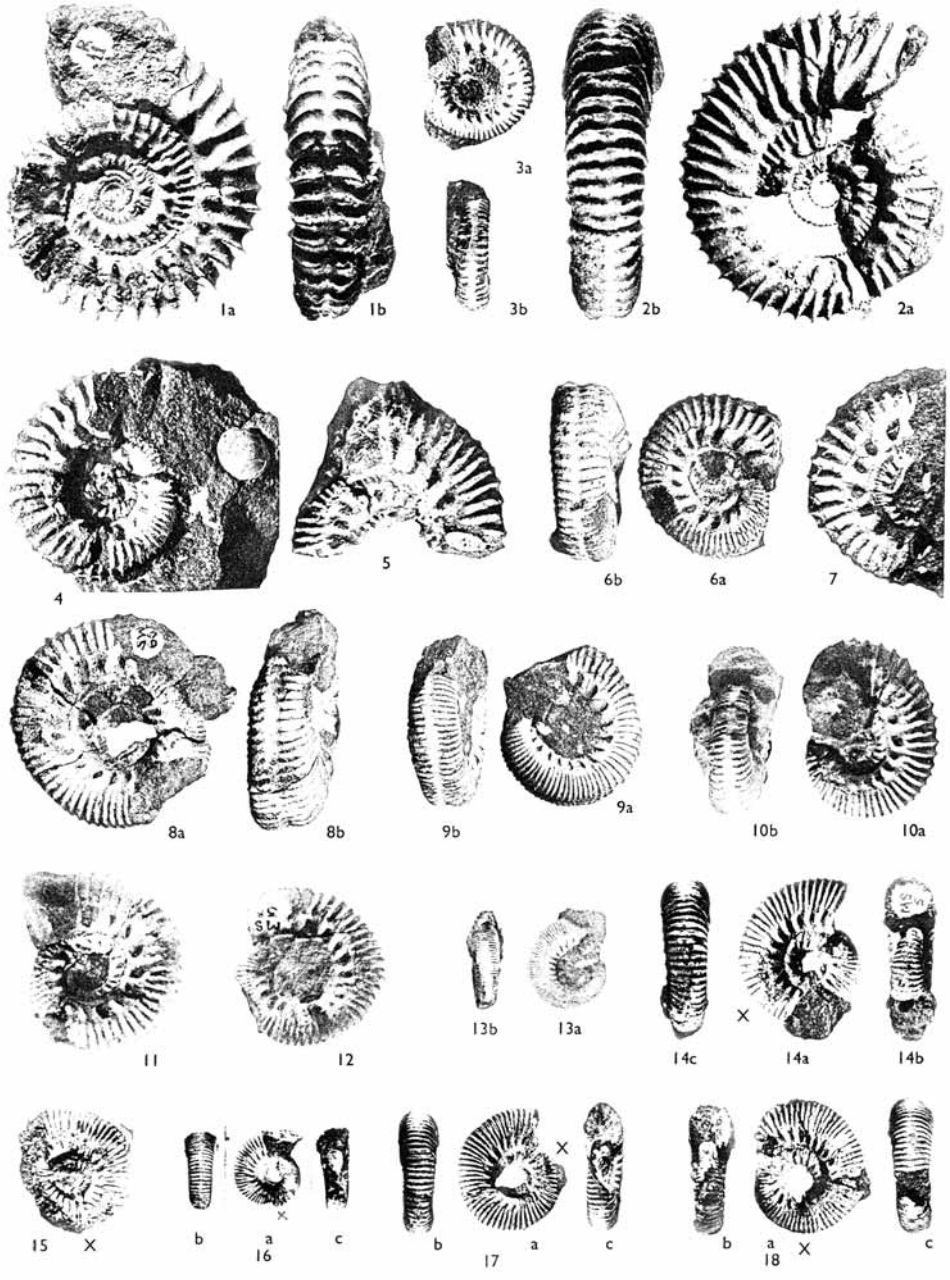

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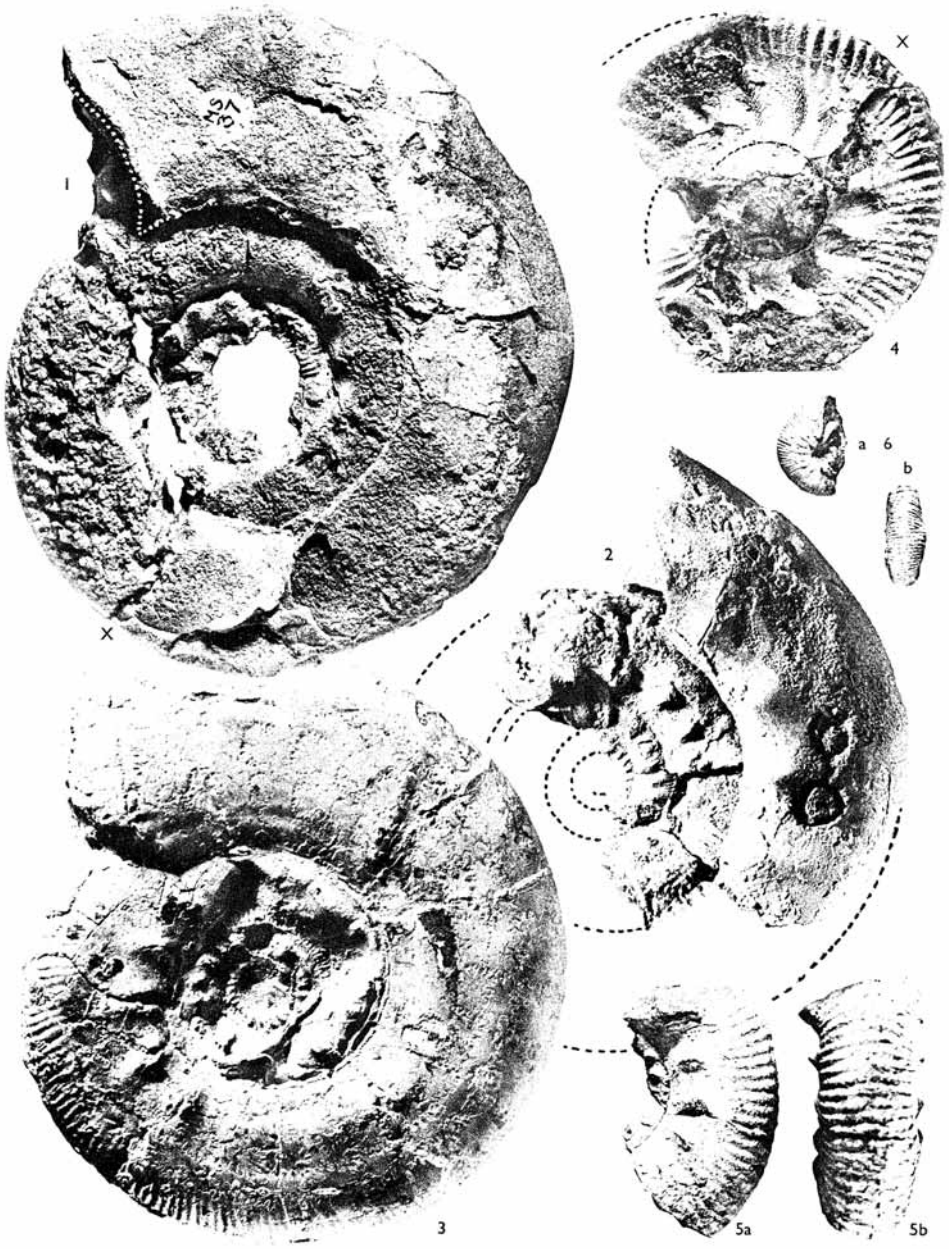

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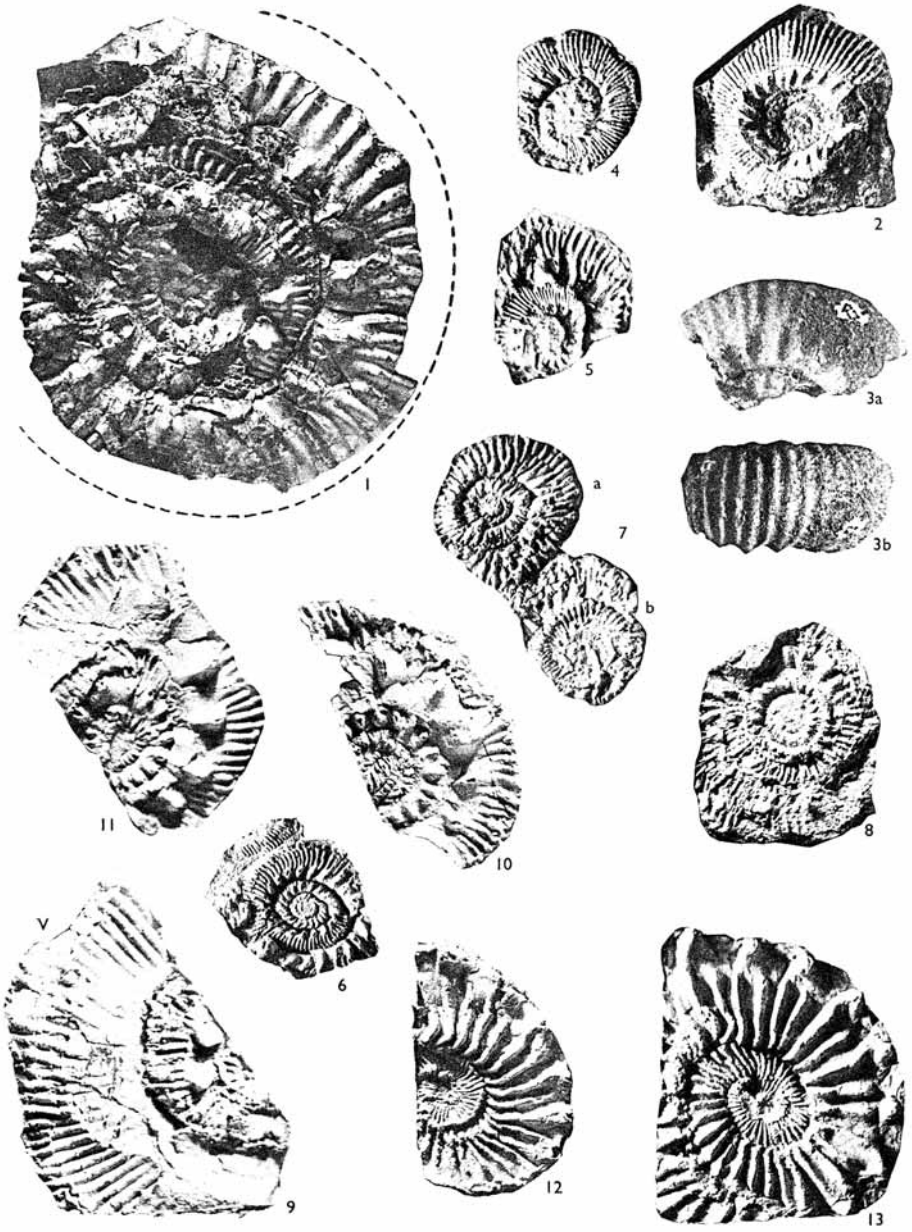

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