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by

JOHN H. CALLOMON AND TOVE BIRKELUND

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THE AMMONITE ZONES OF THE BOREAL VOLGIAN (UPPER JURASSIC) IN EAST GREENLAND

JOHN H. CALLOMON[1] AND TOVE BIRKELUND[2]

ABSTRACT

Detailed collecting in the Upper Jurassic of Milne Land, central East Greenland, has established a succession of 24 ammonite faunas spanning the Lower and much of the Middle Volgian, up to a non-sequence extending into the Valanginian of the Lower Cretaceous. For the chronostratigraphic classification of the seven Lower Volgian faunas the standard zonation of Britain is used unchanged. The 17 faunas of the Middle Volgian are regionally distinct and form the biostratigraphic basis for a new Boreal provincial standard scale of nine zones. Correlations with Britain, Siberia and the Russian Platform are discussed: there has been great progress in the last 30 years, but many problems remain. Six new ammonite species of the family Dorsoplanitidae are described: three of *Dorsoplanites*, two of *Pavlovia* and one of *Epipallasiceras*.

INTRODUCTION

Most would agree that chronostratigraphy forms the basis of historical geology. Its successes in the Mesozoic are well known, particularly in the Jurassic, deriving as they do in large measure from the fortunate circumstance that the principal guide-fossils, the ammonites, make possible a particularly rich and detailed biostratigraphy. Faunal provincialism however sets limits to what can be achieved in world-wide correlation by direct methods. In practice, therefore, work proceeds in each faunal province independently, and final interprovincial synthesis is achieved by correlation in regions of overlap. It is in this field that many unresolved problems remain, including some in the Jurassic.

Historically one of the oldest of these problems to be recognized lies in the Upper Jurassic and Lower Cretaceous, and despite the efforts of a century (and the wishful persuasions of committees and codes of stratigraphical nomenclature) a threefold system of chronostratigraphical classification continues to be in use today for the Upper Jurassic, based on three parallel major units, or stages:

Portlandian (Brongniart, 1829 - d'Orbigny, 1850), for Britain, northern and western France, northern Germany, Norwegian-Danish Basin.

Tithonian (Oppel, 1865), for southern Germany, southern France, and almost the whole of the circum-Tethyan Jurassic south of the Alpine fold-belt, up to and including California.

Volgian (Nikitin, 1881), for the Russian Platform northern Siberia, and, by extension through the new discoveries of more recent time, over the whole of the circum-Arctic shelf-deposits known today, including the Barents shelf and northern Canada.

Attempts at finer stratigraphical subdivision, to the level of zones, have necessarily to be even more restricted geographically, reflecting the existence within the broad faunal realms outlined above of numerous lesser faunal provinces.

One of the finest Upper Jurassic successions in the world is now known to be the one preserved in a small relict on crystalline basement in Milne Land, central East Greenland (71°N 26°W) (Figure 1). The first collections of the abundant and beautifully-preserved faunas were brought back by Rosenkrantz f 1929) during Koch's first expeditions of 1926 - 1927, and made famous in two monographs by Spam (1935, 1936). The outline of the stratigraphy was worked out by Aldinger (1935).

These works continue to form a solid basis for our modern descriptions, but what was lacking was the close connection between fauna and horizon that is needed to define a standard of reference. Subsequent expeditions in 1957 - 1958, 1970 and 1977 filled the gaps. Some 2000 ammonites were collected bed by bed from over 50 carefully-recorded sections (Figure 1), and a succession of 47 Jurassic ammonite faunas could be characterised, terminating in a major non-sequence. Of these, faunas 1 - 19 were described on a previous occasion (Callomon and Birkelund, 1980) and range from Middle Jurassic to the lowest part of the Kimmeridgian. Faunas 20 - 30 cover the rest of the Kimmeridgian (lower Kimmeridgian in the English sense) and lower Volgian (middle, or lower upper Kimmeridgian *sensu anglico*). They are so similar to those of Britain that the same zonal classification may be used (Cope, 1967, 1980), and only a brief summary is needed here.

Faunas 31 - 47 span almost the whole of the middle Volgian (upper upper Kimmeridgian *sensu anglico* and lower Portlandian). The similarities with Britain now become so slight, however, that the same zonal classification (Cope, 1978, 1980) cannot be used. Such similarities as exist are now equally strong with the successions of northern Russia and Siberia, although these, in turn, are so far known only in broad outlines. The main purpose of the present paper is therefore to present a first description of the Milne Land succession, lying as it does in an area in which those defining the Volgian and Kimmeridgian/Portlandian classifica-

[1] University College London, Gower Street, London WC1. U.K.
[2] Institut for historisk Geologi og Palaeontologi, Oster Voldgade 10. 1350 Copenhagen K, Denmark

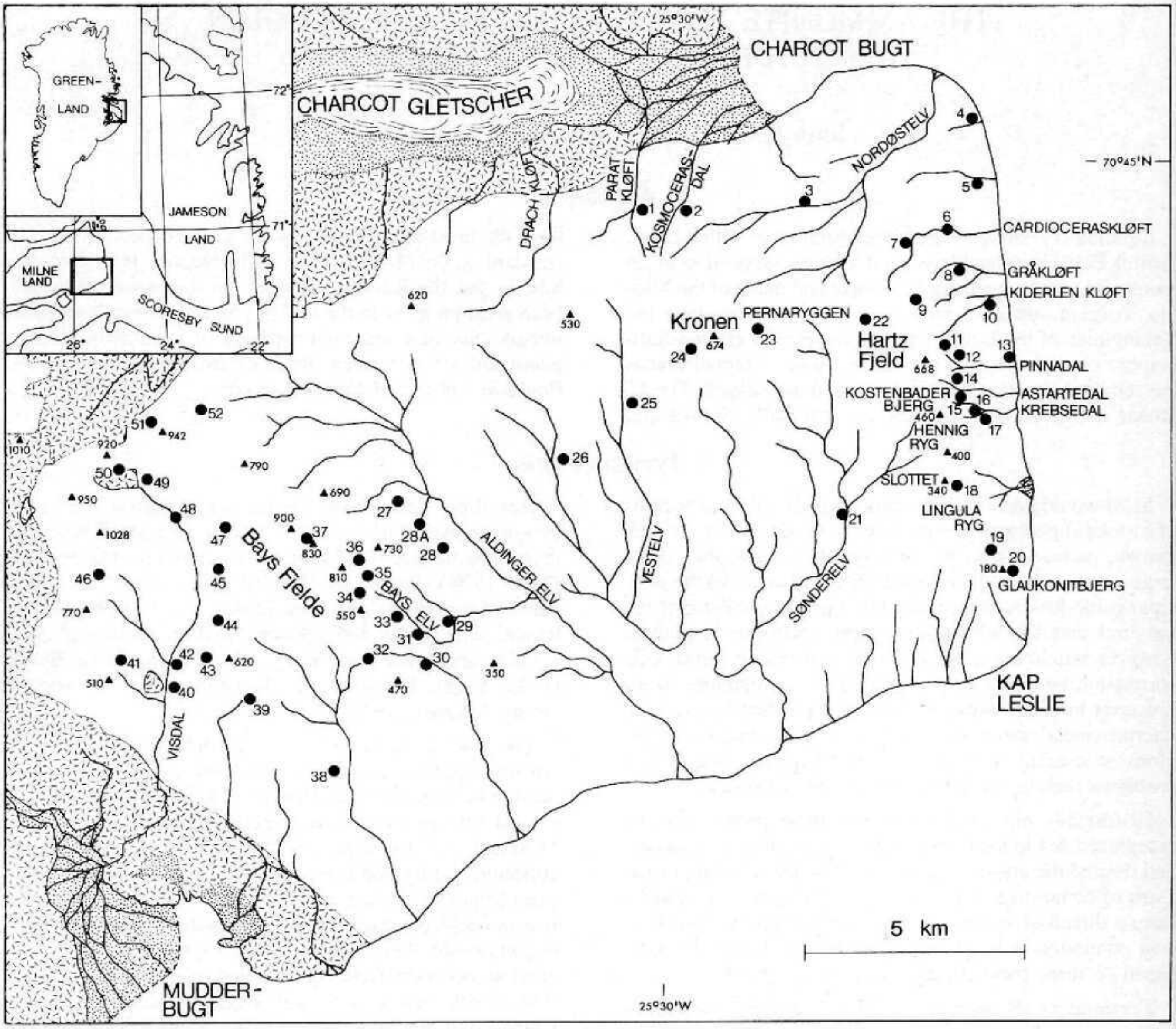

Fig. 1. Map of the Jurassic and Cretaceous deposits in Milne Land, giving place-names and the localities of the principal sections that have been measured and collected (nos. 1 - 52). Outcrops of crystallines indicated.

tions intermingle. The faunal succession is summarized in Table 1. The faunas are there grouped into a scheme of 9 standard zones which it is hoped will be a standard of reference for the region and find application in areas further afield, including the Barents Shelf and northern North America. Correlations between this scheme and those of other regions are briefly discussed at the end. Full description of the new results is a major task and will take time. Most of the critical ammonites have however already been described in considerable detail by Spath, so that in many cases reference to his work should suffice. Only a handful of new species are needed for the present purposes, and to avoid *nomina nuda* brief descriptions are appended.

SUMMARY OF LITHOSTRATIGRAPHY

The lithostratigraphy of the Mesozoic of Milne Land is summarised in Table 2. The succession is divided into three formations of which the lowest, the Charcot Bugt Formation, was described previously and is omitted. Some of the members into which the formations are divided were also defined elsewhere (Birkelund *et al., inprep.*), but are largely recognisable in terms of previously-described units also shown in Table 2.

FAUNAL SUCCESSION

The notes that follow contain numerous citations of and references to the names of ammonite species founded by

	FAUNAS	ZONES AND SUBZONES			
48	*Tollia groenlandica*	*Tollia klimovskiensis*		VALANG.	
47	*Laugeites groenlandicus*	*Laugeites groenlandicus*		MIDDLE	VOLGIAN
46	*Crendonites anguinus*	*Crendonites anguinus*			
45	*Pavlovia* aff. *subgorei*				
44	*Dorsoplanites intermissus* n.sp.	*Epipallasiceras pseudapertum*			
43	*Pavlovia groenlandica*				
42	*Epipallasiceraspseudapertum*				
41	*Epipallasicems acutifurcatum* n.sp.				
40	*Epipallasicems rotundiforme*	*Dorsoplanites gracilis*			
39	*Dorsoplanites gracilis S*				
38	*Dorsoplanites antiquus*				
37	*Dorsoplanites liostracus* n.sp.	*Dorsoplanites liostracus*			
36	*Dorsoplanites gracilis ft*				
35	*Pavlovia variocostata* n.sp.	*Pavlovia communis*			
34	*Pavlovia communis*				
33	*Pavlovia rugosa*	*Pavloviarugosa*			
32	*Pavlovia iatriensis*	*Pavlovia iatriensis*			
31	*Dorsoplanites primus* n.sp.	*Dorsoplanites primus*			
30	*Paravirgatites* sp. *B*	*Pectinatites pectinatus*	*P. paravirgatus*	LOWER	
29	*Paravirgatites* sp. *A*				
28	*Pectinatites eastlecottensis*		*P. eastlecottensis*		
27	*Pectinatites groenlandicus*				
26	*Pectinatites* cf. *abbreviatus*	*Pectinatites hudlestoni*			
25	*Sphinctoceras* spp.	*Pectinatites wheatleyensis*			
24	*Pectinatites elegans*	*Pectinatites elegans*			
23	*Aulacostephanus* cf. *kirghizensis*	*Aulacostephanus au tissiodorensis*			KIMMERIDGIAN
22	*Amoeboceras elegans*	*Aulacostephanus eudoxus*			
21	*Hoplocardioceras decipiens*				
20	*Amoeboceras kochi*				
19	*Xenostephanus borealis*	*A ulacostephanoides mutabilis*			
18	*Rasenia* aff. *evoluta*	*Rasenia cymodoce*			
17	*Rasenia cymodoce*				
16	*? Pachypictonia* sp.				
15	*Rasenia inconstans*				
14	*Pictonia* cf. *normandiana*	*Pictonia baylei*			

Table 1. The succession of ammonite faunas in Milne Land and their zonal classification.

FORMATIONAL UNITS		Aldinger, 1935 Spath, 1935,36	DESCRIPTIONS	
Hartz Fjeld Formation	Pinnadal Mb (n)	Hartz fjaeld Sandstone	Sandstones, non-marine	~1 00 m
			Shales, lagoonal, Hauterivian	-30 m
	Hennig Ryg Mb (n)		Sandstones with marine *Tollia* beds, L. Valanginian, fauna 48	~180 m
		- ooo *Lingula* Bed	Sandstones with *Lingula* Bed, M. Volgian, fauna 47	~30 m
Kap Leslie Formation	Astartedal Mb (n)	Glauconitic - oooα	Fine micaceous shales, non-glauconitic, M, Volgian, fauna 46	0-25 m
	Pernaryggen Mb (n)	Series	Glauconitic shales and sandstones, many shell-beds, M. Volgian faunas 3745	15-60 m
	Krebsedal Mb (n)	*Pallasiceras* Beds - oooβ *Pectinatites* Beds	Fine micaceous shales, variably glauconitic in upper part, with layers of concretions, L.-M. Volgian, faunas 25-36	-200 m ?
	Gråkløft Mb (n)	Oil Shales	Laminated black shales, Kimmeridgian-L. Volgian, faunas 20-24	160 m
	Cardioceraskløft Mb (CB)	- ooo *V* *Amoebites* - ooo δ	Bioturbated dark shales, L. Kimmeridgian, faunas 15-19	30 m
	Bays Elv Mb (CB)	Shales	Fine micaceous shales with glauconites, U. Oxfordian-L. Kimmeridgian, faunas 12-14	20 m
	Aldinger Elv Mb (CB)	*Pecten* Sandstone	Cross-bedded sandstone with shell-banks, U. Oxfordian, fauna 1 1	0-70 m
	Kosmocerasdal Mb (CB)	*Cardioceras* Shales	Bioturbated dark shales, U. Callovian-U. Oxfordian, faunas 2-10	5-170 m

Table 2. Summary of lithostratigraphicat formations and members. n: new; CB: Callomon and Birkelund (1980), 000α - 8: Layers of concretions labelled by Aldinger (1935).

Spath (1935, 1936). The material at his disposal was however accompanied by only the barest stratigraphical information. His classification had thus to be almost exclusively and narrowly morphological, paying little attention to the intraspecific variability normally to be found in a contemporaneous (stratigraphically homogeneous) ammonite assemblage. With the new information available, it is therefore not surprising to find that, on the one hand, a single assemblage might contain several of Spam's species side by side, linked by morphological intermediates and most probably but morphological variants of a single biospecies; while on the other hand, any one of Spath's morphospecies might be found to range as a constituent over several faunas and horizons. A morphological classification such as Spath's is therefore "vertical", while a description in terms of successive stratigraphical assemblages, such as is now outlined below, is "horizontal". To convert from one to the other raises formal problems of synonymy and nomenclature, the solution of which cannot be attempted here. Nevertheless it is a useful starting point to know the precise horizons from which the type-specimens of existing species came, for this defines "the ages of the nominal species" in their strictest sense and indicates the names already available for labelling successive assemblages in a horizontal classification. The ages in this sense of almost all of Spath's species are now known, either from closely-matching topotypes newly collected in place, or from the identification of beds by unmistakable matrix and previous indications of height and place, or both. It is primarily in this sense, therefore, that Spath's names are used in what follows below. Further systematic problems arise from the recognition in the ammonites, here as elsewhere, of a strong dimorphism. Beyond indicating the dimorphs as macroconchs (M) and microconchs (m) where necessary in the usual way, no further attempt at systematic unifications is made here either. The proportions of dimorphs in an assemblage were found to vary greatly between both extremes.

To give some ideas of the extent of the information available we indicate the number of specimens in the various assemblages. Those of Spath's that could be unambiguously assigned in this way were added in. They include only figured specimens. In some cases he had further material to which he alluded in the text, but this material appears now to be lost. The collections in Copenhagen contain only his figured material, including the types of his new species.

(a) Faunas 1 - 19: Boreal **Bathonian-Kimmeridgian,** lower **part:** See Callomon and Birkelund, 1980.

(b) Faunas 20 - 23: **Kimmeridgian,** upper part.

Faunas in this part of the succession in Milne Land are highly sporadic. Ammonites occur at only four isolated horizons in a thick sequence of shales. Most if not all of the faunas have also been found elsewhere along the east coast of Greenland and in Spitsbergen, but conversely, and perhaps more significantly, no other faunas in this age-range have so far been found in this extended area that are not known from Milne Land. This suggests that ammonites may have colonized the whole region at only the four levels represented here.

The ammonites of these faunas are in course of being described (Birkelund and Callomon, *in prep.*).

Fauna 20.

Amoeboceras (Euprionoceras) kochi Spath, 1935, p. 26. Several localities; ca. 35 specimens. Possibly a synonym of "*Cardioceras*" *sokolovi* Sokolov and Bodylevsky, 1931, p. 86, but this question must remain unsolved until more material of this species is available.

— Probably Eudoxus Zone.

Fauna 21.

Amoeboceras (Hoplocardioceras) decipiens Spath, 1935, p. 36; (M) + (m). Many localities; ca. 70 specimens.

Aulacostephanus eudoxus (d'Orbigny, 1850) Ziegler, 1962, p. 80; 2 localities; 2 specimens, and fragments.

— Eudoxus Zone.

Fauna 22.

Amoeboceras (Amoebites) elegans Spath, 1935, p. 33; (M) + (m). Several localities; ca. 50 specimens. Well-defined bed only 3 m above fauna 21.

— Probably Eudoxus Zone.

Fauna 23.

Aulacostephanus cf. *khirgisensis* (d'Orbigny, 1845). Ziegler, 1962, p. 95; one specimen, and fragments; ca. 50 m above fauna 21.

— Probably Autissiodorensis Zone.

(c) Faunas 24-30: Lower Volgian

= lower part of upper Kimmeridgian *sensu anglico*.

Almost all species are close to or identical with English forms (Cope, 1967). There is little or no overlap with the faunas in the lower part either of the Volgian basin or from the northern Urals, which consisted largely of endemic *Ilowaiskya*.

Fauna 24.

Pectinatites (Virgatosphinctoides) elegans Cope, 1967 (M). Spath 1936, Plate 1, Figure 3; 2 specimens.

Pectinatites (Virgatosphinctoides) major Cope, 1967 (M). 2 specimens.

Pectinatites (Virgatosphinctoides) spp. (m) = *Subdichotomoceras?/Subplanites? spp.* Spath, 1936, Plate 1, Figures 2, 3. 3 specimens.

— Elegans Zone.

Fauna 25.

Pectinatites (Virgatosphinctoides) smedmorensis Cope, 1967 and *laticostatus* Cope, 1967. 5 specimens.

Sphinctoceras (Eosphinctoceras) cf. or *aff. magnum* Mesezhnikov, 1974, or *distans* Neaverson, 1925, (M) + (m). The evolute, round-whorled, regularly-ribbed and constricted coiling are unmistakable. The secondary ribs are however polyplicate on the outer whorl, said to distinguish the earlier forms of *Eosphinctoceras* Mesezhnikov from the regularly biplicate *Sphinctoceras s.s.* that occurs slightly higher in the succession in the northern Urals. In Britain only *Sphinctoceras s.s.* has been found so far, in the lower Wheatleyensis Zone (Cope, 1967). 6 specimens, and fragments; ca. 50 m above fauna 24.

— about Wheatleyensis Zone.

Fauna 26.

Pectinatites (Virgatosphinctoides) cf. or *aff. abbreviatus* Cope, 1967 (M). 3 specimens; ca. 30 m above fauna 25.

— about Hudlestoni Zone.

Fauna 27.

Pectinatites (Pectinatites) groenlandicus Spath, 1936, p. 25 (M). 1 specimen.

Pectinatites (Pectinatites) aff. eastlecottensis Salfeld, 1913 (M) + (m). 4 specimens.

Pectinatites (Pectinatites) cf. cornutifer, (Buckman, 1925) (m). 4 specimens and many fragments.

— Pectinatus Zone.

Fauna 28.

Pectinatites (Pectinatites) eastlecottensis Salfeld, 1913 (M) + (m). Spath, 1936, p. 19.

Pectinatites (Pectinatites) cf. pectinatus (Phillips, 1871) (M).

Pectinatites (Pectinatites) cornutifer, naso, etc. (Buckman, 1925) (m).

Pectinatites (Wheatleyites) rarescens Buckman, 1925 (M). Altogether 17 specimens, and fragments.

— Pectinatus Zone, Eastlecottensis Subzone.

Fauna 29.

Paravirgatites spp. A (M) + (m). Including Spath, 1936, *P. aff. devillei* and *cf. boidini,* Plate 7, Figure 2; Plate 13, Figure 2; several localities; 42 specimens.

The name *Paravirgatites* is used for forms intermediate between true *Pectinatites* and *Pavlovia,* to either of which it has been ascribed in the past (Cope, 1967, 1978). Greenland material is fairly plentiful but fragmentary, English material crushed, so close comparisons are difficult.

— Pectinatus Zone, Paravirgatus Subzone.

Fauna 30.

Paravirgatites sp. B (M) + (m). Material small but well localized: 23 m above fauna 29; 2 specimens.

— Pectinatus Zone, Paravirgatus Subzone.

(d) Faunas 31 - 47: Middle **Volgian,**

= upper part of upper Kimmeridgian + Portlandian *sensu anglico.*

These span the most fossiliferous part of the section. They represent what are probably successive evolutionary stages of the two genera *Dorsoplanites* and *Pavlovia* developing in parallel. Morphological difference between successive faunas of each genus may appear to be slight, but are consistent and easily recognizable in material of the volume and quality available. The relative proportions of the two genera in successive faunas can however vary enormously, from 1:10 to 10:1 either way. Both genera clearly had their origins in some *Pectinatites* of the lower Volgian, and their earlier forms may not always be easy to assign to one genus rather than the other, but the late forms are quite distinct. *Dorsoplanites* is almost unknown in Britain but dominates at many levels elsewhere in the Arctic as well as in Greenland. Whether the Greenland forms of *Pavlovia* are really distinct from those of Britain is in many cases hard to judge because of the poor preservation or scarcity of the British material. In some cases the affinities are certainly also close with the faunas known from the northern Urals.

Fauna 31.

This is taken to cover material found somewhat unlocalised over a range of beds and may therefore contain some heterogeneous elements. The principal component is however homogeneous.

Dorsoplanites primus n. sp. See description below: 25 - 30 m above fauna 30; 9 specimens.

Pavlovia sp. 6 specimens.

Fauna 32.

Pavlovia iatriensis Ilovaisky, 1917 (m). Includes *Pavlovia jubilans* Spath, 1936, p. 39 and *Dorsoplanites subpanderi* Spath, 1936, holotype only; 150 specimens and fragments. This is one of the most abundant and well-localised faunas in Milne Land. There are close matches with the whole range of variability shown in Ilovaisky's figures, both in adult size and the characteristic irregular ribbing on the adult body chamber. The peristomes retain residual trumpet-like flares and horns as in *Pectinatites.* There are however small but consistent differences — the Greenland forms are slightly more involute and compressed on the inner whorls. The Greenland assemblage could therefore be differentiated as a subspecies *jubilans* Spath.

More general is the question of differentiating *Pavlovia* from *Dorsoplanites. P. iatriensis* is the type-species of *Pavlovia,* and both Ilovaisky's assemblage from the Urals and that from Greenland consist overwhelmingly of microconchs. Both the type of *Dorsoplanites, D. dorsoplanus* (Vishniakov, 1882) and the specimen figured by Michalski, 1890 and reproduced in the *Treatise* (Arkell, 1957, Figure 432) are however macroconchs, and it is not impossible that *P. iatriensis* (m) *s.s.* and *D. dorsoplanus* (M) *s.s.* are merely dimorphs of the same genus. *Dorsoplanites* and *Pavlovia* as interpreted by Spath in Greenland more generally are however clearly separable, both morphologically and phyletically. The English fauna most closely similar is that of *Pavlovia pallasioides* (Neaverson) of the Pallasioides Zone.

Pavlovia (iatriensis?) sp. (M). 3 specimens.

Dorsoplanites cf. and *aff. dorsoplanus* (Vishniakov, 1882) (M). 3 specimens.

— Iatriensis Zone.

Fauna 33.

Pavlovia rugosa Spath, 1936, p. 52 (m). 5 specimens.

These characteristic forms with straight widely-spaced ribs closely resemble a group from the Russian platform: *P. menneri* Michailov (1966, p. 47) said to occur in the subzone of *Zaraiskites zarajskensis*.

Pavlovia alterneplicata Spam / *kochi* Spath, 1936, p. 50, 51 (M).

Pavlovia inflata Spath 1936, p. 49 (M).

Pavlovia allovirgatoides Spath/*similis* Spath, 1936 p. 37, 54 (m).

Pavlovia variabilis Spath, 1936, p. 48: the type only. Altogether 50 specimens.

Dorsoplanites sp. 29 specimens, mainly nuclei and inner whorls.

This assemblage came from some 10 m of glauconites that are probably subdivisible into a number of beds, but the faunas could not be altogether separated. *P. rugosa* and *P. alterneplicata* may therefore represent distinct faunas.

— Rugosa Zone.

Fauna 34.

Pavlovia communis Spath, 1936, p. 41 (m).

Pavlovia regularis Spath, 1936, p. 42 (m).

Pavlovia subaperta Spath, 1936, p. 45 (m).

Pavlovia perinflata Spath, 1936, p. 44 (m + M).

Altogether 51 specimens.

Dorsoplanites gracilis Spath, 1936, p. 72 (m) a, 3 specimens.

The pavlovids have an obvious and close similarity with the famous fauna of *Pavlovia rotunda* (Sowerby) from the Rotunda Zone of Britain and particularly Chapman's Pool, Dorset. Some of the Milne Land forms are almost identical with the small *P. concinna* Neaverson (*cf.* Spath, 1936, Plate 10, Figure 2) with its very dense and fine ribbing on involute inner whorls modifying to an evolute, coarsely-ribbed bodychamber. Both assemblages are also similarly highly variable. *Dorsoplanites gracilis,* interpreted as a microconch only, is rather long-ranging, successive assemblages being only slightly different from each other. To distinguish them according to level, they are therefore given informal labels α - η. The type came from fauna 40, ϵ (*q.v.*). At several levels the macroconchs that go with them already have separate names. No attempt is made here to revise the species systematically.

— Communis Zone.

Fauna 35.

Pavlovia variocostata n. sp. (m). See description below, 28 specimens. All the material came from two concretions and is thus very sharply localised.

— Communis Zone.

Fauna 36.

Dorsoplanites gracilis Spath (m) p. Like a, but more coarsely ribbed, evolute and bigger. 8 specimens.

— Liostracus Zone.

Fauna 37.

Dorsoplanites liostracus n. sp. (M) + (m). See below; (M), 10 specimens; (m), 26 specimens and fragments.

Pavlovia corona n. sp. (M). See description below; 10 specimens.

Dorsoplanites gracilis Spath (m) γ.

Pavlovia sp. Transitional to *Epipallasiceras; 2* specimens.

— Liostracus Zone.

Fauna 38.

Dorsoplanites antiquus Spath/*transitorius* Spath, 1936, p. 68, 69 (m). Small forms with coarsely ribbed bodychambers. 26 specimens.

— Gracilis Zone.

Fauna 39.

Dorsoplanites gracilis Spath (m) 5. Material fairly plentiful but not well enough preserved to identify more closely with Spath's numerous figures. 14 specimens.

Pavlovia sp. (m). 1 specimen.

— Gracilis Zone.

Fauna 40.

Dorsoplanites gracilis Spath, 1936, p. 70 (m) *s.s.* (ϵ).

Dorsoplanites aldingeri Spath, 1936, p. 74 (m).

Dorsoplanites crassus Spath, 1936, p. 72 (m).

Dorsoplanites triplex var. mutabilis Spath, 1936, p. 79 (M).

Altogether 120 specimens.

Epipallasiceras rotundiformis Spath, 1936, p. 55 (m). Includes *Pavlovia aff.rugosa* Spath, Plate 12, Figure 1 and *P. (E.) aff costata* Spath, Plate 18, Figure 3. 16 specimens.

Pavlovia sp. (m). 6 specimens.

Widespread; but the principal locality is in two prominent *Pinna*-beds at the top of the ridge south of Krebsedal on the east coast, north of Kap Leslie, whence came most of the material described by Spath, including the type of *D. gracilis.*

The *Epipallasiceras* is of great interest and importance. It is the lowest of three successive faunas of this genus, easily recognised by the highly characteristic bifurcation of its ribs into pairs of closely-spaced secondaries, (Plate 3, Figure 2, Plate 4, Figure 2), and apparently largely restricted to East Greenland. In this, the earliest form, the *Epipallasiceras* stage is already strongly accentuated but confined largely to the inner whorls, the ribbing on the bodychamber reverting to that of normal *Pavlovia.* A fragment very close in style was already described long ago by Buckman (1926, Plate 693, as *Virgatites pallasianus*) from the Massive Bed of

Purbeck. This marks the base there both of the Portland Sand and of the Albani Zone, and hence of the Portlandian Stage. Also Jameson Land, Rauk Elv Formation, Salix Dal Member (Surlyk *et al.*, 1973, Plate 2, Figure 2).

— Gracilis Zone.

Fauna 41.

Epipallasiceras acutifurcatum n sp. (M) + (m). Together 62 specimens. See description below.

The type of this new species is a macroconch, whereas that of the earlier *rotundiforme* is a microconch and came from the previous fauna and horizon. The latter was only slightly glauconitic, and *Dorsoplanites* dominated. The present fauna was found in greensand and contained almost no *Dorsoplanites* (1 specimen). The *Epipallasiceras*-stage of ribbing now extends into the bodychamber in the microconchs. There is a very close match with a specimen from Boulogne in the Pellat collection labelled "P le plus bas, limite de 0" indicating the basal Gres des Oies (Ager and Wallace, 1966) or Gres a *Trigonia gibbosa* et *Cardium pellati* of Pruvost (1925). The age of this is discussed further below.

— Pseudapertum Zone.

Fauna 42.

Epipallasiceras pseudapertum Spath, 1936, p. 56 (m). Including *E. costatum* Spath, p. 58, 130 specimens.

Epipallasiceras praecox Spath, 1936, p. 60 (M). Including *E. tumidum* Spath, p. 59. 9 specimens.

Dorsoplanites maximus Spath, 1936, p. 71 (M). 5 specimens.

Dorsoplanites gracilis Spath, η. 9 specimens.

This is the most abundant and widespread fauna of *Epipallasiceras*, found everywhere in Milne Land in highly glauconitic greensands or ironstones and making an excellent marker. Individual variants resemble some found in earlier faunas, but as a whole the shells are more inflated, and broad-ventered, the secondaries less accentuated.

— Pseudapertum Zone.

Fauna 43.

Pavlovia groenlandica (Spath, 1936), p. 66 (M). Referred to *Behemoth* by Spath. 1 specimen.

Pavlovia sp. transitional to *Crendonites*. 2 specimens.

Dorsoplanites aff. gracilis Spath. 8 specimens.

The huge holotype of *"Behemoth" groenlandicus* Spath remains unique, but its assignment to this level can be made with confidence on the strength of the matrix with its considerable auxiliary fauna of non-ammonites, and in the framework of the highly detailed stratigraphy now available and Rosenkrantz's indications of height and locality. The species is a typical evolute pavlovid of the kind found in the lower Portland Sand of southern England, e.g., *Leucopetrites caementarius* Buckman, 1926, Plate 677, and not otherwise closely related to the "giants of the Portlandian", such as *Behemoth* or *Titanites*.

—Pseudapertum Zone.

Fauna 44.

Dorsoplanites intermissus n. sp. (m). See description below. 4 specimens.

Widespread throughout Milne Land and easily recognisable, even when as usually rather poorly preserved. the involute, compressed whorl-section and subdued, ventrally projected ribbing indicate an evolutionary position of these forms intermediate between *Dorsoplanites* and *Laugeites*.

— Pseudapertum Zone.

Fauna 45.

Pavlovia aff. subgorei (Spath, 1936) (m). Spath, 1936, p. 62, Plate 9, Figure 5; Plate 14, Figure 2 (from England). 7 specimens.

Marks the topmost glauconite of the Pernaryg Member on the east coast, rich also in terebratuloid brachiopods. Material neither plentiful nor well-preserved, but bears an unmistakably close resemblance to the small species of *"Crendonites"* described by Spath from the Glauconitic Beds of Swindon, Wiltshire.

— Anguinus Zone.

Fauna 46.

Crendonites anguinus Spath, 1936, p. 65 (m); including

Crendonites euglyptus Spath, 1936, p. 63 (m);

Crendonites lesliei Spath, 1936, p. 62 (m);

Crendonites subregularis Spath, 1936, p. 64 (m).

Together 30 specimens, and fragments. (See also Surlyk *et al.*, 1973, Plate 2, figure 1, from southern Jameson Land). The numerous specimens illustrated by Spath under these names cover the range of forms well. They all occur together at each of two well-separated horizons (Aldinger's concretion "a") that cannot be faunally distinguished. There appear to be all intermediates, so the conclusion seems inescapable that they were all but members of a single highly variable species. One bodychamber is barely distinguishable in size, coiling and ribbing from the equally deficient holotype of the type species of *Crendonites, C. leptolobatus* Buckman (1923, Plate 401). Even so, the continued use of the generic name *Crendonites* is merely conventional, following Spath, for the dividing line between it and *Pavlovia* is quite arbitrary. The associated macroconchs may give a better basis for separation, but except for rare and quite indeterminable fragments they remain unknown in Greenland. The position in Britain is more hopeful but there, in turn, the association stratigraphically of numerous unlocalised macro- and microconchs remains to be established. The sharp lithological breaks at the base and top of the Astartedal Member are not reflected in comparable faunal discontinuities, for the differences between faunas 45, 46, and 47 are still quite small.

Dorsoplanites sp. (m). 3 specimens.

— Anguinus Zone.

Fauna 47.

Laugeites groenlandicus (Spath, 1935), p. 82 (M) + (m). 4 specimens, and fragments.

Crendonites cf./aff.subgorei Spath / *elegans* Spath, 1936, p. 35, 62 (m). 6 specimens, and fragments.

Despite considerable search, no more specimens comparable with the holo- and paratypes of *L. groenlandicus* figured by Spath have come from the type-locality, in the *Lingula* Bed of Kap Leslie. The inner whorls of the holotype are most revealing and are therefore illustrated here for the first time (Plate 5, Figure 2). They are involute and compressed, with ventrally strongly projected secondary ribbing, characteristic of the upper Volgian *Subcraspedites*. They give the genus *Laugeites* a satisfactory and important transitional position, therefore, intermediate between ancestral *Dorsoplanites* of the Dorsoplanitinae and *Subscraspedites* of the Craspeditinae, themselves the earliest and hitherto somewhat cryptogenic members of the whole long lineage of Boreal perisphinctids terminating in *Simbirskites* of the Hauterivian. Very close to the Milne Land forms, if not identical, are also the specimens from southern Jameson Land figured by Spath (1936, Plate 37, Figures 1, 3; Plate 36, Figure 2; Plate 38, Figure 2) questionably as *Pectinatites*.

The *Crendonites* are much as in fauna 46, except that the change in ribbing and coiling between the involute, coarsely and straight-ribbed adult bodychamber is even more sudden and marked. The affinities of these, the youngest pavlovids known from East Greenland, are still undoubtedly closest with the early Portlandian forms of the *subgorei* group from the Glaucolithus Zone, rather than with any of the younger forms of *Kerberites* or *Titanites* more usually associated with the general concept of Portlandian ammonites. Deposits of their age, if ever present in Milne Land, have been wholly lost by erosion.

— Groenlandicus Zone.

— Non-sequence.

(e) Lower Cretaceous, Lower Valanginian.

Fauna 48.

Tollia groenlandica (Spath, 1936), p. 84 (M) + (m). Referred to *Subcraspedites* by Spath; including

Tollia ferruginea (Spath) (m) (as *Craspedites;* p. 86);

Tollia lepta (Spath) (m) (as *Craspedites;* p. 85).

Together 20 fragments and casts.

Considerably more material of this fauna has been collected. It occurs in about three of the succession of thin, ferruginous and phosphatic hard-grounds terminating and separating individual units in the rythmically-deposited sandstones of the Hennig Ryg Member of the lower Hartz Fjetd Formation, (Sykes and Brand, 1976). The quality of this new material is little better than previously, but the inclusion of pieces of the characteristically smooth and discoidal bodychambers of large macroconchs leaves the assignment to *Tollia* in little doubt. The age is thus lowest Valanginian, and the closest affinities are with Spitsbergen, northern Russia and arctic Siberia.

— Klimovskiensis Zone. (See Shulgina, 1972).

CHRONOSTRATIGRAPHY

The biostratigraphical horizons characterised by the faunal assemblages described in the previous section can now be used to define a scale of standard zones. We define each standard zone only in terms of its base, i.e., the lower of the two boundaries, located in a type-section. Its top, the upper boundary, is defined by the base of the succeeding zone, except when the zone is truncated in its type-section by what is manifestly a major non-sequence. In this way we arrive at a continuous scale of zones that is free of gaps and overlaps (e.g., Callomon and Donovan, 1974), a scale that may be used as a standard of reference in regional chronostratigraphical correlations. The choice of such standard zones is arbitrary but should be governed largely by criteria of usefulness and balance. The scheme proposed here is shown in Table 1.

(a) Kimmeridgian

The ammonite faunas of East Greenland are very similar to those of Britain but much sparser. They contribute therefore little that is new to generalised stratigraphy and may be classified within the existing standard zonation of the Kimmeridgian of Britain (Cope, 1980). The latter is itself being currently refined, most of its zones being certainly further divisible into subzones; and it may one day be preferable to adopt a subzonal scheme in Greenland and the Arctic based on the succession of Boreal *Amoeboceras* of faunas 20 - 22 rather than the species of sub-Boreal *Aulacostephanus* that dominate the Eudoxus Zone of Britain.

(b) Lower Volgian

Similar remarks apply. The ammonite faunas of Milne Land are barely distinguishable from those of Britain but again sparser, and contribute nothing new to the general succession.

(c) Middle Volgian

At this point the faunas of Greenland diverge from those of Britain and require a separate zonation. The zonal indices are illustrated in Plates 1 - 5.

(1) Zone of *Dorsoplanites primus sp. nov*.

Characterised by fauna 31, dominated by the first appearance of typical *Dorsoplanites.* Type section: Bays Bjerge (Figure 1), section 35, bed 9, 25 - 35 m above marker-bed with *Pectinatites pectinatus* of fauna 28.

(2) Zone of *Pavlovia iatriensis* llovaisky.

A horizon of *Pavlovia iatriensis* was first recognised by llovaisky in the banks of the rivers Yatria and Syortina in the eastern foothills of the subpolar Urals (llovaisky, 1917). Formal designation of zone in anything resembling modern usage appears to go back only to Bodylevsky (1944) or Mikhailov (1957); and a thorough revision of the regional stratigraphy by Mesezhnikov in the late 1950s is summarised by Zakharov and Mesezhnikov (1974). The faunas in East Greenland (no. 32) and West Siberia appear to be sufficiently similar to use the same zonal name. No type-section appears to have been formally designated so far, and we suggest Ilovaisky's classical locality on the right bank of the Yatria near the mouth of the tributary Bolshaya Lyulia, bed 9 (Golbert, Klimova and Saks, 1972, p. 27; Zakharov and Mesezhnikov, 1974, p, 31). The best reference-sections in Milne Land are on the south and east slopes of Kronen, section 23, bed 16. The pavlovids of this zone are easy to distinguish in the field from those above by their characteristically irregular ribbing.

(3) Zone of *Pavlovia rugosa* Spath.

Fauna 33: coarsely but regularly-ribbed evolute *Pavlovia*. Type section: N.W. ridge of Hartz Fjeld, section 22, beds 15 - 19.

(4) Zone of *Pavlovia communis* Spath.

Faunas 34 - 35. Small *Pavlovia* with extremely strongly-ribbed inflated body-chambers. Type section: E slopes of Hartz Fjeld, section 17, beds 12 - 14.

(5) Zone of *Dorsoplanites liostracus sp. nov*.

Faunas 36 - 37. The first of two zones characterised mainly by *Dorsoplanites*, the earlier forms having characteristically smooth macroconchs; also rather involute large *Pavlovia*. Type section: Bays Fjelde, sections 34 - 35, in non-glauconitic shales 0 - 10 m below the base of the first greensand of the Pernaryggen Member (''Glauconitic Series" of Aldinger and Spath).

(6) Zone *of Dorsoplanites gracilis* Spath.

Faunas 38 - 40. Although still dominated by *Dorsoplanites*, rather more coarsely-ribbed than the previous forms, the first true *Epipallasiceras* appears in fauna 40. There would have been some advantage, therefore, in putting this fauna already into the Pseudapertum Zone above in which the genus *Epipallasiceras* dominates. The microconchs of *Dorsoplanites* are all close to and include *D. gracilis* Spath, which has also been recorded from the northern U.S.S.R. It suggests itself therefore as the natural choice of index for the zone. Unfortunately, the type of *D. gracilis* also came from fauna 40, and to avoid possible confusion in the future it seems best to ensure that the type of the nominal index-species came from its nominal zone by still including fauna 40 in the Gracilis Zone. Type section: base, N.E. slopes of Hartz Fjeld, section 9, beds 11 - 13 (fauna 38); higher parts, E slopes, section 17, beds 20 - 27 (faunas 39, 40).

(7) Zone of *Epipaliasiceras pseudapertum* Spath.

Faunas 41 - 44. *Epipaliasiceras* characterises the lower part of the zone (faunas 41, 42), which is however carried upwards to include some higher faunas (43, 44) which are not by themselves particularly striking. Includes the horizon of the macroconch type of *Dorsoplanites maximus* Spath, a Greenland species that has been used as index of a Maximus Zone in the northern U.S.S.R. (Mesezhnikov, e.g., *in* Zakharov and Mesezhnikov, 1974). The macroconchs of *Dorsoplanites* are however rare and poorly known in this part of the succession in Greenland and the few specimens there are tend to be rather featureless. It is hard to judge whether the specimens ascribed to *D. maximus* in the northern Urals really are of the same "horizontal" species; one of those figured (Zakharov and Mesezhnikov, 1974, Plate 18, Plate 19, Figure 1) certainly is not. We prefer therefore not to use D. *maximus* as zonal index in Greenland and thus to avoid possible miscorrelation of two widely separated stratigraphical entities bearing the same name. Type section: base, Bays Fjelde, section 36, bed 3 (fauna 41); higher parts, Hartz Fjeld, section 17, beds 30 - 35; Kronen, section 23, bed 65 (fauna 44).

(8) Zone of *Crendonites anguinus* Spath.

Faunas 45 - 46. Easily recognised by the small, variocostate microconch pavlovids characteristic of *Crendonites*. Type section: Hartz Fjeld, eastern slopes, section 17, beds 37 - 38.

(9) Zone of *Laugeites groenlandicus* Spath.

Fauna 47. Represented in Milne Land by only a single faunal horizon, the *Lingula* Bed in the lower Hartz Fjeld Formation (sections 18, 19), which therefore defines the base of the zone. Its upper boundary is the base of the next higher zone, that of *Epilaugeites vogulicus* (Ilovaisky). This is defined in the region of the river Yatria in the north-eastern Urals (Zakharov and Mesezhnikov, 1974) but can also be recognized elsewhere in Greenland. In southern Jameson Land it is represented by scattered finds (Surlyk *et al.*, 1973, Plate 3, Figure 1) but in Wollaston Foreland its fauna occurs in sequence above a fauna of *Laugeites parvus* Donovan, with rare *L. groenlandicus* (Donovan, 1964, Surlyk, 1978, p. 28), indicating the presence of higher parts there of the Groenlandicus Zone than those known in Milne Land. A Groenlandicus Zone has also been used in the northern Urals, but it seems doubtful whether any of the material figured from there (Zakharov and Mesezhnikov, 1974) includes the true *L. groenlandicus*. Most of it seems referable to *L. lambecki* (Ilovaisky, 1917) (holotype Plate 22, Figure 2, and topotypes, in Mikhailov, 1966), closer to *L. parvus* Donovan.

(d) **Higher Zones**

The truncated Groenlandicus Zone of the middle Volgian is directly succeeded in Milne Land by some sparsely fossiliferous horizons assignable to the lower Valanginian. The large non-sequence is unmarked by any obvious lithological

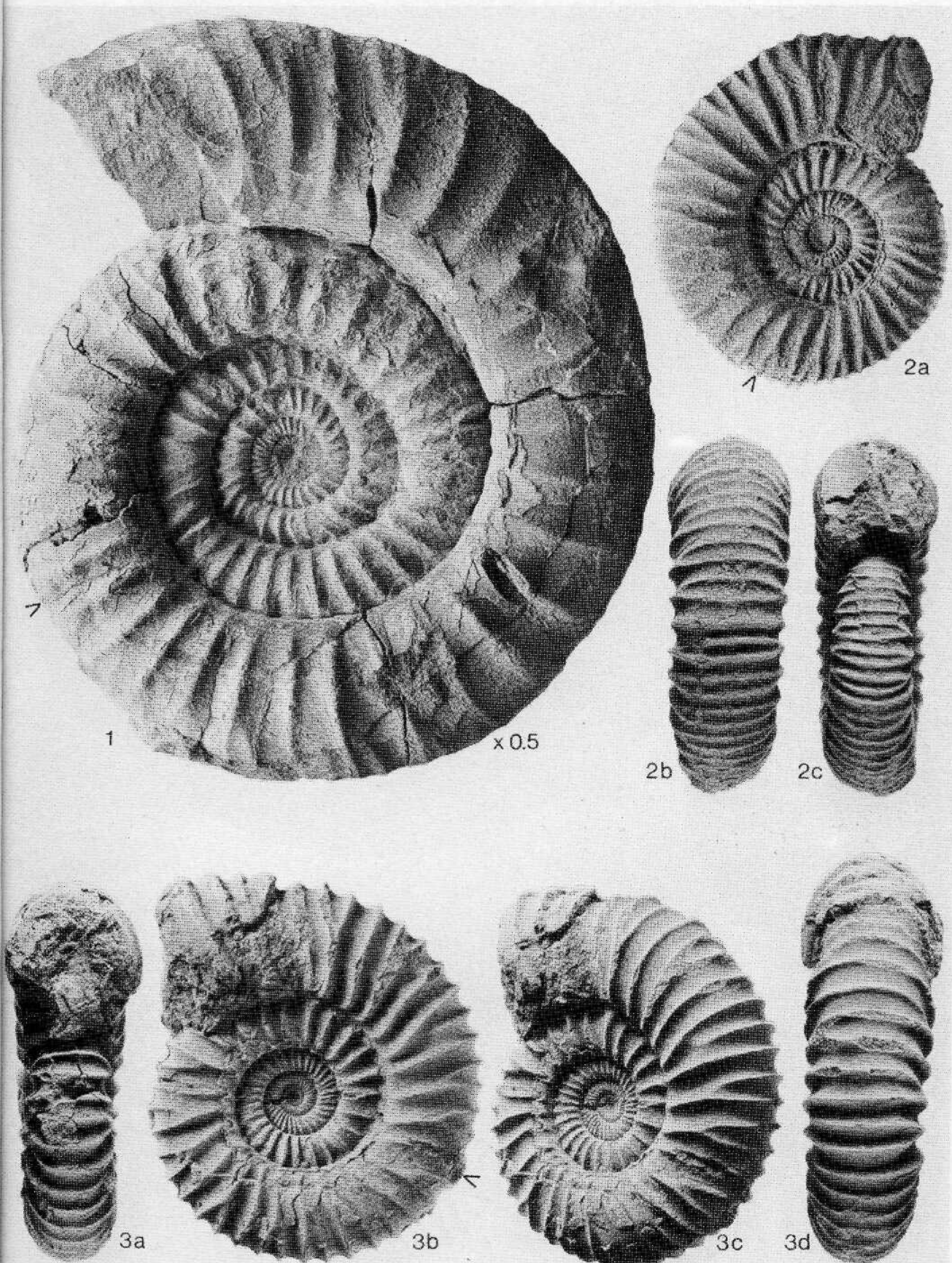

Plate 1. All figures natural size, except where stated; arrows mark last suture; photos by Jan Aagaard, Copenhagen.

Fig. 1. Dorsop/an/fes *primus sp. nov.* Holotype (M), MGUH 15898 (JHC 510), x 0.5; complete adult. Index, Primus Zone, fauna 31. Bays Fjelde, section 35, between 12 and 35 m above fauna 28.

Fig. 2a-c. *Pavlovia iatriensis* llovaisky (m), MGUH 15899 (JHC 767); complete adult with peristome, typical variant. Index, latriensis Zone; fauna 32. Kronen, south ridge, section 23, bed 16.

Fig. 3a-d. *Pavlov/a rugosa* Spath. Chorotype, (m), MGUH 15900 (GGU 234015); complete adult with peristome. Index, Rugosa Zone; fauna 33, Hartz Fjeld, N.W. ridge; section 22, bed 18.

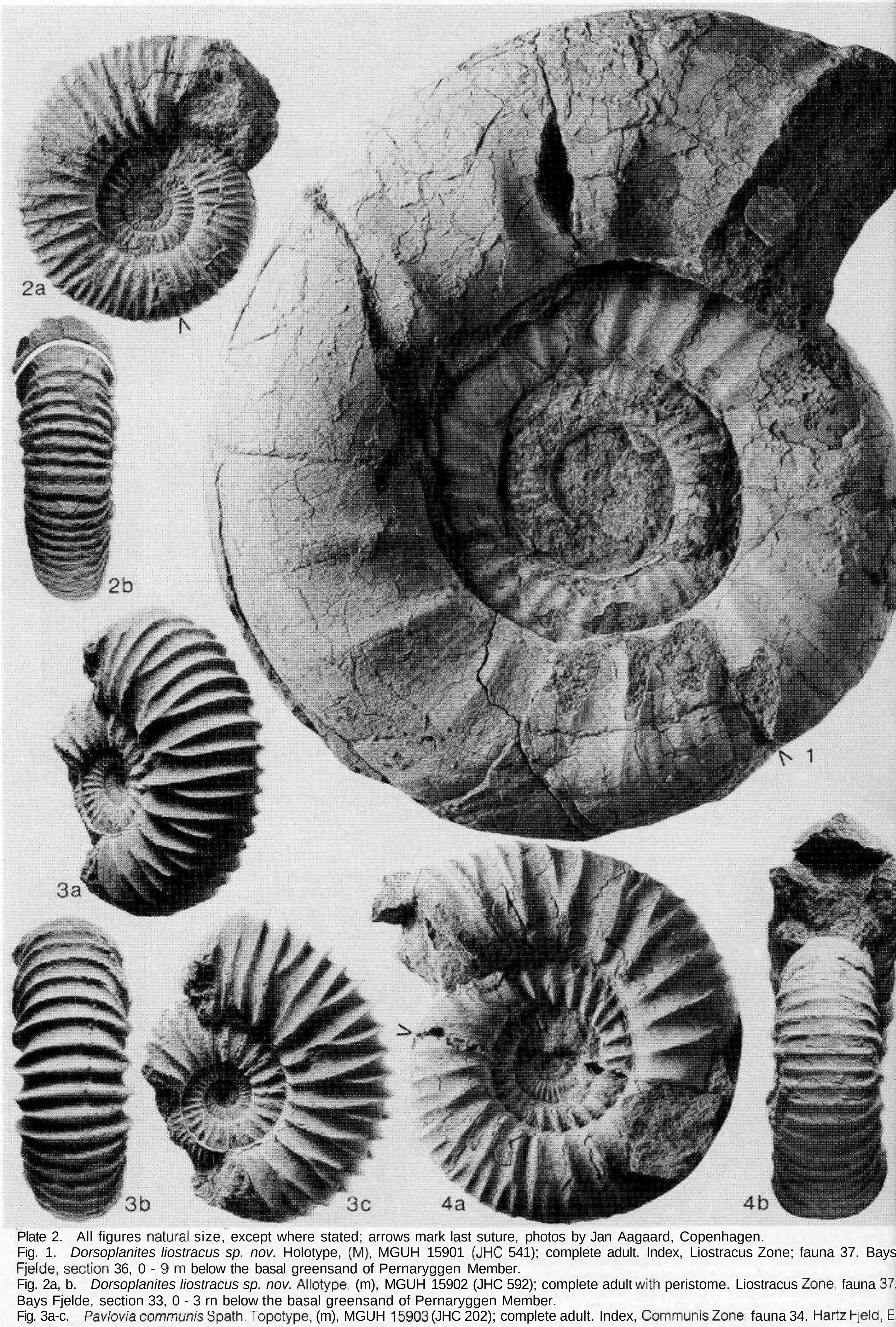

Plate 2. All figures natural size, except where stated; arrows mark last suture, photos by Jan Aagaard, Copenhagen.

Fig. 1. *Dorsoplanites liostracus sp. nov.* Holotype, (M), MGUH 15901 (JHC 541); complete adult. Index, Liostracus Zone; fauna 37. Bays Fjelde, section 36, 0 - 9 m below the basal greensand of Pernaryggen Member.

Fig. 2a, b. *Dorsoplanites liostracus sp. nov.* Allotype, (m), MGUH 15902 (JHC 592); complete adult with peristome. Liostracus Zone, fauna 37. Bays Fjelde, section 33, 0 - 3 rn below the basal greensand of Pernaryggen Member.

Fig. 3a-c. *Pavlovia communis* Spath. Topotype, (m), MGUH 15903 (JHC 202); complete adult. Index, Communis Zone; fauna 34. Hartz Fjeld, E. slope, section 17, bed 14.

Fig. 4a, b. *Pavlovia variocostata sp. nov.* Holotype, (m), MGUH 15904 (GGU 234090/2); complete adult. Communis Zone, fauna 35. Bays Fjelde, loose concretion S.W. of Ft 810 m; between 10 and 25 m below the basal greensand of Pernaryggen Member.

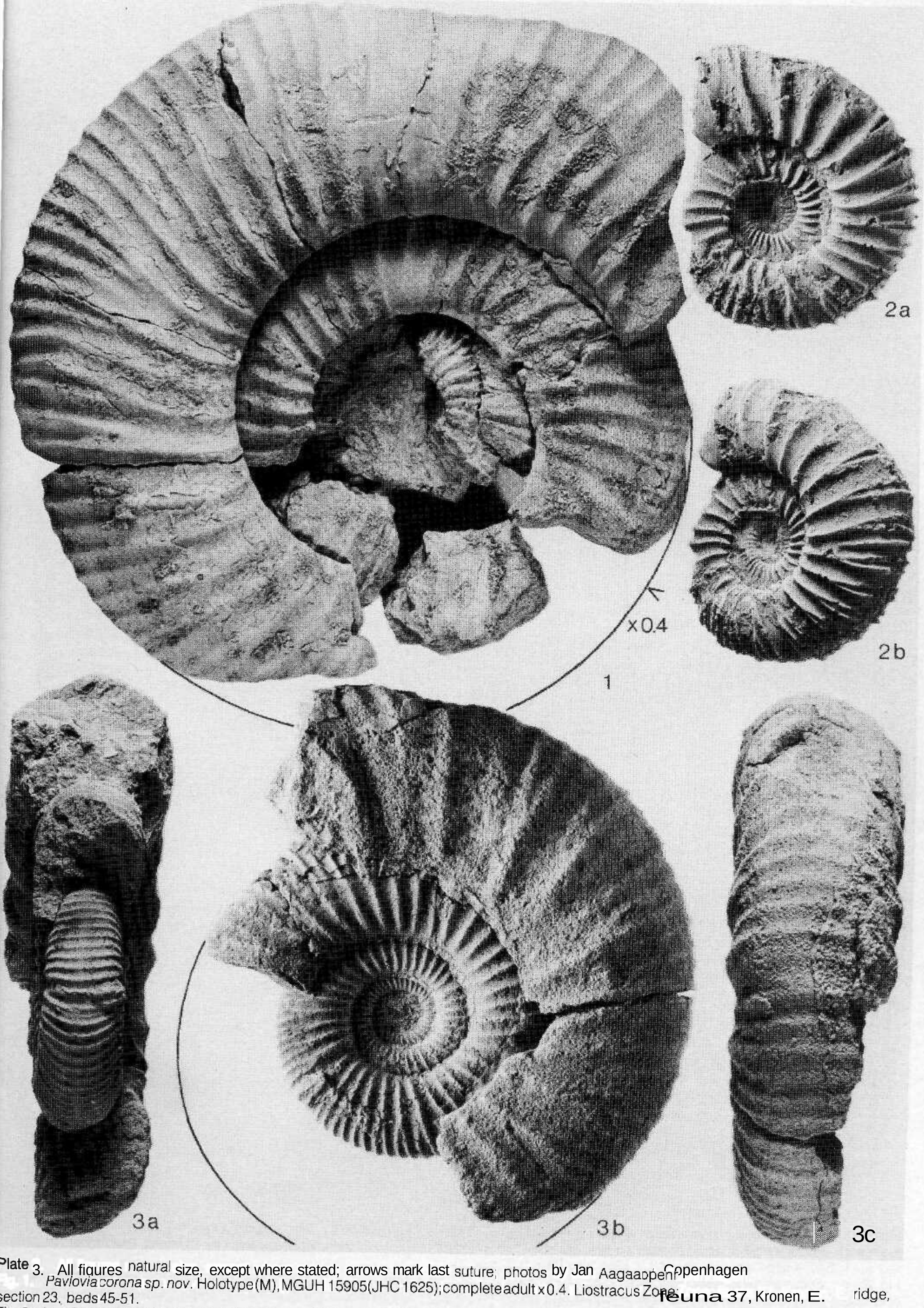

Plate 3. All figures natural size, except where stated; arrows mark last suture; photos by Jan Aagaard, Copenhagen

Fig. 1. *Pavlovia corona sp. nov.* Holotype (M), MGUH 15905 (JHC 1625); complete adult x 0.4. Liostracus Zone; fauna 37, Kronen, E. ridge, section 23, beds 45-51.

Fig. 2a, b. *Epipallasiceras acutifurcatum sp. nov.* Allotype, (m), MGUH 15906 (JHC 798); wholly septate but the last few sutures approximated and simplified. Pseudapertum Zone; fauna 41. Bays Fjelde, section 36, bed 3. (See also Plate 4, Figure 1).

Fig. 3a-c. *Dorsoplanites gracilis* Spath *s.s.* (ϵ). Topotype, (m), MGUH 15907 (JHC 265); nearly complete adult, the last half whorl body-chamber. Index, Gracilis Zone; fauna 40. Hartz Fjeld, E. slope, section 14, bed 15.

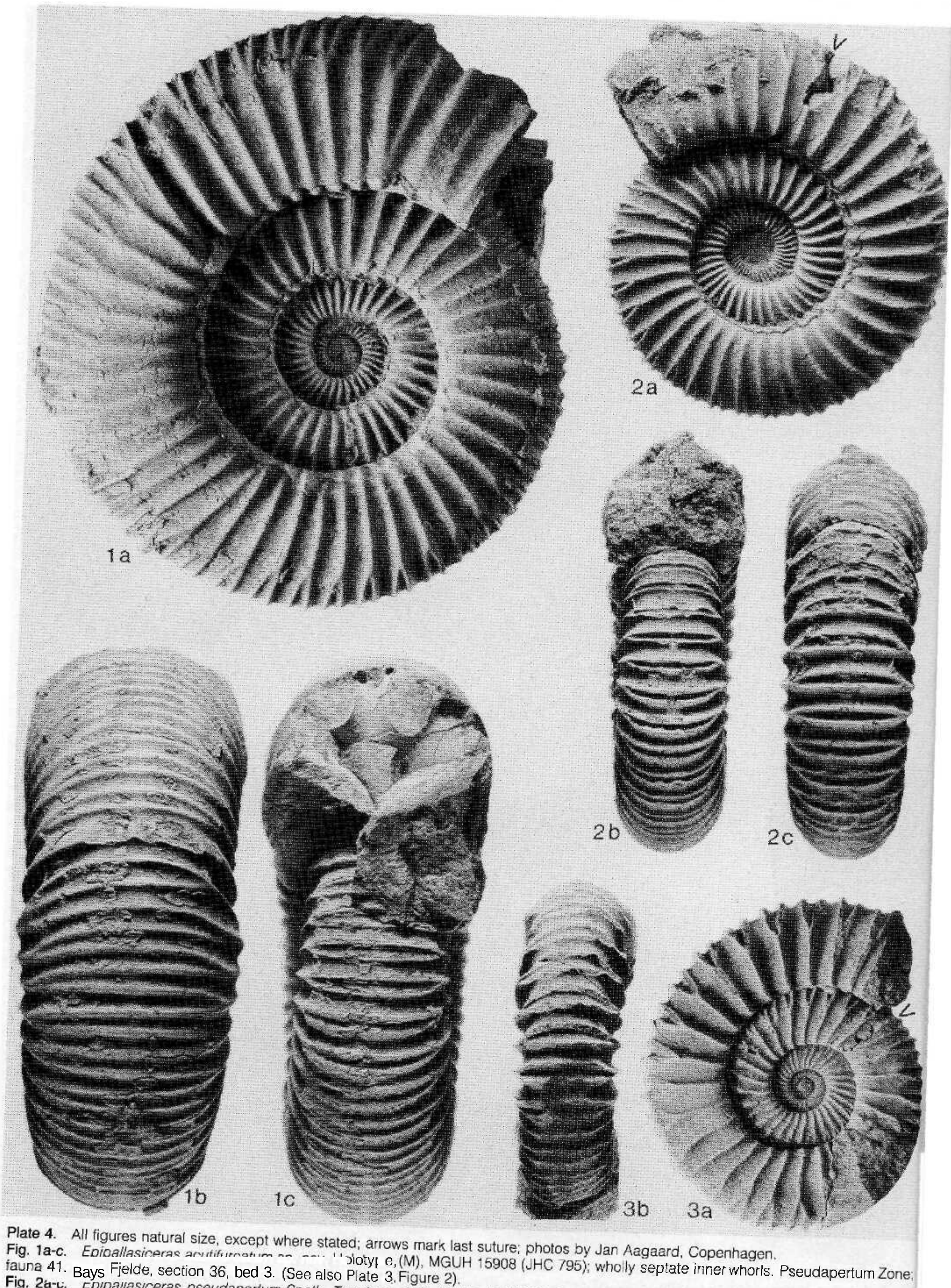

Plate 4. All figures natural size, except where stated; arrows mark last suture; photos by Jan Aagaard, Copenhagen.

Fig. 1a-c. *Epipallasiceras acutifurcatum* sp. nov. Holotype, (M), MGUH 15908 (JHC 795); wholly septate inner whorls. Pseudapertum Zone; fauna 41. Bays Fjelde, section 36, bed 3. (See also Plate 3, Figure 2).

Fig. 2a-c. *Epipallasiceras pseudapertum* Spath. Topotype, (m), MGUH 13909 (JHC 52), adult but incomplete, the last eighth of a whorl bodychamber and the final sutures approximated and simplified. Index, Pseudapertum Zone; fauna 42. Hartz Fjeld, E. slope, section 17, bed 30.

Fig. 3a, b. *Crendonites anguinus* Spath. Topotype, (m), MGUH 15910 (JHC 473); complete adult with peristome. Index, Anguinus Zone; fauna 46. Hartz Fjeld, E. slope, slipped beds near section 18, equivalent to section 17, bed 38.

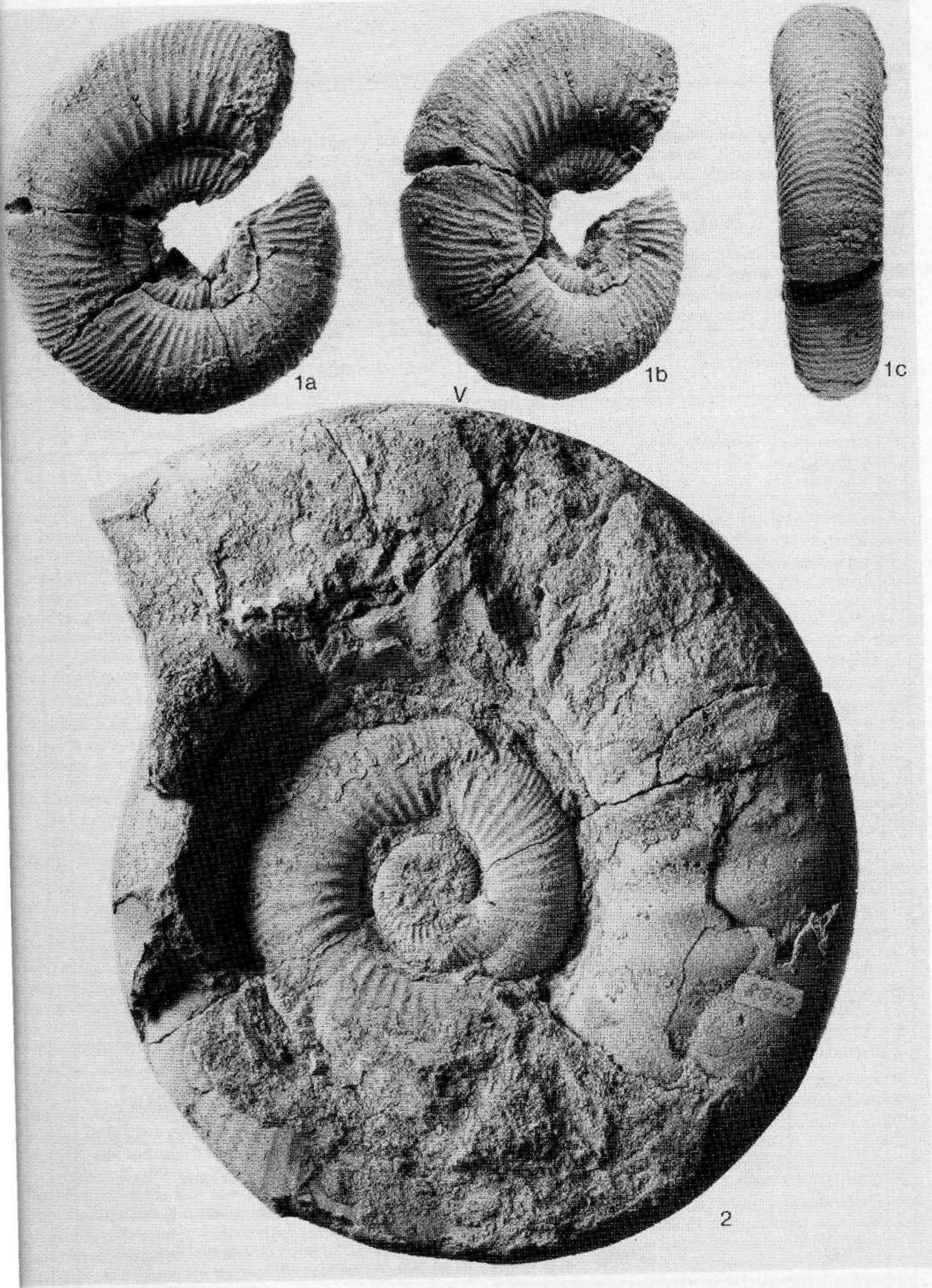

Plate 5. All figures natural size, except where stated; arrows mark last suture; photos by Jan Aagaard, Copenhagen.

Fig. 1a-c. *Dorsoplanites intermissus sp. nov.* Holotype, (m), MGUH 15911 (JHC 1567); wholly septate but probably complete phragmocone. Top Pseudaperta Zone; fauna 44. Kronen, E. ridge, section 23, bed 64.

Fig. 2. *Laugeites groenlandicus* Spath. Holotype, (M), MGUH 8342; the obverse side of the one figured by Spath (1936, Plate 38, Figure 1a), the last tenth whorl bodychamber. Inner whorls developed, to show the slightly flexuous, ventrally projected, finely fasciculate ribbing. Index, Groenlandicus Zone; fauna 47. Hartz Fjeld. S.E. ridge, at or near section 20, *Lingula* Bed.

break. Some of the missing faunas are found elsewhere in East Greenland (see Surlyk, 1978), but they contribute little to general chronostratigraphy and are not considered further here.

CORRELATION

Attempts to correlate the Volgian of Greenland with areas further afield raises many fascinating questions. A tentative correlation-chart for three other areas is shown in Table 3. Such charts are to a large degree conventional and in the absence of any estimates of absolute time-durations thei appearance depends much on the arbitrary choice of time scales. We take here as primary scale of reference the stand ard zonal succession in Britain giving the contiguous ful zones equal spacings. As the Table shows, close correla tions are so far only possible in relatively few parts of th columns and the choice of the English scale as the primar standard reveals what must be major non-sequences in th other columns, each of which would otherwise have beef shown as continuous in its own area.

Stage	ENGLAND	E GREENLAND	N & NW SIBERIA	VOLGA BASIN	Volgian
RYAZANIAN	Kochi	Kochi J W	Kochi	Kochi	RYAZANIAN
RYAZANIAN	Runctoni	(Maynci) J W; (*Chetaites* sp) J W =	Sibiricus; Chetae	Rjazanensis	RYAZANIAN
PORTLANDIAN	Lamplughi		Taimyrensis	?; Nodiger (Nodiger; Mosquensis)	UPPER
PORTLANDIAN	Preplicomphalus		Originalis	Subditus	UPPER
PORTLANDIAN	Primitivus	(Tenuicostatus) W	Okensis; Exoticus	Fulgens (Okensis; Fulgens)	UPPER
PORTLANDIAN	Oppressus (Oppressus; Anguiformis)		?	?	MIDDLE
PORTLANDIAN	Kerberus			Blakei	MIDDLE
PORTLANDIAN	Okusensis			?	MIDDLE
PORTLANDIAN	Glaucolithus	(Vogulicus) J W; Groenlandicus 47	Vogulicus; Groenlandicus	Nikitini	MIDDLE
PORTLANDIAN	Albani	Anguinus 46 45; Pseudapertum 43 44 41 42	*Crendonites* spp; Maximus	Virgatus (Rosanovi)	MIDDLE
UPPER KIMMERIDGIAN	Fittoni	Gracilis 39 40 38; Liostracus 37 36	Ilovaiskii; ?	Virgatus (Virgatus)	MIDDLE
UPPER KIMMERIDGIAN	Rotunda	Communis 35 34; Rugosa 33	?; Strajevskyi	Panderi (Zaraiskensis; Pavlowi)	MIDDLE
UPPER KIMMERIDGIAN	Pallasioides	Iatriensis 32; Primus 31	Iatriensis	?	LOWER
UPPER KIMMERIDGIAN	Pectinatus (Paravirgatus; Eastlecott'sis)	Pectinatus 29 30 28 27	Lideri	Tenuicostata	LOWER
UPPER KIMMERIDGIAN	Hudlestoni (Encombensis; Reisiformis)	Hudlestoni 26	?	Pseudoscythica	LOWER
UPPER KIMMERIDGIAN	Wheatley'sis (Wheatley'sis; Smedmor'sis)	Wheatleyensis 25	Subcrassum	Sokolovi	LOWER
UPPER KIMMERIDGIAN	Scitulus	Scitulus	Magnum	Sokolovi	LOWER
UPPER KIMMERIDGIAN	Elegans	Elegans 24	?	Klimovi	LOWER

Table 3. Correlation chart for the Volgian successions in the Boreal Realm. Numbers in the second column refer to the ammonite faunas Milne Land; J = Jameson Land, W = Wollaston Foreland.

(a) England

The Kimmeridgian-Portlandian part of the succession is based largely on the work of Cope and Wimbledon (summarised in Cope *et al.*, 1980), the higher part on that of Casey (1973). Oppressus and Anguiformis are shown as two subzones of the Oppressus Zone, for their faunas differ only to a minor degree. *Titanites (Paracraspedites) oppressus* Casey is the youngest form found at the top of the Portlandian, below the non-marine Purbeck Beds, in the Portlandian Province of southern England, and almost the oldest form found at the base of the transgressive Upper Volgian in the Spilsby Province of eastern England. It is probably little more than the microconch of the more familiar "Portland giants", including *T. (Titanites) anguiformis* Wimbledon and Cope (1978), from the Portland Freestone of southern England, immediately below. Oppressus then has priority for the name of the zone as a whole. (The Anguiformis Subzone together with the higher parts of the Kerberus Zone are equivalent to Salfeld's original Giganteus Zone (1914, p. 130, 203), but it now appears that Sowerby's syntypes of *Am. giganteus* came either from the lower Kerberus Zone or from the Glaucolithus Zone, i.e. the index of the Giganteus Zone did not occur in its nominal zone as originally defined.) The radical faunal break between the last of the titanitid Pavloviinae of the Oppressus Zone and the subcraspeditid Dorsoplanitinae of the Primitivus Zone, not linearly related, suggests that there may remain a considerable residual non-sequence in the English succession at this level.

Close correlation between all four columns is resumed at the top, in the zone of *Hectoroceras kochi*, whose index has been found in all four areas.

(b) Greenland

As stated previously, correlation with the lower Volgian of England presents no problems because of the occurrence common to both areas of *Pectinatites*. This genus also reached the northern Urals in the Pectinatus Zone. Below this, the links with Siberia are more tenuous because the forms endemic to that area, of the genus *Sphinctoceras*, were but rare visitors to Britain and Greenland. *S. cf.* or *aff. magnum* was found in fauna 24 in Greenland, and in England *S. crassum* occurs in the Wheatleyensis Zone and Subzone. Close correlation with the Russian Platform, on which the Volgian Stage is defined, is wholly problematical because its faunas of *Ilowaiskya* are endemic, found neither in Britain nor in Greenland. (The limits of the Volgian Stage are discussed further below.)

In the middle Volgian, direct correlations are possible here and there. *Dorsoplanites* appears first in the Primus Zone of Greenland, and the only known British occurrence of the genus, *D. ultimus* (Neaverson), is in the Hartwell Clay, Pallasioides Zone. The pavlovids of the Iatriensis Zone have their closest counterparts also in the English group of *P. pallasioides*, while the pavlovids of the Rugosa Zone can be compared in part with those of the lower Rotunda Zone of England and those of the Pavlowi Subzone of the Panderi Zone of the Volga Basin (e.g., in particular *P. menneri* Mikhailov, 1966). The Communis Zone correlates unambiguously in part with the Rotunda Zone of Dorset, although the boundaries almost certainly do not coincide. Contrary to widespread belief, "the" Rotunda Nodule Bed of Chapman's Pool is not a layer of concretions concentrated at a single level. The famous uncrushed ammonites occur scattered over a range of several metres of clay, and the zone encompasses a further considerable thickness of clays with abundant but crushed ammonites (Cope, 1978) whose closer comparison with the uncrushed material from Greenland is difficult.

Upwards, correlation becomes possible again in fauna 40 at the top of the Gracilis Zone, whose *Epipallasiceras rotundiforme* matches closely Buckman's *"Virgatites pallasianus* d'Orbigny sp." (1926, Plate 693) from the Massive Bed of Hounstout, Purbeck, the basal bed of the Albani Zone and hence of the Portlandian; Spath's *Crendonites pregorei* (1936, Plate 22, Figure 2) from slightly higher in the Albani Zone at the same locality; and other specimens from similar levels at Boulogne (Pellat collection) and Jutland (Birkelund and Pedersen, 1980). The giant *"Behemoth" groenlandicus* Spath (1936, Plates 23 - 24) from fauna 43 finds its closest English match with the large evolute pavtovids of the top Albani or lower Glaucolithus Zone (see previous discussion), not the "giants of the Portlandian" proper. The small *Crendonites* of the Anguinus Zone, which persist with little change into the *Laugeites groenlandicus* Zone, match closely the microconchs of the lower-middle Glaucolithus Zone, as Spath correctly perceived, and the importance of this correlation lies in fixing the age of the non-sequence that terminates the Volgian in Milne Land. It is also of great value in dating the genus *Laugeites,* with little doubt the root of the subsequent development of the Boreal Dorsoplanitinae that reappear in England in the Primitivus Zone as *Subcraspedites* and that led on to the Craspeditinae and hence all the other Boreal perisphinctids of the Polyptychitidae (Callomon 1981).

The higher faunas that occur sporadically in East Greenland correlate closely with their Siberian counterparts as shown, and are discussed by Surlyk (1978). *"Virgatosphinctes" tenuicostatus* Shulgina (1967) is a Siberian species well represented in Wollaston Foreland and is now ascribed to the genus *Praechetaites* Sazonova and Sazonov (1979) to avoid confusion with unrelated true *Virgatosphinctes* from the Sub-Austral lower Tithonian.

(c) Siberia

The successions are richly fossiliferous and have been well described, yet the present chart (based on Zakharov and Mesezhnikov (1974) for the lower-middle Volgian, and Shulgina (1972) for the upper Volgian-Ryazanian) indicates many non-sequences that may not have been suspected previously. Correlation of the Iatriensis Zone has already been discussed. A problem arises with the *Strajevskya strajevskyi* Zone immediately above. According to Zakharov and Mesezhnikov the faunas of the two zones overlap — hence their relegation to subzones of the latriensis Zone. Yet the closest resemblance of *St. strajevskyi* to the faunas of Greenland lies in the *Pavlovia* of the *P. communis* Zone there. Numerous concretions packed with ammonites that we cracked during a visit to the R. Yatria in 1977 contained either *P. iatriensis* s.l. or *St. strajevskyi* but not both. The Strajevskyi Zone may therefore range rather higher than shown in Table 3, with perhaps a non-sequence below it. The Ilovaiskii and Maximus Zones may well correlate with the zones shown opposite them in the Greenland column, although it would be necessary to lay the rather poorly time-diagnostic *Dorsoplanites* from both areas side by side to be sure. The last *Laugeites* of the Vogulicus Zone seems then to be followed by almost as great a non-sequence as that in Greenland, equivalent to most of the upper Portlandian of England.

In the Kheta River basin of North Siberia most of the middle Volgian appears to be missing. There is but a single fauna of *Epivirgatites variabilis* Shulgina, 1967, between beds with *Pectinatites* (Pectinatus Zone) and *Craspedites* (Okensis Zone), for which an *Epivirgatites variabilis* Zone was created (Shulgina, 1969). Its affinities may well be closest with the *Epivirgatites nikitini* Zone of the Russian Platform (see below), equivalent to the *Crendonites* Zone of the northern Urals and the lower Glaucolithus Zone of England, and not equivalent to the uppermost Portlandian as suggested by Casey (1973, p. 221).

Correlation of the upper Volgian with that of the Russian Platform is satisfactory up to a point a little below the base of the Cretaceous. The base of the Ryazanian, and hence the Boreal Jurassic-Cretaceous boundary as defined by the base of the Riazanensis Zone is not precisely recognizable either in Siberia or in Greenland. The Zone of *Chetaites chetae* is conventionally put still into the upper Volgian.

(d) Russian Platform — Volga Basin

The Table (based on Mikhailov, 1966; Gerasimov, 1969; Kutek and Zeiss, 1974; Casey, 1973; Mesezhnikov and Shulgina, 1977) expresses what continue to be largely unresolved problems of correlation deriving from the long-ranging endemism of the ammonites in the interior of the Russian Platform. In the lower Volgian it is the succession of forms of the genus *Ilowaiskya;* in the middle Volgian, of *Virgatites* and its allies; in the upper Volgian, of *Craspedites;* and in the lowest Ryazanian, of *Riasanites*. Points of contact with the other columns remain few.

The division of the Volgian into lower, middle and upper substages is a recent modification (Mikhailov, 1966, Gerasimov and Mikhailov, 1966) of the original division into lower and upper only, which itself has evolved over the years (see summary in Mikhailov, 1964). Today's Volgian, defined in terms of its lowest zone, is based on the succession on the river Berdyanka, close to the river Ural near Orenburg, at the type-locality of the *Ilowaiskya klimovi* Zone (Mikhailov, 1964, p. 383; Mikhailov and Gustomesov, 1964). The correlation of the base of the lower Volgian at least roughly with the lower-upper Kimmeridgian boundary *sensu anglico* seems well assured, largely on the basis of the genus *Gravesia* found in the Klimovi Zone on the Volga at Gorodistshe (the "stage lectostratotype'' of the Volgian, of Soviet authors; Mikhailov, 1964). The correlation of the base of the middle Volgian is much less certain. The highest lower Volgian of the Volga-Ural region belongs to the *Ilowaiskya pseudoscythica* Zone (the *I. tenuicostata* Zone was introduced for higher beds in Poland) and is immediately followed by the *Pavlovia pavlowi* Subzone of the *Dorsoplanites panderi* Zone. The pavlovids of this subzone suggest strongly a rough parallel with the Rugosa Zone of Greenland and something around the Pallasioides-Rotunda boundary in Britain. The fauna of the Pseudoscythica Zone, in contrast, seems much more reminiscent of the Wheatleyensis Zone of Britain and perhaps the Magnum-Subcrassum Zones of Siberia (in e.g., '*'Pectinatites'' ianschini* (Ilov.-Florensky) Mikhailov and Gustomesov, 1964, Plate 12, Figure 1, Plate 17, Figure 2: *Eosphinctoceras?)*, i.e. considerably lower. If true, there must thus be another faunal gap in the succession on the Volga; and the level at which the lower-middle Volgian boundary is conventionally drawn in Britain and Greenland would be rather lower than it is defined in the type area.

Higher in the succession, the group of *Evivirgatites nikitini* (Michalski, 1890) (lectotype Plate 12, Figure 5, refigured and designated by Arkell (1956), legend to Plate 46, Figure 6, from Kashpur on the Volga) has been equated with various levels of the English Portlandian, but the revisions of recent years led Wimbledon and Cope (1978) to reaffirm Arkell's correlation (1956, p. 489) by identifying it firmly in the Albani-Glaucolithus Zones. The presence of major non-sequences equivalent to most of the English Portlandian was first pointed out by Casey (1967) and seems indisputable. More recently (1973, p. 219) he suggested that most of the gap may lie betow the Nikitini Zone, but Cope's finds suggest the opposite view, as shown in Table 3. Amongst the thin and patchy phosphorites covering the Russian Platform there do appear to be occasional indications of the missing faunas. *Lomonossovella blakei* (Pavlow) has long been known from the area around Moscow (holotype refigured by Mikhailov, 1957, Plate 1, Figure 3) and appears to be a true *Kerberites* Buckman from the Kerberus Zone, as are associated *K. mosquensis* Mikhailov (1957, Plate 1, Figure 4), *K. portlandensis* Cox (= *Am, triplicatus* Blake, 1880, *non* Sowerby) (Pavlow, 1890, Plate 2, Figures 1, 2) and *K. (''Lomonossovella'') lomonossovi* (Vishniakov, 1882) (lectotype, here designated, Plate 2, Figure 4). The Blakei Zone (Moscow) and Nikitini Zone (Kashpur) thus seem to be well separated in time and not equivalent, as Pavlow and subsequently many others thought. Other finds indicate traces of the Oppressus Zone in the region of Kashpur (Casey, 1973, Plate 1, Figure 4).

The upper Volgian begins everywhere with the abrupt appearance of *Craspedites*. Correlation with England remains tentative, made more difficult by possibly the existence of a non-sequence below the Primitivus Zone in England as well. The problems are discussed by Casey (1973, p. 219). The closest correspondence he can suggest is between the Nodiger Zone and the Preplicomphalus Zone, in which true *Craspedites* has also been found.

CONCLUSION

The columns in Table 3 represent great advances in our knowledge made in the last 30 years, and the Table as a whole provides an interesting commentary on an age-old problem, the "problem of dissimilar faunas". The basic question is: are two faunas at two distant places dissimilar because of a difference in age, or because they belonged to two different faunal provinces? For the Mesozoic ammonites, on which so much chronostratigraphy depends, each view has had its adherents. The first advocates of faunal provincialism were of course Neumayr and Uhlig, and they have been followed by many. But on the other hand neither Buckman nor Spath could believe in provincialism as a major factor, Spath continuing to support to the end of his days (1952, p. 7, 39) what had now become elevated into "Buckman's doctrine of dissimilar faunas", that dissimilar faunas meant dissimilar ages (Buckman, 1923, p. 29 - 31) — applied to some of the very strata included in Table 3. What, then, is the verdict? Not surprisingly, that both sides are right. Considerable faunal gaps have become real, not just conjectural. But the Boreal Upper Jurassic also still provides classical examples of the difficulties that faunal provincialism can create in attempts to set up a general standard chronostratigraphy by biostratigraphical correlation. Local schemes continue to be necessary. The newly-established ammonite succession in East Greenland should provide a useful alternative standard of reference in an area in which the existing standards cannot be easily applied.

APPENDIX: DESCRIPTION or NEW SPECIES

Some six of the Volgian faunas listed above are made up of hitherto undescribed species. To avoid *nomina nuda* we give brief descriptions below. The material is in the Geological Museum of the University of Copenhagen (MGUH).

Genus *Dorsoplanites* Semenov, 1898

1. *Dorsoplanites primus n.sp.* (Plate 1, Figure 1).

Material: holotype (JHC 510). 6 paratypes, and 2 other specimens (M). Fauna 31.

Localities and horizons: S.E. slopes of Bays Bjerge, sections 33, 35 and 36, in concretions in shales, between 12 - 36 m above a well-defined bed with *Pectinatites pectinatus*, fauna 28.

Description: The holo- and paratypes are all adult macroconchs, slightly crushed, with some test preserved. Maximum diameters range from 200 to 430 mm (holotype 300 mm) with adult bodychambers of ¾ - % whorl. Coiling is evolute at all stages, the whorl-section round to oval, from slightly depressed to slightly compressed on the bodychamber. The ribbing is strong and fairly coarse, with straight, regular, slightly prorsiradiate sharp primaries on the inner whorls, furcating at about mid-flank at first into sharp pairs of secondaries, later into less regular and distinct twos and threes. The number of ribs per whorl is remarkabiy constant, varying in the holotype only between 28 and 32. The ribbing fades on the outer whorl, in some of the paratypes more than in the holotype, giving the adult bodychamber the rather smoothish appearance now generally regarded as characteristic of *Dorsoptanites* macroconchs. It does not however, die out altogether, even the secondaries persisting to the end with some resimplification to bifurcation with intercalatories. The species is thus only mildly variocostate. Constrictions on inner and middle whorls are strong and deep. The microconchs have not yet been identified, and appear to be rare at this horizon in Milne Land.

The species is in many ways intermediate between *Pectinatites*, *Pavlovia* and the more typical later *Dorsoplanites* (see *D. liostracus* below). The more evolute, inflated and coarsely-ribbed inner whorls mark a departure from the style of *Pectinatites*, and the relatively sparse and subdued ribbing on the adult bodychamber is in contrast with that found in most *Pavlovia*, including its earliest representatives or intermediates to *Pectinatites*, *Paravirgatites*. It seems therefore to be the earliest fauna to be clearly separable from both *Pectinatites* and *Pavlovia* with at least some of the typical features of *Dorsoplanites*, and we therefore name it accordingly.

2. *Dorsoplanites liostracus n.sp.* (Plate 2. Figures 1, 2).

Material: Holotype (JHC 541), 6 paratypes (M): allotype (paratype of opposite sex to holotype) (JHC 592) and several other specimens out of the same concretion (m); and other specimens and fragments. In all, about 18 (M) and 18 (m). Fauna 37.

Localities and horizons: S.E. slopes of Bays Fjelde, sections 33 - 36 between 10 - 13 m below the lowest prominent glauconite, in concretions in non-glauconitic micaceous shales.

Description: The species is defined in terms of its holo- and paratypes, all macroconchs. It is relatively small, the holotype attaining only 175 mm, the other specimens perhaps around 200 mm. Coiling is round-whorled and evolute at all stages, the bodychambers tending to become depressed. Inner ribs are strongly and densely ribbed (25 - 35 primaries per whorl), but the most characteristic feature of the species is the fairly sudden change in style at about the end of the phragmocone, the primaries changing to subdued distantly spaced ridges (10 - 15 per whorl) and the secondaries fading almost altogether. In the transitional region the ribbing is characteristically irregular.

The microconchs are typified by the example figured: strongly ribbed, the adult bodychamber slightly variocostate and irregularly ribbed, the inner whorls strongly constricted, the pcristome with a slight terminal constriction and ventrally projected collar reminiscent of ancestral *Pectinatites*. Similar microconchs occur in several of the other faunas.

3. *Dorsoplanites intermissus n.sp.* (Plate 5, Figure 1).

Material: Holotype (JHC 1567) and 3 paratypes (GGU 234092); all microconchs. Fauna 44.

Localities and horizon: Kronen, cast ridge, section 23. bed 64. near the top of the glauconites, and Bays Fjelde, further N.W. outcrop on the summit ridge, top bed of the glauconites. Common and easy to recognise, but decomposing pyrite makes extraction difficult.

Description: The holotype is entirely septate at its maximum diameter of 77 mm as is one of the paratypes. Another, however, is adult and septate to 65 mm, with a piece of the bodychamber preserved and the last two septa crowded together. Coiling and style of ribbing are very much as in the common, earlier. *D, gracilis*, compressed and prominently constricted. The characteristic feature is however the fineness and density of the ribbing (53 primaries on the last whorl of the type), subdued at all stages and finally almost fading, and pronounced forward projection of the secondaries on the venter. These are the characters that distinguish *Dorsoplanites* from *Laugeites*, and the present species is exactly intermediate. The next stage in the evolution may well be represented by the forms described as *Laugeites plaints* or *L. borealis* by Mesezhnikov (Zakharov and Mesezhnikov, 1974. 127 - 130), from the northern Urals, but these are all smaller, more compressed and more delicately-ribbed than *D. intermissus*.

Genus *Pavlovia* Ilovaisky, 1917.

4. *Pavlovia variocostata n.sp.* (Plate 2, Figure 4).

Material: The holotype (GGU 234090/2) and 12 paratypes out of the same concretion; and another 17 specimens and fragments, in part also out of the same concretion. All microconchs. Fauna 35.

Localities and horizons: Bays Fjelde, S.E. slope, from concretions crowded with ammonites lying between ca. 50 - 60 m above the *pectinatus* bed (fauna 28) and 10 - 20 m below the lowest glauconite.

Description: The presence of 10 - 20 ammonites together in a single concretion, embedded at all angles, provides an unusually good opportunity of observing the variability of what must have been an exactly contemporaneous assemblage. In the present case this variability is almost hard to believe. All the specimens appear to be adult, with trumpet-like peristome preserved. The maximum sizes range from 40 - 130 mm; the coiling from involute to evolute (umbilical width 35 - 50% of the diameter) and compressed to inflated (30 - 45%). All share one feature however: the sudden modification of the ribbing on the adult bodychamber, from the regular, strong, dense bifurcation on the inner whorls to more subdued, irregular widely-spaced and extremely coarse bifurcating secondaries. This distinguishes the assemblage from e.g., *P. iatriensis*. The holotype is typical and near the centre of the range of variation. Such a high variability seems to be a feature of the genus *Pavlovia*. for it is met time and time again: in the *P. iatriensis* assemblages described above (fauna 32) and by Ilovaisky; in the *P. communis* assemblage (fauna 34) and its analogue *P. rotunda* in Dorset, England; in *''Strajevskya' strajevskyi* (including *hoffmani* (Ilovaisky) from the northern Urals; and the *Crendonites anguinus* assemblage (fauna 46).

The macroconchs of this fauna have yet to be positively identified.

Pavlovia corona n.sp. (Plate 3, Figure 1).

Material: The holotype (JHC 1625), three paratypes (macroconchs) and about 4 inner whorls or parts of microconchs.

Localities and horizons: Kronen, east ridge, section 23, beds 45 - 51 (the holotype); Bays Fjelde, S.E. slope, in non-glauconitic shales ca. 10 m below the lowest glauconite, associated with *Dorsoplanites liostracus*. Fauna 37.

Description: This large species almost qualifies as the first of the "giants of the Portlandian". The holotype has a diameter of ca. 400 m, is septate to ca. 230 mm and has almost a whole whorl of bodychamber. The paratypes are preserved to somewhat lesser diameters, but must have been of comparable size when complete. The inner whorls have the evolute coiling, the rounded slightly depressed section and strong, regular biplicate ribbing of classical *Pavlovia* of the *rotunda* group (*cf. P. rotunda gibbosa* Buckman, in Cope, 1978 on Plates 50 - 52), but the outer whorls revert to the slightly more involute, compressed and densely, flexuously ribbed style of the earlier *Paravirgatites*. The whorl-section is then somewhat ogivale, crown-shaped (hence the new name). The ribbing remains strong to the end, so that the species is only barely perceptibly variocostate in the macroconch, in common with most other *Pavlovia*. It occurs together with the highly variocostate *Dorsoplanites liostracus*, and the distinction between the two genera as separate entities at this level could hardly be clearer.

Genus *Epipallasiceras* Spath, 1936.

Epipaliasiceras was introduced by Spath as a subgenus of *Pavlovia*, and in a systematic evaluation of the group as a whole such ranking would be fully justified. In the present work, which is primarily stratigraphical, we drop the distinction on grounds purely of convenience and refer to the group as just *EpipaUasiceras* for simplicity. As genera and subgenera are co-ordinate in nomenclature such abbreviation has no formal consequences.

6. *Epipallasiceras acutifurcatum n. sp.* (Plate 3. Figure 2; Plate 4, Figure 1).

Material: The holotype (JHC 795), three paratypes. inner whorls and fragments, together some 13 macroconchs; allotype (JHC 798) and other specimens, together some 26 microconchs. Fauna 41.

Localities and horizons: S.E. Hartz Fjeld, section 17, bed 28; Bays Fjelde, section 36, bed 3 — the types and most of the well-preserved material, in glauconitic ironstone.

Description: The holotype illustrates well the beautifully regular, straight and sharp ribbing on whorls with consistently depressed section. It is wholly septate at 120 mm, as are the paratypes. There are fragments also still septate at 170 mm, so complete macroconchs may have attained a considerable size. The closely-paired but well-separated sharp secondaries characteristic of *Epipallasiceras* are found on the inner whorls of the macroconchs only, reverting to more normal *Pavlovia*-like style as the shell grew. In the microconchs, the pairing of the secondaries is acute and attains the adult bodychamber.

This is the second of three faunas of *Epipallasiceras* in Greenland. It resembles quite closely the third, that of *E. pseudapertum* already amply illustrated by Spath. It differs from it in being consistently more inflated and depressed, round-whorled rather than subquadrate; with microconchs that are smaller, have a more arched and angular venter and show the bifurcate ribbing more acutely. Individual variants may be hard to place, but the assemblages as a whole are readily distinguished.

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