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Abstract

This stratigraphical analysis is concentrated on the Brentskardhaugen conglomerate bed, which is a regional marker horizon, separating shallow shelf to marginal marine deposits of the Wilhelmøya Formation (Norian — Toarcian) from deeper shelf deposits of the Janusfjellet Formation (Callovian — Hauterivian).

The conglomerate is a remaniė deposit containing phosphorite, chert and quartz pebbles in a sandy carbonate matrix. The bed was formed by condensation of Toarcian, Aalenian and Bajocian deposits as shown by its fossil content consisting mainly of bivalves and ammonites.

Based on information derived from the Brentskardhaugen Bed and adjacent strata, the Lower and Middle Jurassic development of Spitsbergen may be summarized as follows. After a Lower Jurassic regressive period a transgression culminated in the Toarcian and decreased in effect upwards in the Middle Jurassic. This transgression introduced shallow shelf to marginal marine conditions to Spitsbergen with formation of the phosphorite pebbles of the Brentskardhaugen Bed. The pebbles were formed by concretionary growth of apatite around sites of organic decay, and contain early diagenetic francolite cement and carbonate replacements. These deposits underwent erosion and reworking during a regression culminating probably in the Bathonian. A new reworking, and final deposition of the Brentskardhaugen Bed have taken place during the late Bathonian transgression.

The paleontological analysis includes fossils from the Brentskardhaugen Bed and Wilhelmøya Formation. Totally 3 brachiopod, 24 bivalve, 10 ammonite and 2 decapod taxa are distinguished. The majority of these are illustrated.

1. Introduction

1.1 *The scope of the study*

The present paper is concentrated on the Brentskardhaugen conglomerate and adjacent strata in central Spitsbergen (Fig. 1). This remaniė bed has an average thickness of 60 cm in the studied areas, and is characterized by a high content of fossil bearing phosphatic clasts. Its wide regional distribution and characteristic lithology make it an important marker horizon separating the deltaic to shallow marine sand-shale sequence of the Kapp Toscana Group from the marine dark shale succession of the Janusfjellet Formation. The Brentskardhaugen Bed is present in its typical development in all areas of Svalbard where the junction between these two units is preserved, except Kong Karls Land and north eastern Spitsbergen.

The purpose of the present study has been to throw some new light on the Lower and Middle Jurassic history of Spitsbergen through a combined sedimentological and paleontological analysis of the conglomerate, the dating of the different depositional events, and the origin of the pebbles found within the bed.

1.2 *Previous work*

Stratigraphical information on the Brentskardhaugen Bed is spread in a large number of papers, and only those which are of special importance to the present study are included in the following account.

Three papers by Frebold (1929a, b; 1930) contain extensive faunal descriptions from the Brentskardhaugen Bed which he referred to the Upper Liassic. The name «Brentskardhaugen Bed» was introduced by Parker (1967) for the «Lias Conglomerate» of earlier authors. He in-

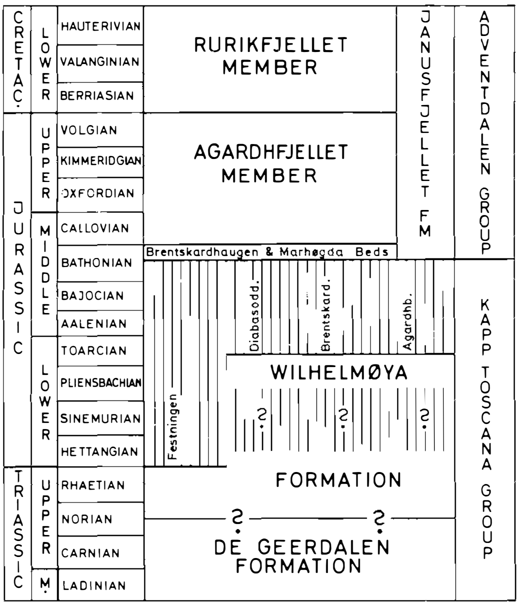

Fig. 1. Lithostratigraphical scheme and age relationships of Jurassic and adjacent deposits in central Spitsbergen.

cluded the bed in the Kapp Toscana Group because of its content of reworked material from that group, and because of its well-marked upper boundary. On the other hand Flood et al. (1971) and Birkenmajer (1975) regarded the Brentskardhaugen Bed as a basal unit of the Janusfjellet Formation mainly because of the presence of an extensive hiatus at its base. As seen in more recent literature, there is still a divergence about the formation assignment of this bed.

A description of the fossil content of the Brentskardhaugen Bed in southern Spitsbergen (SW Torell Land) is published by Birkenmajer & Pugaczewska (1975). The faunas described in that paper are dominated by bivalves and ammonites, but a few gastropods and brachiopods are also reported. The authors concluded that the assemblages found in the bed are mixtures of species representing the Toarcian-Bajocian interval.

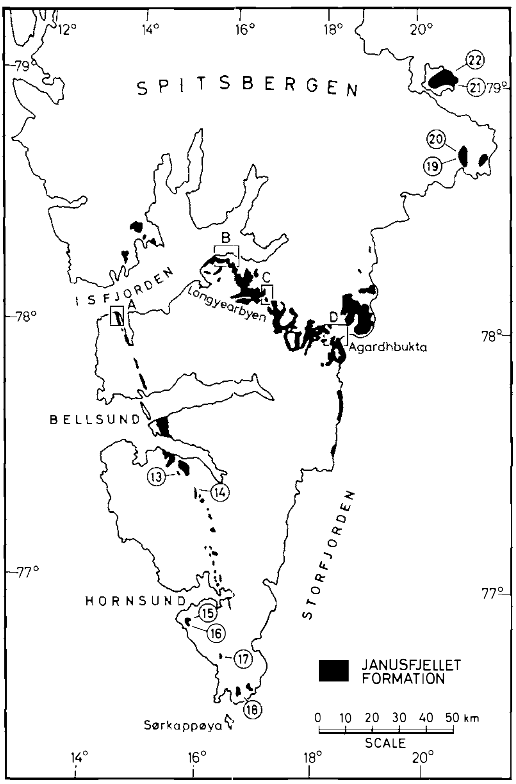

Fig. 2. Location map showing the distribution of the Janusfjellet Formation in Spitsbergen. The boxed areas A to D are reproduced on a larger scale in Fig. 3 where the position of localities 1 to 12 is marked. The position of localities 13 to 22 is shown on this map.

Extensive correlations within the Upper Triassic to Middle Jurassic succession of Svalbard are published by Pcelina (1980). The paper includes the Brentskardhaugen Bed and adjacent strata in western and central parts of Spitsbergen as well as equivalent deposits in eastern areas.

The faunas of the Brentskardhaugen Bed along the southern coast of Sassenfjorden are recently treated by Wierzbowski et al. (1981). Aslo here, the assemblages consist mostly of bivalves and ammonites, but some gastropods, serpulids, and crinoids are also present. According to that paper the age of these assemblages is Middle Toarcian to Early Aalenian.

1.3 *The investigated localities*

The present paper is based on field data and samples collected from 22 localities. Detailed field work was made during the summers of 1976, 1977 and 1978 in four areas in central Spitsbergen where 12 of the localities are situated. The positions of these localities are shown on Fig. 3. The other localities are scattered over southern and northeastern Spitsbergen, and their positions are marked on Fig. 2. A list of the localities is given below:

Festningen area:
Loc. 1 West of Festningen
» 2 Vardebreen

Diabasodden area:
Loc. 3 Deltaneset
» 4 East of Konusdalen
» 5 Marhøgda
» 6 Wimandalen
» 7 Knorringfjellet

Brentskardet area:
Loc. 8 Juvdalskampen
» 9 Drønbreen

Agardhbukta area:
Loc. 10, 11 Klementievfjellet
» 12 Rurikfjellet

Southern Spitsbergen:

Loc. 13 Leinryggen
» 14 Lågryggen
» 15 Lidfjellet
» 16 Liddalen
» 17 Karentoppen
» 18 Kistefjellet

Northeastern Spitsbergen:

Loc. 19 Hellwaldfjellet, 29 m below top of Wilhelmøya Fm.
» 20 Hellwaldfjellet, at the top of Wilhelmøya Fm.
» 21 Wilhelmøya, 7 m above base of Wilhelmøya Fm.
» 22 Wilhelmøya, 10 m below top of Wilhelmøya Fm.

At localities 1—12 and 14, field data and fossils are collected by the authors; at localities 13 and 15—17, fossils are collected by E. Nysæther; and at localities 18—22, fossils are collected by D. Worsley.

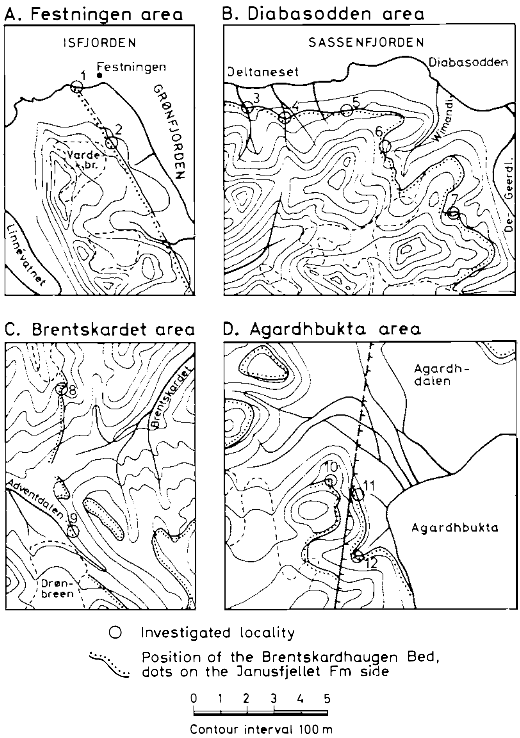

Fig. 3. Detail maps of four areas showing position of localities 1—12.

1.4 *Sedimentological methods*

The grain-size distribution of the clastic material in the phosphorite pebbles was determined by the conventional sieving method. The apatite cement of the pebbles was dissovled in dilute hydrochloric acid.

Pulverized samples were analyzed for bulk mineralogical content by the X-ray powder diffraction method. The mineral identifications are based on Berry (1974) and Fang & Bloss (1966).

The chemical composition of the phosphorite pebbles was determined by X-ray fluorescence spectrometry analyses of samples fused into glass pills. The precision of the procedure is estimated to be better than $\pm$ 4% of the results achieved.

The chemical composition of rim cement around quartz grains in a phosphorite pebble was studied by energy dispersive analysis of a thin section by means of electron microscope.

1.5 *Paleontological material and methods*

The fossil collection discussed in this paper consists mainly of bivalves and ammonites, but in addition a few belemnites and brachiopods are included. The fossils are preserved in well rounded phosphorite pebbles. Most of the ammonites and bivalves at hand are internal molds, sometimes with attached fragments of the shell. A few of the specimens are represented only by external molds.

On the surface of some internal molds of bivalves, muscle scars and the palial line could be observed. On a few internal molds of ammonites the sutures were visible without preparation.

The methods for preparation and drawing of suture lines are in accordance with the procedures described by Nagy (1970). Exceptions are two small ammonites of which the sutures were traced by means of a camera lucida mounted on a stereo-microscope, and one ammonite of which the sutures were obtained from an enlarged photograph.

The whorl sections of the ammonites have been drawn by the following method: A latex cast of the ammonite was made, whereafter the cast was cut at the selected cross section. A print of the cross section was obtained by using ordinary print blacking, and a drawing of the outline of the whorl was then made.

The internal and external molds figured on the plates were coloured with a light grey poster paint to achieve a homogeneous and favourable colour for photographing. Some of the photographs shown on the plates are made from latex casts of external molds. When making the casts, pulverized coal was mixed into the latex to achieve the same colour as on the natural molds. A single-lens reflex camera with a 50 mm macro lens was used when photographing the fossils.

2. Regional stratigraphy of the conglomerate and adjacent strata

2.1 *General features of the Brentskardhaugen Bed*

In the areas studied in central Spitsbergen the thickness of the Brentskardhaugen Bed (Table 1) varies from 5 cm (west of Festningen) to 135 cm (east of Konusdalen). The unit rests with an erosive basal contact on the Wilhelmøya Formation. The erosive nature of this boundary is expressed by its uneven surface, and by the fact that the beds underlying the conglomerate differ in lithology from place to place over short distances.

The bed contains varying amounts of quartz, chert and phosphorite pebbles floating in a matrix of medium- to coarse-grained quartz and cemented by microsparitic Fe-rich dolomite. The quartz and chert pebbles are usually well rounded, show an excellent sorting, and have a mean diameter of about 1 cm. The phosphorite pebbles are also well rounded, but vary considerably in size (from less than 0.5 cm to 30 cm), and have a mean diameter of about 5 cm. Their colour varies from dark-grey to black on freshly fractured surfaces, and red-brown to brown when weathered.

The amount of pebbles is strongly variable within the unit, both horizontally and vertically. At some localities the conglomerate is clast supported, while at other places it is matrix supported with only a minor content of pebbly material. The phosphorite pebbles usually contain a comparatively rich marine fauna, while no fossils have been observed in the matrix, and sedimentary structures (like cross bedding and bioturbation) are very scarce.

The conglomerate is usually well consolidated, but at some localities the pebbles could be picked out by hand from a matrix consisting of almost unconsolidated sand.

Table 1. *The thickness of the Brentskardhaugen Bed and the overlying Marhøgda Bed at the investigated localities in central Spitsbergen.*

Area	*Locality number-name*	*Thickness in cm*	
		Brentskard-haugen Bed	*Marhøgda Bed*
Festningen	1-West of Festningen	5	40
	2-Vardebreen	45	covered
Marhøgda	3-Deltaneset	120 [x)]	150 [x)]
	4-East of Konusdalen	135	150 [x)]
	5-Marhøgda	40—60	150
	6-Wimandalen	45	130
	7-Knorringfjellet	45	120
Brentskardet	8-Juvdalskampen	covered	covered
	9-Drønbreen	100—130	30
Agardhbukta	10-Klementievfjellet	covered	covered
	11-Klementievfjellet	15 [x)]	100 [x)]
	12-Rurikfjellet	removed	removed

[x)] Upper part covered, or removed by Quaternary erosion.

2.2 *Description of the Marhøgda Bed*

In the Diabasodden and Brentskardet areas the Brentskardhaugen Bed passes gradually upwards into a 30—150 cm thick microsparitic limestone, partially dolomitized and sideritized, containing some quartz and chert grains, ooids and glauconite (Fig. 6). The name «Marhøgda Bed» is here proposed for this unit. Its type section is on Marhøgda, locality 5 (Fig. 3) where its thickness is 1.5 m.

On freshly fractured surfaces the ooids appear as light grey, rounded structures (1—2 mm in diameter) in a dark grey carbonate matrix. Some bioturbation was observed in the bed, and a few indeterminable belemnites were also found. The bed weathers into white, light grey and reddish colours which are easy to recognize in the field. Scattered pebbles of quartz, chert and phosphorite occurring in the lower part of the bed accord with the gradational contact between this unit and the underlying Brentskardhaugen conglomerate. In the Diabasodden area and at Drønbreen the Marhøgda Bed is overlain by silty strata which pass upwards into the shales typical of the Agardhfjellet Member.

The Marhøgda Bed was recognized in its typical development, with ooids, in the Diabasodden and Brentskardet areas. A light grey to reddish weathering carbonate bed is, however, also present at Festningen and on Klementievfjellet just above the Brentskardhaugen conglomerate. At both localities it shows the same lithology as in the type section, except that ooids were not recognizable in the field nor in thin sections.

2.3 *Festningen area*

The section measured at locality 1 starts with a phosphorite conglomerate regarded as the base of the Wilhelmøya Formation (Fig. 4). This formation is 17.5 m thick and consists of cross bedded, bioturbated sandstones with thick mudstone intercalations in the lower half. The marine character of the unit is indicated by its content of saurian bones and marine types of trace fossils. The upper half of the unit consists of two coarsening upward sequences interpreted as barrier sand bodies. The top of the formation contains Rhaetian palynomorphs according to T. Bjærke (pers. comm.).

The Wilhelmøya Formation is overlain by the Brentskardhaugen Bed which is developed as a 5 cm thick conglomeratic sandstone containing pebbles of quartz, chert and phosphorite. The same bed reaches a thickness of 45 cm at locality 2, east of Vardebreen.

2.4 *Diabasodden area*

Five localities were studied in this area where the most complete section was found on Marhøgda. The thickness of the Brentskardhaugen bed varies from 40 to 135 cm, and its content of pebbles shows marked local differences. The lower boundary of the bed is always sharp with the conglomerate resting on an uneven surface of shale, sandstone or silty limestone (Fig. 5). Its upper boundary, toward the Marhøgda carbonate bed (Fig. 6), is gradational. This carbonate bed passes again gradually into the overlying silty shales which are typical for the lowermost part of the Agardhfjellet Member.

The pebbles in the Brentskardhaugen Bed were counted and grouped after lithology at localities 5 and 6 in the lower 30 cm of the bed, and at locality 4 in the interval 75—120 cm above the base. At localities 5 and 6 the lower 30 cm of the bed is well consolidated and matrix supported while the upper 15 cm is unconsolidated and therefore not suitable for pebble counting in the field. This upper portion is clast supported and was probably deposited under increased energy conditions.

As it appears from Figs. 7 and 8, chert pebbles are most common, and are followed (in decreasing order) by quartz and phosphorite clasts. The size of the chert and quartz pebbles is nearly equal and mostly smaller than the size of the phosphorite pebbles. The excellent sorting of the chert and quartz pebbles and the much poorer sorting of the phosphorite pebbles are clearly expressed by Fig. 9.

2.5 *Brentskardet area*

The Brentskardhaugen Bed is extensively exposed in the area between Brentskardhaugen and Drønbreen at locality 9. Here the bed is up to 130 cm thick and consists of two conglomer-

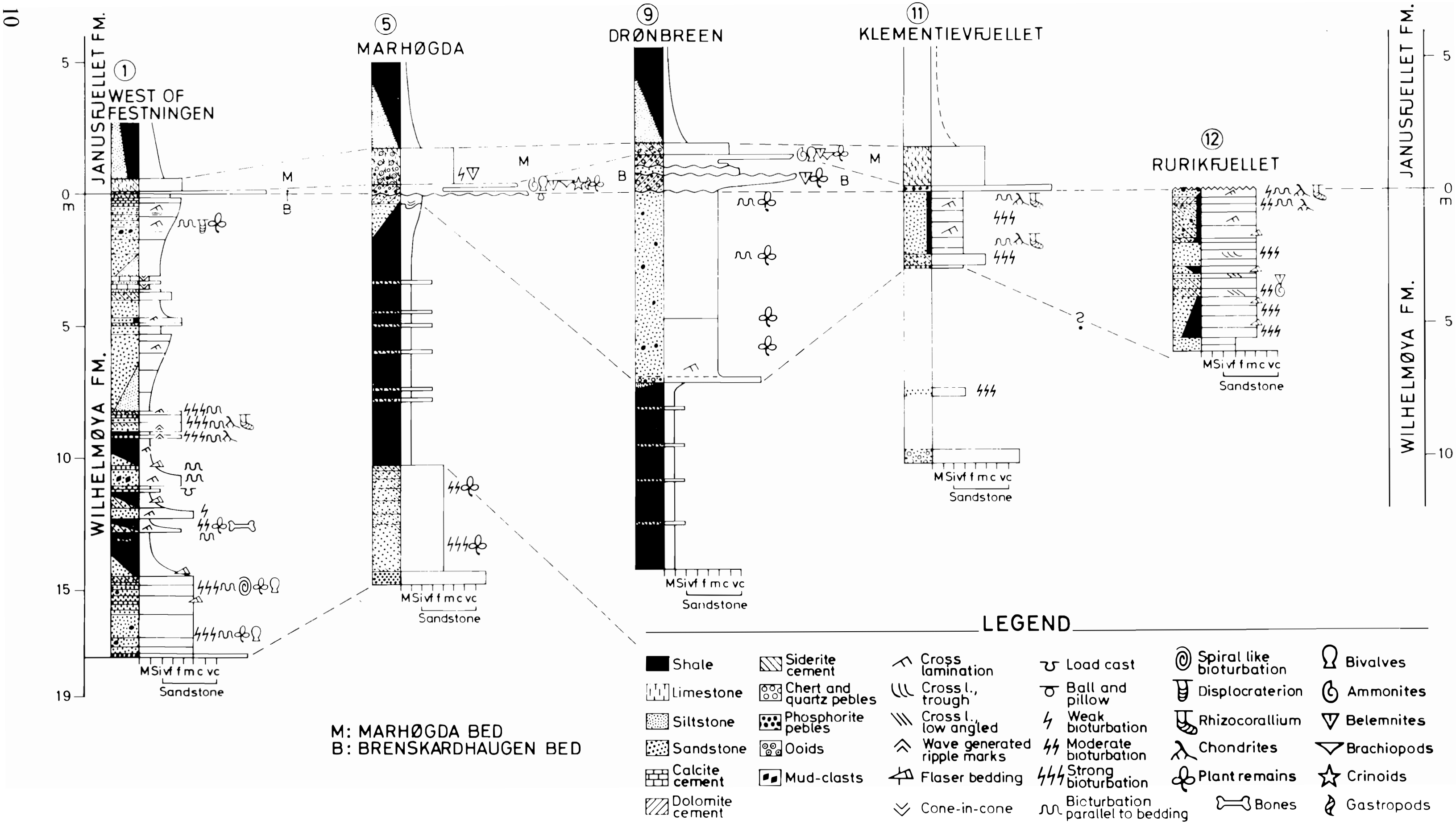

Fig. 4. Stratigraphical sections from central Spitsbergen covering the Brentskardhaugen and Marhøgda beds with adjacent strata.

atic horizons separated by a sandy intercalation (Fig. 10).

The lower boundary is sharp, with the conglomerate resting on a 4 to 8 m thick bioturbated sandstone forming the top of the Wilhelmøya Formation (Fig. 4). This sandstone contains plant remains, scattered pebbles of quartz, chert and phosphorite, and locally a conglomerate is developed at its base. The lithology of the pebbles found in this conglomerate is strongly variable within the area: phosphorite, quartz, shale and silt clasts have been observed. Below the conglomerate is a mudstone sequence of which the upper 7 m is exposed at locality 9. Both the mudstone and sandstone sequences are correlative on palynological evidence with similar lithologies forming the upper part of the Wilhelmøya Formation in the Diabasodden area (T. Bjærke pers. comm.).

In the lower part of the Brentskardhaugen Bed numerous sandstone clasts are present. They are mostly angular and less commonly rounded in shape, and can have diameters of up to 30 cm. They show the same lithology as the sandstone bed just below, indicating that the top of the Wilhelmøya Formation was eroded contemporary with the development of the conglomerate.

In the Brentskardhaugen Bed at locality 9, oblong phosphorite pebbles rest with their longest axis parallel to the bedding plane. The orientation of the longest axis was measured in 200 pebbles to obtain information about the direction of the paleocurrent during deposition. The results presented in Fig. 11 show a maximum at 118° suggesting a water movement from 28° or 208°. In this connection it must be noted that cross laminae in the sandy intercalation in the middle of the Brentskardhaugen Bed show a current flow roughly towards the south.

At locality 9 a total of 135 phosphorite pebbles have been examined for their fossil content by crushing; 56% of the crushed pebbles contained macrofossils (Fig. 12). It is, however, highly probable that this amount is too low because the pebbles were usually broken into only two pieces.

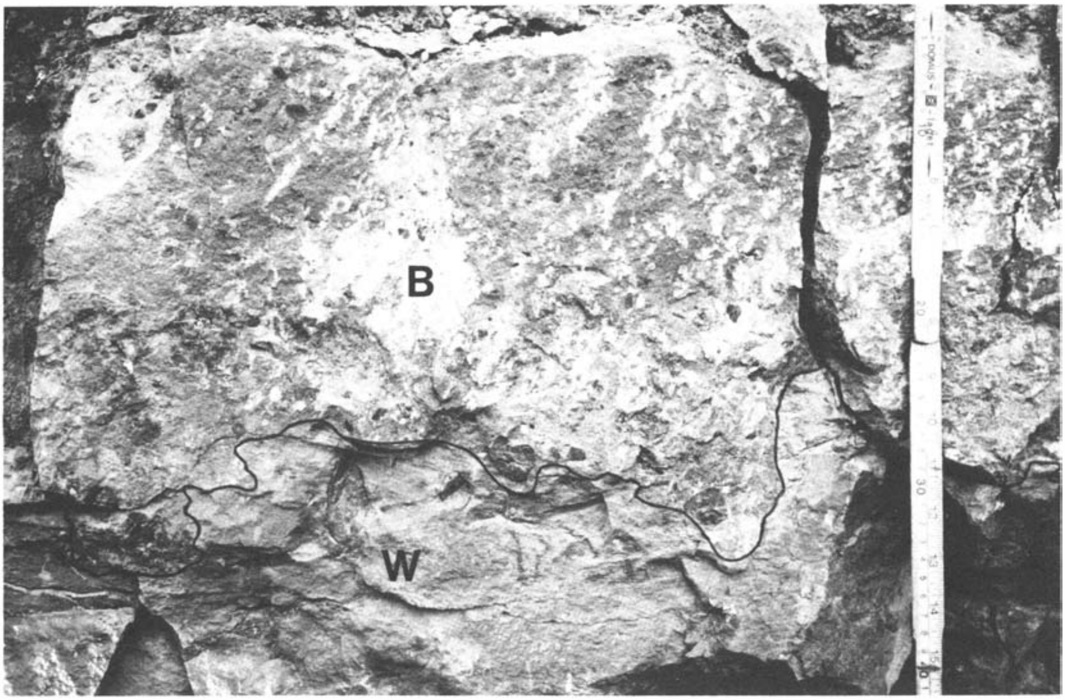

Fig. 5. The contact between the Brentskardhaugen Bed and the underlying silty limestone on Marhøgda, Diabasodden area. W = Wilhelmøya Formation, B = Brentskardhaugen Bed.

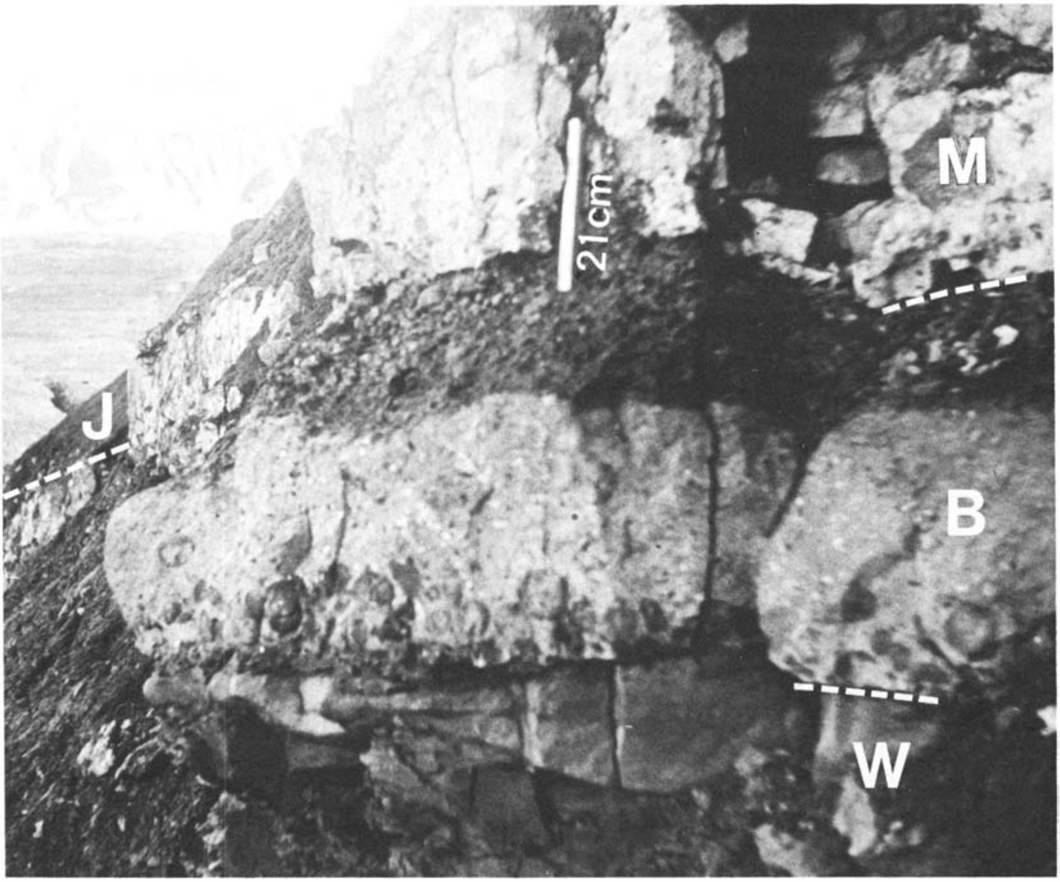

Fig. 6. The Brentskardhaugen Bed and adjacent strata on Marhøgda, locality 5. W = Wilhelmøya Formation, B = Brentskardhaugen Bed, M = Marhøgda Bed, J = Janusfjellet Formation.

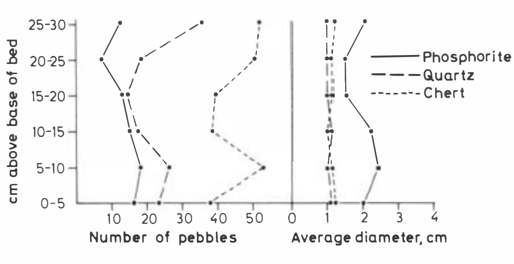

Fig. 7. The amount of pebbles and their size distribution in the Brentskardhaugen Bed at localities 5 and 6. At both localities the counts were made on a 30 cm high and 70 cm broad vertical surface starting at the base of the bed.

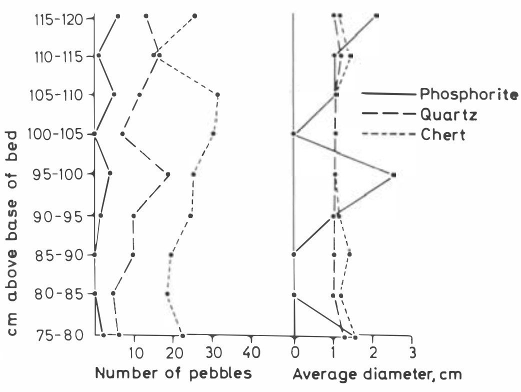

Fig 8. The amount of pebbles and their size distribution in the Brentskardhaugen Bed at locality 4. The counts were made on a 45 cm broad vertical surface 75—120 cm from the base of the bed.

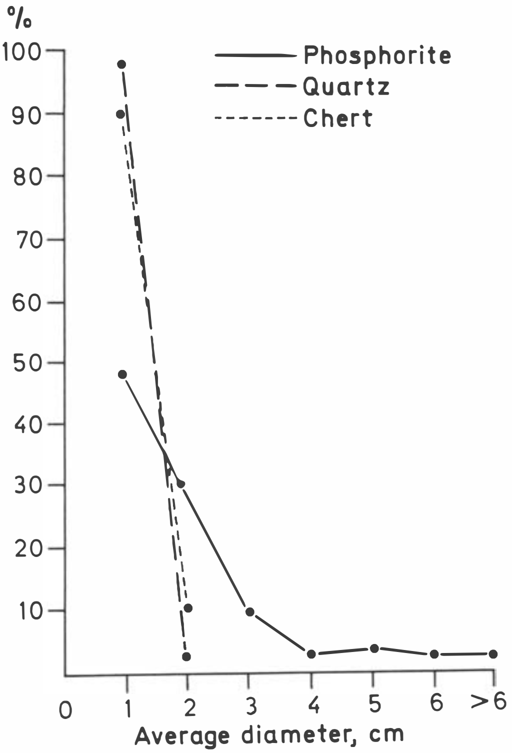

Fig. 9. Sorting of the three groups of pebbles in the Brentskardhaugen Bed expressed by size frequency curves based on counts at locality 4, 5 and 6.

On Juvdalskampen (locality 8) the Brentskardhaugen Bed is scree-covered except for a few incomplete exposures. The position of the conglomerate is usually marked by large amounts of loose chert, quartz and phosphorite pebbles just above a sandstone horizon.

In the area at the front of Drønbreen the Brentskardhaugen conglomerate passes gradually upwards into the Marhøgda Bed which shows the same lithology as in the Diabasodden area. Its thickness is 30 cm at locality 9. The shale sequence forming the bulk of the Agardhfjellet Member has an upwards fining, silty development in its lowermost portion on Brentskardhaugen, at the front of Drønbreen (locality 9), on Flexurfjellet and on the western slope of Fonnhetta.

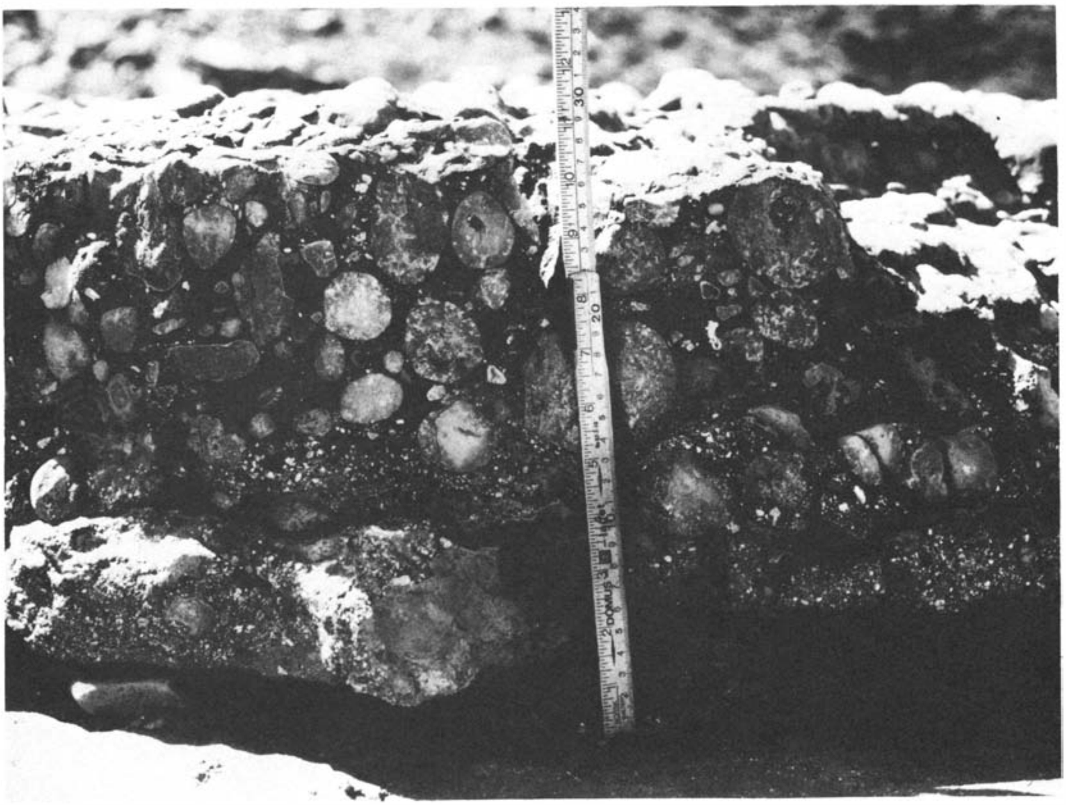

Fig. 10. Exposure of the upper 25 cm of the Brentskardhaugen Bed at locality 9.

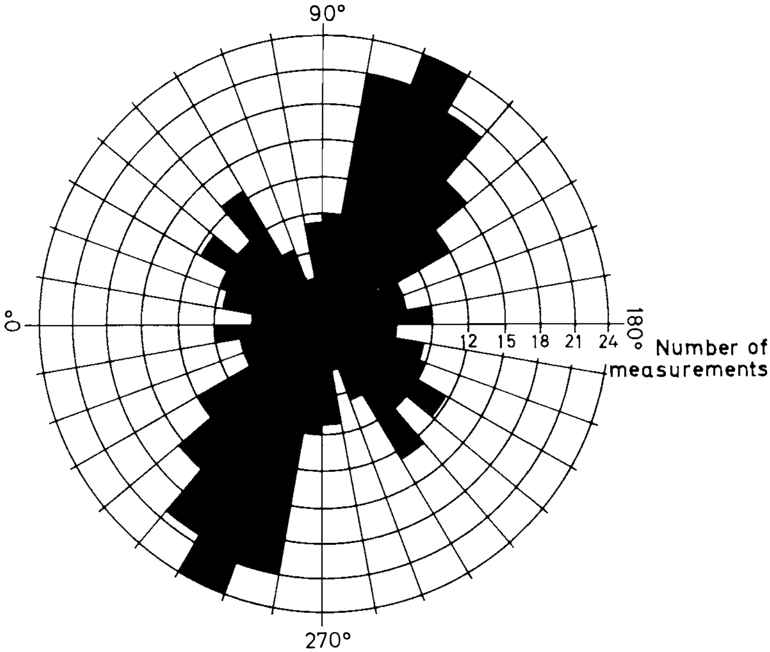

Fig. 11. Orientation of the longest axis of 200 phosphorite pebbles in the Brentskardhaugen Bed at locality 9.

2.6 *Agardhbukta area*

Locality 10 is situated on Klementievfjellet, on the western side of the Lomfjorden fault zone. The Brentskardhaugen Bed is covered, but its position is marked by large numbers of pebbles weathered loose from the bed. At this locality the size and roundness of 160 pebbles were measured and their fossil content was registered. 51 % of the pebbles were fossil bearing (Fig. 12). The size of the pebbles varied from 2.4 to 13 cm with an average of 5.1 cm. Their roundness was decided visually by comparison with Power's scale. As it appears from Fig. 13 the pebbles are generally well rounded, with the size group < 5.1 cm more rounded than the size group ⩾ 5.1 cm.

Locality 11 lies on the eastern slope of Klementievfjellet, east of the Lomfjorden fault zone. The top of the Wilhelmøya Formation here is formed by a 3 m thick, cross-laminated and strongly bioturbated sandstone containing *Chondrites, Rhizocorallium* and *Thalassinoides.* Above it the lower 15 cm of the Brentskardhaugen Bed is exposed. The conglomerate rests

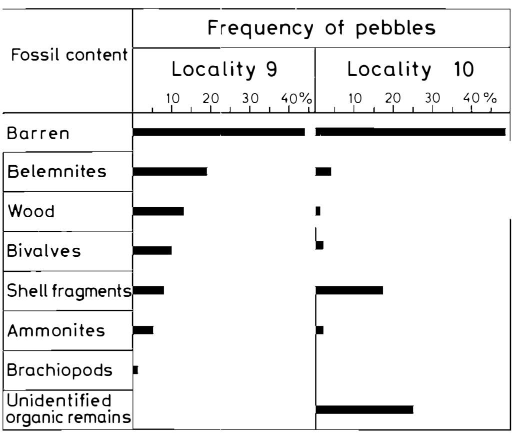

Fig. 12. Frequency of phosphorite pebbles with and without macrofossils in the Brentskardhaugen Bed. The diagram is based on 135 pebbles from locality 9, and 160 pebbles from locality 10.

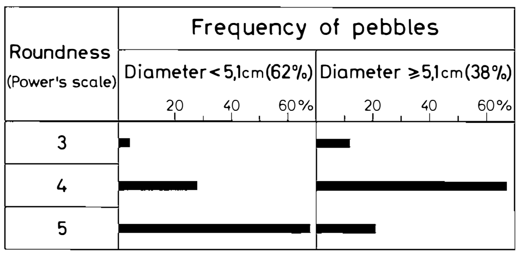

Fig. 13. Roundness of pebbles of the Brentskardhaugen Bed at Locality 10. The diagram is based on 160 pebbles. These are divided into two groups at a diameter of 5.1 cm which is the average pebble diameter.

on the eroded surface of the Wilhelmøya Formation and shows a lithology similar to that of the preceding localities. Above the conglomerate 100 cm of the Marhøgda Bed is visible.

At locality 12, on Rurikfjellet, the Brentskardhaugen Bed overlies a 6 m thick cross laminated and strongly bioturbated sandstone. The basal part of the conglomerate is preserved in depressions of this sandstone; the rest is removed by Quaternary erosion. A shale intercalation 4.5 m below the top of the sandstone contained Toarcian palynomorphs identical to those found in the topmost beds of the Wilhelmøya Formation on Marhøgda (T. Bjærke pers. comm.). In a partly phosphorized horizon 4 m below the top of the sandstone a specimen of *Porpoceras polare* was found, indicating the presence of Middle Toarcian. In the upper two metres of the sandstone, scattered phosphorite pebbles are present. The palynomorph assemblages occurring in these clasts are similar to those found in the phosphorite pebbles of the Brentskardhaugen Bed in the Diabasodden area (T. Bjærke pers. comm.).

3. Fossil content and age

3.1 *Ammonites and Belemnites*

The majority of the ammonites found in the phosphorite pebbles of the Brentskardhaugen Bed represents three zones of the Toarcian: the bifrons Zone, the variabilis Zone and the thouarsense Zone (Fig. 14). In addition the falciferum and levesquei Zones of the Toarcian, and the opalinum and murchisonae Zones of the Aalenian are each represented by a few ammonite specimens.

Belemnites are locally common in the Brentskardhaugen Bed. They are, however, of no stratigraphical significance because of their poor state of preservation, insufficient for closer determination.

3.2 *Bivalves*

The bivalves found in the Brentskardhaugen Bed extend the time range of the pebbles to parts of the Middle Jurassic younger than the Aalenian, which is the youngest stage represented by ammonites in the conglomerate (Fig. 15). The number of bivalve species decreases slightly from the Toarcian to the Aalenian but shows a marked increase in the Bajocian and Bathonian. Totally, ten bivalve species are identified with known species, and five of these occur in Bajocian or younger strata outside Svalbard. The presence of these five species suggests that the fossil content of the Brentskardhaugen Bed has been derived not only from the Toarcian and Aalenian, but also from yonger stages, at least Bajocian.

3.3 *Brachiopods*

Two inarticulate brachiopod species, *Lingulina* cf. *beani* and *Disciniscа* cf. *reflexa* are locally common in the Brentskardhaugen Bed. Both are referred to the Bajocian.

3.4 *Dinoflagellates*

Bjærke (1980) recorded 18 dinoflagellate species from the phosphorite pebbles of the Brentskardhaugen Bed on Knorringfjellet. The stratigraphical occurrence of four of these species in other areas is reported to be Late Pliensbachian — Bajocian, Bajocian?, Toarcian — Bajocian, and Toarcian — Bathonian. Several of the species reported by Bjærke are found in Toarcian and Aalenian (opalinum Zone) deposits in England.

Based on our present knowledge of the stratigraphical distribution of these dinoflagellates it can be concluded that their occurrence in the Brentskardhaugen Bed suggests the presence of the Toarcian, Aalenian and possibly Bajocian, a time range in general agreement with that indicated by the ammonite and bivalve assemblages.

3.5. *Faunal comparisons*

The geographical distribution of ammonites and bivalves recorded from the Brentskardhaugen Bed is shown in Fig. 16. Information on the mollusc faunas occurring in regions relevant for comparison are obtained from the papers included in the synonymy lists (paleontological part of this paper), and from the following publications: Frebold (1958b), Ravn (1912), Rosenkrantz (1934) and Spath (1947).

As it appears from Fig. 16, all the bivalve spe-

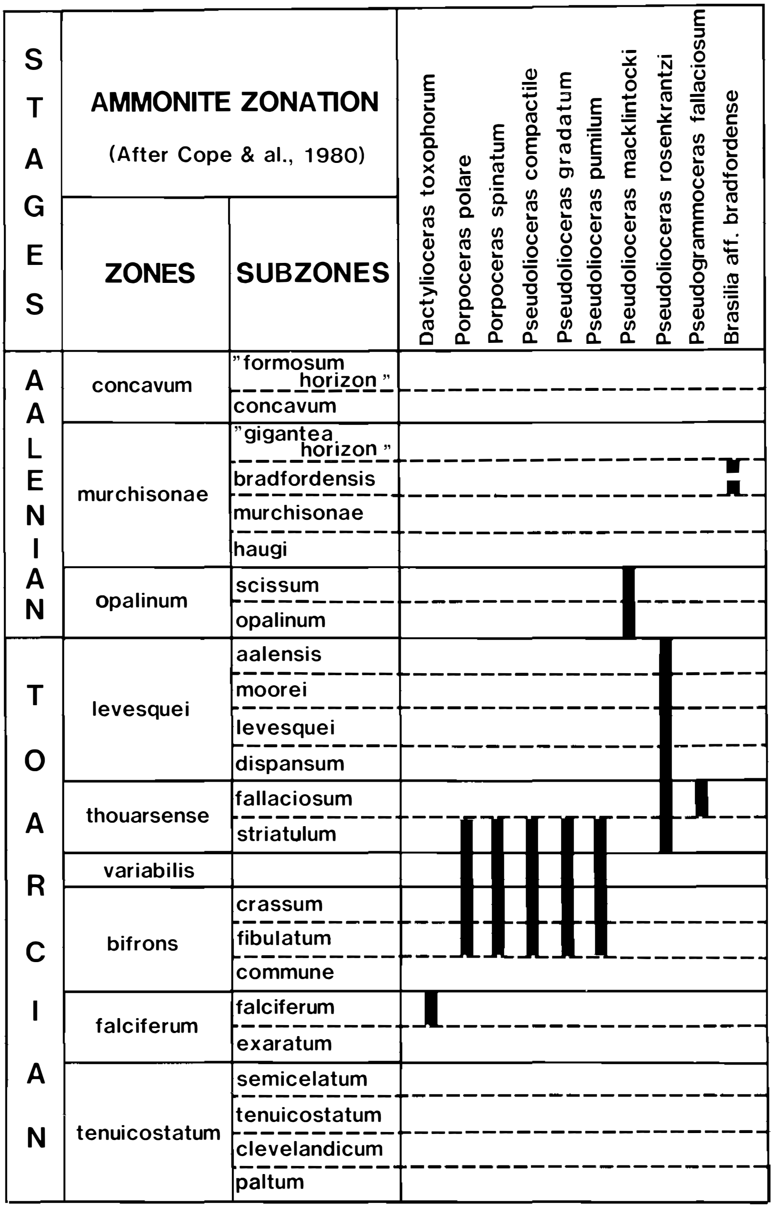

Fig. 14. Stratigraphical distribution of ammonites occurring in the phosphorite pebbles of the Brentskardhaugen Bed.

cies recorded from the Brentskardhaugen conglomerate are known from Western Europe, while four are found in East Greenland, one in Arctic Canada, and none in Alaska.

The ammonite species recorded from the conglomerate show the following distribution outside Spitsbergen: six species occur in Western Europe, two in East Greenland, four in Arctic Canada and two in Alaska.

Thus, the bivalve assemblages of the Brentskardhaugen Bed show surprisingly high similarities to contemporary faunas known from Western Europe. On the other hand, they are much different from the faunas of East Greenland, and

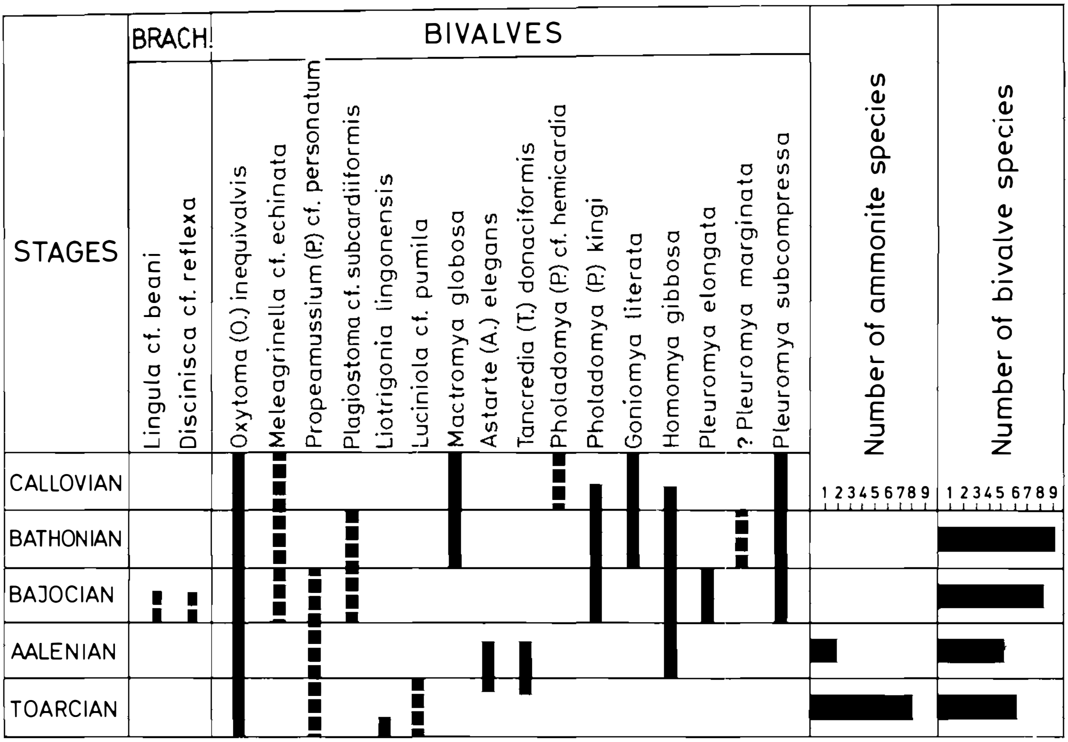

Fig. 15. Stratigraphical distribution of brachiopods and bivalves occurring in the phosphorite pebbles of the Brentskardhaugen Bed. The number of ammonite and bivalve species shown to the right.

still more from the faunas of Canada and Alaska. These differences are probably caused by divergencies in facies which might have a marked influence on the distribution of this benthic group.

The ammonite assemblages of the conglomerate show the greatest similarities to Western Europe, but they are also clearly like the faunas of Arctic Canada and Alaska. The most probable reason for this regional similarity is the pelagic mode of life of this group.

Based on the relations presented above we can conclude that in the Toarcian-Bathonian interval a pelagic faunal communication has existed directly between Western Europe and Spitsbergen, and from here to north-western North-America. The marked similarity between the benthic faunas of Spitsbergen and Western Europe is in accordance with the presence of the narrow Jurassic shelf sea that connected the Barents Shelf directly with the North Sea along the Norwegian coast.

3.6. *Age of the Brentskardhaugen Bed and adjacent strata*

The composition of the ammonite, bivalve and dinoflagellate assemblages found in the phosphorite pebbles demonstrates that the fossil content of the Brentskardhaugen Bed was formed by mixing of elements of different ages. The assemblages contain Toarcian, Aalenian and Bajocian species, while presence of Bathonian forms cannot be totally excluded.

On the basis of palynological analyses the beds just below the Brentskardhaugen conglom-

Fig. 16. Bivalves and ammonites recorded from the Brentskardhaugen Bed and their occurrence in other regions. (*Species recorded from Spitsbergen in earlier publications).

	SPITSBERGEN	WESTERN EUROPE Southern England France Germany Switzerland Poland	EAST GREENLAND	CANADA Arctic Archipelago (Prince Patrick Isl. Axel Heiberg Isl.)	ALASKA
BIVALVES	Oxytoma (O.) inequivalvis*	×	×	×	
	Meleagrinella cf. echinata*	×			
	Propeamussium (Parvamussium) cf. personatum*	×			
	Plagiostoma cf. subcardiiformis	×			
	Liotrigonia lingonensis	×	×		
	Luciniola cf. pumila*	×			
	Mactromya globosa	×			
	Astarte (A.) elegans	×			
	Tancredia (T.) donaciformis*	×	×		
	Pholadomya (P.) cf. hemicardia*	×			
	Pholadomya (P.) kingi	×			
	Goniomya literata*	×			
	Homomya gibbosa	×			
	Pleuromya elongata	×	×		
	? Pleuromya marginata	×			
	Pleuromya subcompressa	×			
AMMONITES	Dactylioceras toxophorum	×			
	Porpoceras polare*			×	
	Porpoceras spinatum			×	
	Pseudolioceras compactile*	×	×	×	×
	Pseudolioceras gradatum*	×			
	Pseudolioceras pumilum*	×	×		
	Pseudolioceras macklintocki			×	×
	Pseudolioceras rosenkrantzi*				
	Pseudogrammoceras fallaciosum	×			
	Brasilia aff. bradfordense	×			

erate (Fig. 1) are referred to the Toarcian in the Diabasodden, Brentskardet and Agardhbukta areas (Bjærke & Dypvik 1977.) This dating in the Agardhbukta area is confirmed by finds of *Porpoceras polare* on Rurikfjellet 4 m below the Brentskardhaugen Bed. At Festningen the Brentskardhaugen Bed rests on Rhaetian deposits (T. Bjærke pers. comm.).

The basal siltstones of the Agardhfjellet Member on Marhøgda contain *Kepplerites* cf. *tychonis* Ravn 1912 at two places, only 3 m above the Marhøgda Bed. The presence of this ammonite indicates an uppermost Bathonian — basal Callovian age.

The age of the Brentskardhaugen Bed can only be determined indirectly because no fossils have been found in its matrix. The deposition of the bed must have taken place after the formation of its phosphorite pebbles (see next chapter), but before the deposition of the basal shales of the Janusfjellet Formation. It seems most probable that the bed reached its final development in the late Bathonian, an assumption supported by the transitional relation between this bed, the Marhøgda Bed and the shales of the Agardhfjellet Member.

4. Pebble content and origin

4.1. *Phosphorite pebbles*

X-ray diffraction (Fig. 17) and thin section analyses have shown that the phosphorite pebbles essentially contain carbonate-fluorapatite and quartz, and lesser amounts of pyrite, clay minerals, rock fragments and glauconite. The apatite occurs as cement between the clastic grains. Shell fragments and plant remains have been replaced by phosphorite. The cement in the pebbles can be recognized optically as a microcrystalline, anisotropic variety of apatite, collophane (Kerr 1959). X-ray fluorescence analyses have confirmed that the cement is a fluoride-rich variety of apatite, probably francolite. According to McConnell (1958) francolite is a carbonate-fluorapatite with F-content greater than 1%.

Analysis of the grain-size frequency distribution of the clastic material in nine phosphorite pebbles was carried out by dissolving the pebbles in dilute hydrochloric acid (Fig. 18 and Table 2). The results show that the original sediment in which the pebbles were formed, was a well sorted quartz sand. The average amount of the clastic material is 53 weight-%, which means that the apatite cement constitutes on average 47 weight-% of the phosphorite pebbles. Both the quartz content of the pebbles and the average grain-size show a rather homogeneous distribution throughout Spitsbergen.

Several phosphorite pebbles show internal bioturbation features formed while the sediment was still unconsolidated (Fig. 19). The bivalves found in the pebbles are often closed, showing that they were protected within the sediment until lithification.

Pebbles containing macrofossils clearly show a correlation between their shape and the shape of the fossils enclosed in them. The results presented in Table 3 have been obtained by a visual comparison of the shape of 144 pebbles with the enclosed macrofossils. Pebbles containing bivalves which have the same length as height are often almost circular in outline. If the bivalves are oval in outline, then the pebbles will also have this shape. The pebbles containing ammonites have their shortest axis oriented parallel to the umbilical axis of the ammonite shells. Pebbles containing pieces of wood or belemnites are oval, or even cigar-formed.

In cross sections the phosphorite pebbles often show internal concentric structures (Fig. 19). This is also reflected by the fact that the pebbles, when dissolved in dilute acid, seem to peel off in concentric flakes.

In thin sections of the pebbles a rim of phosphorite cement around the clastic particles can often be observed (Fig. 20). The composition of the rim-cement is confirmed by energy dispersive analysis of thin sections using electron microscope (Fig. 21). The individual phosphorite crystals (length up to 10 μm) are oriented radially out from the clastic particles. The remaining pore space is filled with microsparitic phosphorite. The rim-cement, however, is not always developed; sometimes the microsparitic phosphorite cement is totally dominating.

In recent literature several theories are presented in order to explain the formation of

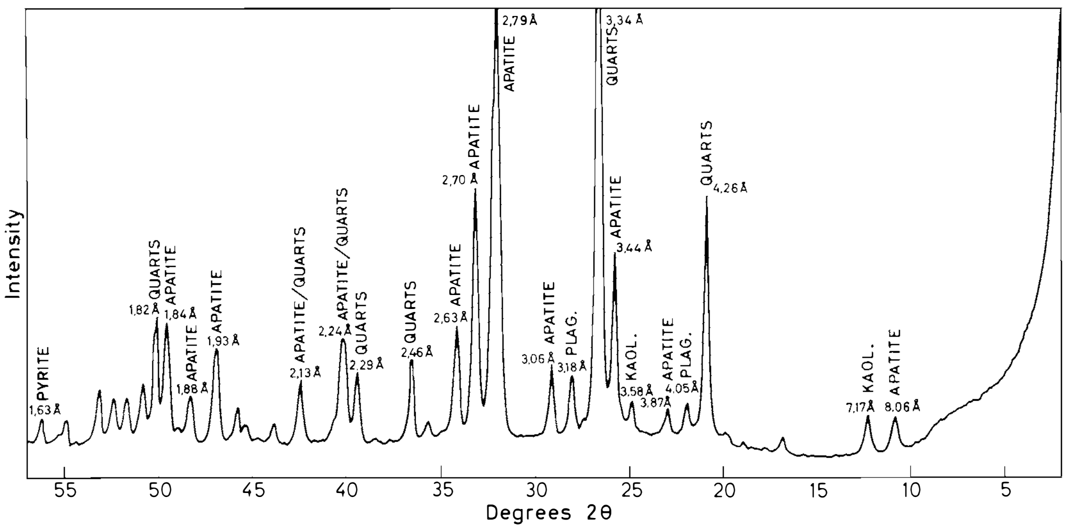

Fig. 17. X-ray diffractogram of a phosphorite pebble from the Brentskardhaugen Bed.

marine phosphatic sediments. A model is based on the hypothesis that phosphorite is formed by replacement of already existing materials, usually carbonates. D'Anglejan (1967) reported phosphorite deposits formed by replacement of calcareous shell debris from the sea floor off southern California. This region is characterized by upwelling of phosphate-rich water and a low rate of clastic sedimentation. Peaver (1966) interpreted Tertiary phosphorite sediments from the United States as formed in productive estuaries by replacement of previously formed carbonate deposits. Kennedy & Garrison (1975) interpreted Cenomanian phosphatic nodules as formed by replacement of lithified carbonates, either prefossilized internal molds or reworked carbonate concretions.

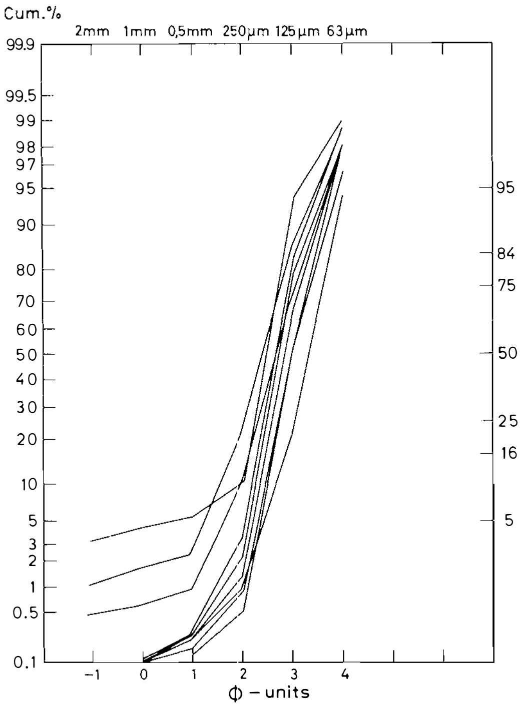

Fig. 18. Grain-size frequency distribution of the clastic material in 9 phosphorite pebbles from the Brentskardhaugen Bed.

Another theory is based on Kazakov's (1937) model of direct inorganic precipitation of marine apatite from sea-water. Dietz et al. (1942) and Emery (1960) assumed that the phosphorite deposits off the California coast were formed in this way.

Atlas (1975) concluded that apatite is formed from the pore-water of anoxic sediments, rather than from the overlying sea-water. Burnett (1977) reported phosphorite deposits from the shelf off Peru and Chile formed by a direct inorganic precipitation of apatite in such an environment. This precipitation took place about 15 cm below the sediment surface.

The results achieved from the study of the phosphorite pebbles of the Brentskardhaugen Bed indicate a close relationship between the formation of these pebbles and the phosphorite pebbles found off Peru and Chile. The characteristic rim cement around the clastic grains in the Spitsbergen pebbles indicates a direct inorganic precipitation of the phosphorite cement. Internal bioturbation occurring in the sandy matrix of the pebbles clearly shows that this precipitation must have taken place within a still unconsolidated sandy sediment. Any evidence that the phosphorite cement has replaced an already lithified sediment (e.g. carbonate) has not been observed, however, shell material and plant remains have been phosphatized by an apatite replacement process.

The fossils found in the pebbles clearly indi-

Table 2. *Average ϕ values and weight-percent of quartz in 9 phosphorite pebbles determined after dissolution of cement.*

Area	*Diabasodden*					*Brent-skardet*		*S. Spits-bergen*	*N.E. Spits-bergen*
Locality	3	4	5	6	7	8	9	14	22
Sample no.	78—76	103—76	13—76	51—76	62—76	4—77	23—77	S5-pl—64	
Average ϕ	2.8	2.4	2.4	2.7	2.8	3.0	2.7	3.3	3.0
Quartz weight %	61	46	43	53	59	56	50	46	60

cate that the sediment was deposited under marine conditions. The correlation between the shape of the pebbles and their fossil content, together with the presence of structures indicating a concentric growth, suggest that the pebbles must have been formed as concretions around the fossils, probably in connection with the decay of organic material. Burnett (1977) assumed that the dissolved phosphate mainly came from such a decay and that a rise in Ph, necessary for the precipitation of apatite, took place because of the formation of NH_4^+ and other nitrogenous bases during the decomposition of proteins and other biochemical compounds.

The chemical composition of nine phosphorite pebbles was determined by means of X-ray fluorescence spectrometry (Table 4). The variation in SiO_2 and P_2O_5 content reflects a variation in the amount of clastic materials versus amount of apatite cement.

Table 3. *Correlation between pebble shape and shape of enclosed fossil based on visual comparison of 144 pebbles with their fossil content.*

Fossil groups	*Number of pebbles*	*Correlation in shape: Pebble — fossil* + cases	— cases
Ammonites	31	29 (94 %)	2 (6 %)
Belemnites	45	35 (78 %)	10 (22 %)
Bivalves	53	42 (79 %)	11 (21 %)
Wood fragments	12	12	0
Saurian bones	3	3	0

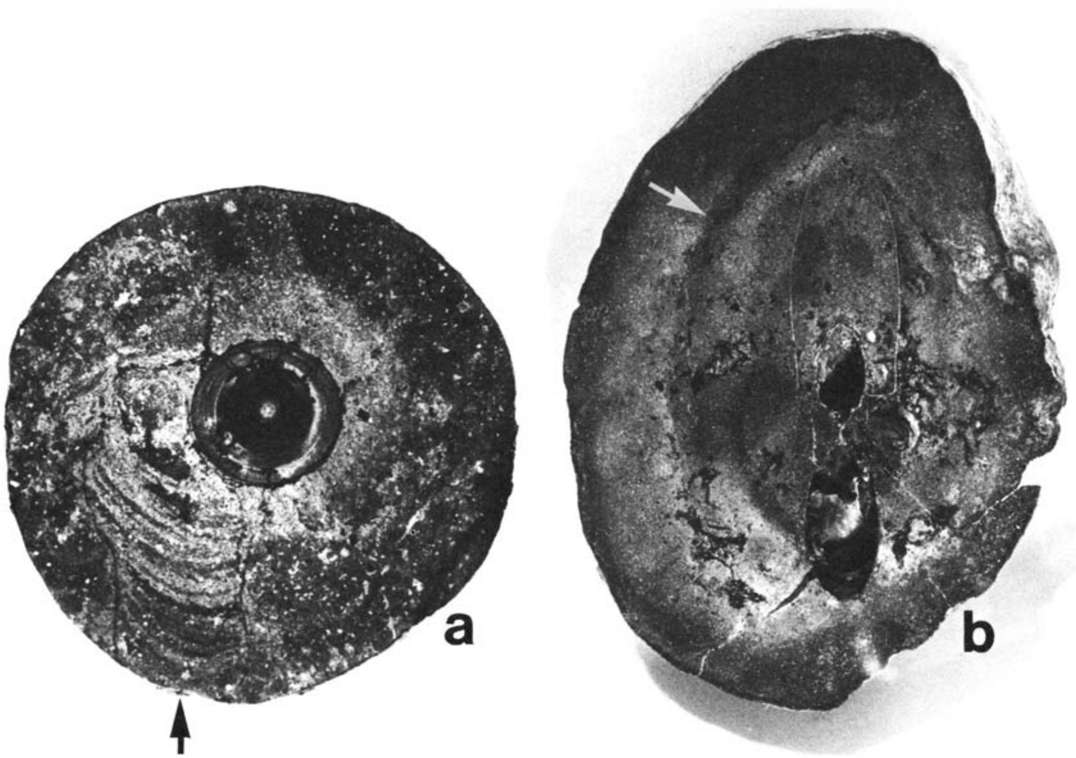

Fig. 19. Internal structures in phosphorite pebbles from the Brentskardhaugen Bed:
a. Bioturbation preserved in a pebble with a belemnite rostrum at the centre (x 1.8).
b. Diffuse concentric structures around an ammonite shell (x 1.2).

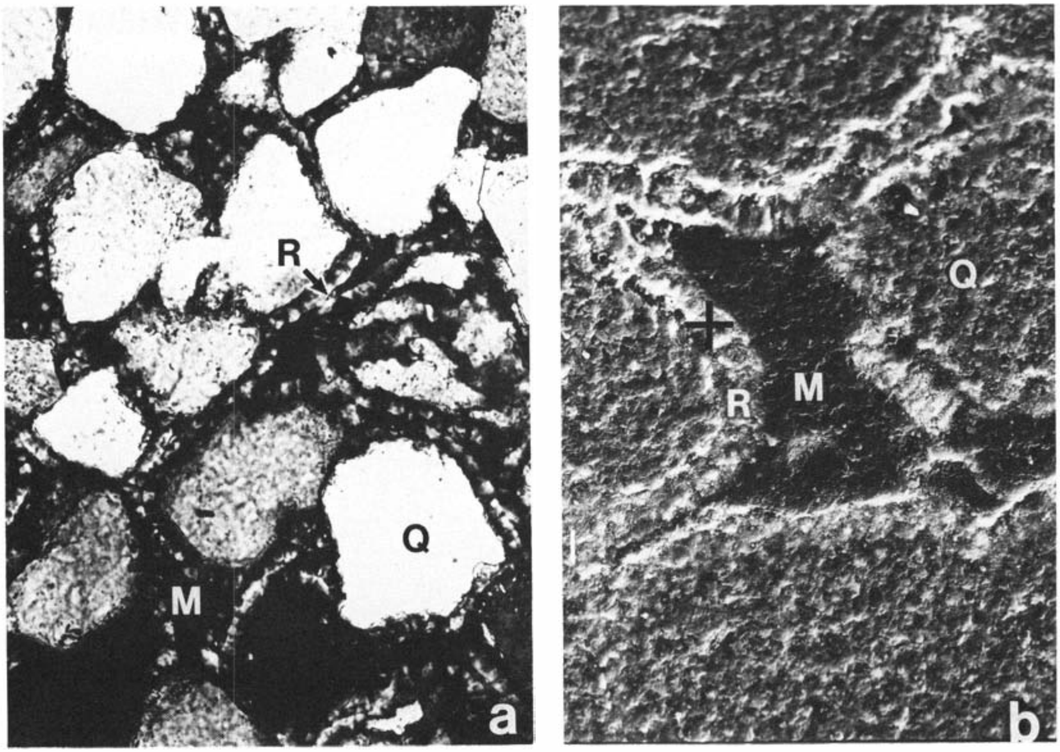

Fig. 20. Thin sections of phosphorite pebbles from the Brentskardhaugen Bed displaying the following details: Q = quartz grain, R = rim cement of Ca-apatite, M = microsparitic phosphorite.

a. Clastic grains partially surrounded by rim cement of phosphorite crystals. Crossed nicols (x 160).

b. SEM photograph (x390; + = point of X-ray analysis, see Fig. 21).

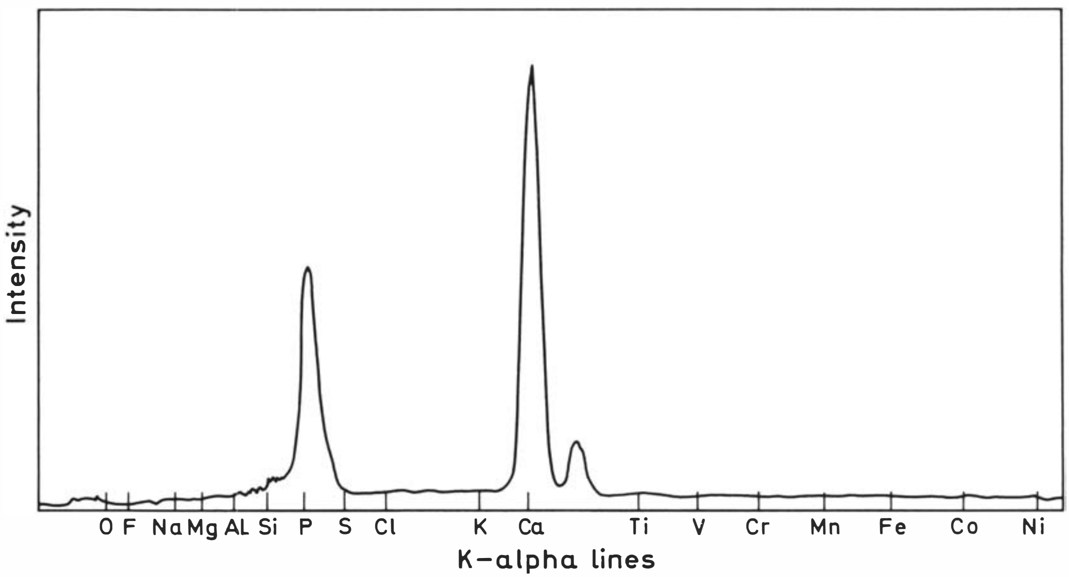

Fig. 21. Curve of a qualitative X-ray analysis of thin section made by electron microscope. It shows that the rim-cement int the phosphorite pebbles is Ca-apatite. The point analysed is shown in Fig. 20.

The CaO/P_2O_5 ratio of the pebbles of the Brentskardhaugen Bed shows only slight changes and the average value is 1.49 (Table 5). According to Burnett (1977), the CaO/P_2O_5 ratio of the phosphorites off Peru and Chile is 1.50 which is only slightly higher than expected for a pure carbonate-fluorapatite phase. He concluded that the CaO not associated with apatite, was probably included in detrital phases, such as plagioclase. Since no other phosphate mineral has been recognized in the samples described in the present paper, it must be assumed that all the P_2O_5 is included in the apatite.

The F/P_2O_5 ratios of the Spitsbergen pebbles are fairly constant (Table 5). In all the samples these ratios are somewhat higher than the ideal ratio of 0.089 given by Burnett (1977) for a non-carbonate-fluorapatite. The samples analysed by Burnett show, however, also slightly higher values. He explains this «excess» of F as probably being incorporated into the apatite lattice to balance the excess positive charge created by substitution of CO_3^{2-} for P_4^{3-}.

The chemical composition of the phosphorite pebbles of the Brentskardhaugen Bed is similar to the results achieved by Burnett (1977) for the

Table 4. *Chemical composition of phosphorite pebbles from the Brentskardhaugen Bed.*

Area	*Diabasodden*					*Brent-skardet*		*Southern Spitsbergen*	
Locality	5	5	5	7	7	9	9	13	18
Sample no.	8—76	9—76	19—76	32—76	85—76	14—77	23—77	S5-pl—64	KIS
Loss on ignition	2.70	3.03	2.77	2.94	1.48	2.35	2.23	1.36	1.00
SiO_2	59.52	46.26	63.11	59.23	62.66	66.66	53.23	60.53	55.46
Al_2O_3	1.79	4.15	1.32	1.96	1.51	3.19	2.83	1.87	0.98
Fe_2O_3	1.76	0.93	0.94	0.95	0.70	1.00	0.70	1.77	0.52
MgO	—	—	0.36	0.06	—	—	—	—	—
CaO	18.56	25.02	18.01	19.37	18.45	14.53	22.24	19.07	22.81
Na_2O	2.64	2.91	2.12	2.40	2.49	1.96	2.77	2.17	2.71
K_2O	0.32	0.49	0.17	0.28	0.14	0.20	0.30	0.19	0.13
P_2O_5	12.48	16.99	11.03	12.60	12.47	9.78	15.47	12.95	16.28
TiO_2	0.12	0.13	0.08	0.12	0.07	0.23	0.15	0.07	0.08
MnO	0.03	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01
Cl	—	0.01	0.01	0.01	0.01	—	0.01	0.01	0.01
F	1.34	1.98	1.43	1.47	1.50	1.33	1.82	1.72	1.95
Total	101.26	101.91	101.36	101.40	101.49	101.26	101.76	101.72	101.94
— O	0.56	0.83	0.60	0.49	0.63	0.56	0.77	0.72	0.82
Total	100.70	101.08	100.76	100.91	100.86	100.70	100.99	101.00	101.12

Table 5. *CaO/P_2O_5 and F/P_2O_5 ratios of phosphorite pebbles from the Brentskardhaugen Bed.*

Area	*Diabasodden*					*Brent-skardet*		*Southern Spitsbergen*	
Locality	5	5	5	7	7	9	9	13	18
Sample no.	8—76	9—76	19—76	32—76	85—76	14—77	23—77	S5-pl—64	KIS
CaO/P_2O_5	1.49	1.47	1.63	1.54	1.48	1.49	1.44	1.47	1.40
F/P_2O_5	0.107	0.117	0.130	0.117	0.120	0.136	0.118	0.133	0.120

pebbles off Peru and Chile (Table 6). It supports the assumption that the pebbles from Spitsbergen and from the South American shelf have been formed under essentially similar conditions.

4.2. *Chert pebbles*

Counting of pebbles at localities 4, 5 and 6 in the Diabasodden area showed that chert pebbles are the most common clasts in the Brentskardhaugen Bed (Figs. 7 and 8). At these three localities the average frequency of chert pebbles is 57% of the total pebble content. The chert pebbles are usually very well rounded, in spite of their resistance against wear, and also show an excellent sorting.

Thin section studies revealed an assemblage of sponge spicules inside some of the chert pebbles (Fig. 22a). In the Svalbard archipelago bedded cherts and other cherty lithologies are well known from the Upper Permian Kapp Starostin Formation, but chert to a considerably smaller extent is also present in the Upper Carboniferous-Lower Permian deposits. Spiculitic cherts are common in the Upper Permian as it appears from Siedlecka (1970). It is therefore

Table 6. *Average chemical composition of phosphorite pebbles from the Brentskardhaugen Bed (9 analyses) compared to the average values reported off Peru and Chile (15 analyses). The values are given in weight-percent.*

	Off Peru and Chile (Burnett 1977)	*Spitsbergen (This paper)*
SiO_2	22.13	58.52
Al_2O_3	5.15	2.18
Fe_2O_3	2.85	1.03
MgO	1.07	0.05
CaO	33.93	19.78
Na_2O	0.85	2.46
K_2O	1.30	0.25
P_2O_5	22.61	13.34
TiO_2	Not determined	0.12
MnO	Not determined	0.01
Cl	Not determined	0.01
S	0.16	Not determined
F	2.22	1.62
Loss on ign.	8.78	2.21
Total	101.05	101.57
—O	0.93	0.66
Total	100.12	100.90
CaO/P_2O_5	1.50	1.49
F/P_2O_5	0.098	0.109

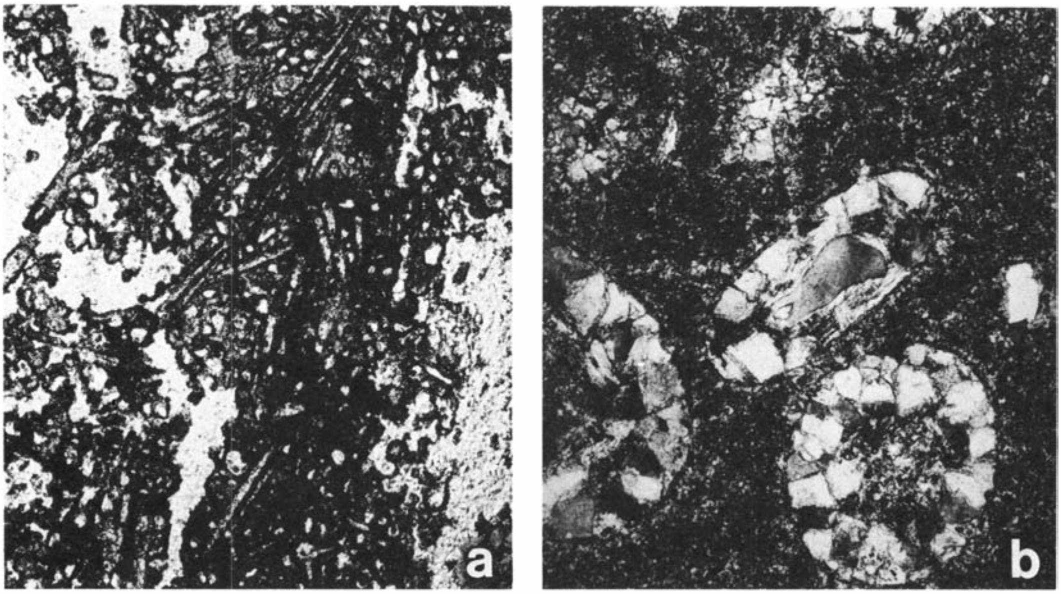

Fig. 22. a. Thin section of a chert pebble from the Brentskardhaugen Bed showing sponge spicules. Crossed nicols (x 51).

b. Thin sectin from the Marhøgda Bed showing ooids with their concentric structure disturbed by sparitic ankerite. Nuclei of quartz are visible. Crossed nicols (x 60).

likely that the chert pebbles of the Brentskardhaugen Bed, at least partially, were derived from those strata.

4.3. *Quartz pebbles*

Polycrystalline quartz pebbles are also frequently found in the Brentskardhaugen Bed. At localities 4, 5 and 6 this pebble type constitutes on average 29% of the total pebble content of the conglomerate. These pebbles are also very well rounded, and their sorting is good. Metamorphic polycrystalline quartz pebbles (often with undulating extinction under crossed nicols) were probably derived from Hecla Hoek. Birkenmajer (1972) described pebbles of vein quartz from the Brentskardhaugen Bed, which he recognized as Hecla Hoek material.

Sandstone clasts with lithologies resembling the sandstones of the Kapp Toscana Group must have been eroded from that unit.

5. The matrix of the conglomerate

The material between the pebbles is dominated by fine to medium grained quartz sand in a carbonate ground mass. At some places this sand is grain supported, while at other localities it is more or less floating in the carbonate ground mass, but variations are observed also within individual sections of the conglomerate bed. The sand is probably derived from the Kapp Toscana Group. Some scattered glauconite grains were also observed.

The cement found in the matrix is a microsparitic carbonate. X-ray diffraction analyses and dyed thin sections have shown that this carbonate is an Fe-rich variety of dolomite (ankerite).

6. Origin of the Marhøgda Bed

The microsparitic limestone forming the bulk of the Marhøgda Bed was originally deposited as carbonate mud. Its content of quartz and chert grains, glauconite and ooids must have been derived from areas outside the carbonate mud environment and then transported into these deposits. The ooids have probably been derived from adjacent areas affected by periodic high energy currents, e.g. tide dominated environments.

Dyed thin sections and X-ray diffraction analyses show that the microsparite has been replaced by siderite, and in some places also by other Fe-rich carbonates (Fig. 22b). The concentric structure of the ooids is often destroyed by sparitic Fe-rich dolomite, otherwise the ooids are replaced by siderite. Grains of quartz, chert, glauconite and kaolinite acted as nucleation centres for the ooids.

7. Concluding remarks on depositional history

7.1. *Source of pebbles*

The material which forms the Brentskardhaugen Bed is to a great extent derived from the Wilhelmøya Formation through reworking in the Middle Jurassic. This origin is indicated by: the erosional basal contact of the conglomerate; the presence of angular sandstone clasts in the lower part of the conglomerate; the occurrence of phosphorite, chert and quartz pebbles both in the conglomerate and in the Wilhelmøya Formation; and the exceptionally high sand content of the phosphorite pebbles.

The phosphorite pebbles of the Brentskardhaugen Bed are mechanically rounded, but a correlation exists between their shape and the shape of the enclosed fossils indicating a concretional origin of the clasts. In spite of their greater resistance against mechanical wear, the chert and quartz pebbles are more rounded and better sorted than the phosphorite pebbles. This relation suggests that the chert and quartz pebbles passed through one or several episodes of mechanical weathering before they became involved in the same events which rounded the phosphorite pebbles.

7.2. *The Ladinian-Pliensbachian interval*

The Ladinian-Norian period in Svalbard is dominated by delta influenced marginal marine to shallow marine conditions which led to the deposition of the De Geerdalen Formation (Fig. 23). In central Spitsbergen the deltaic influence

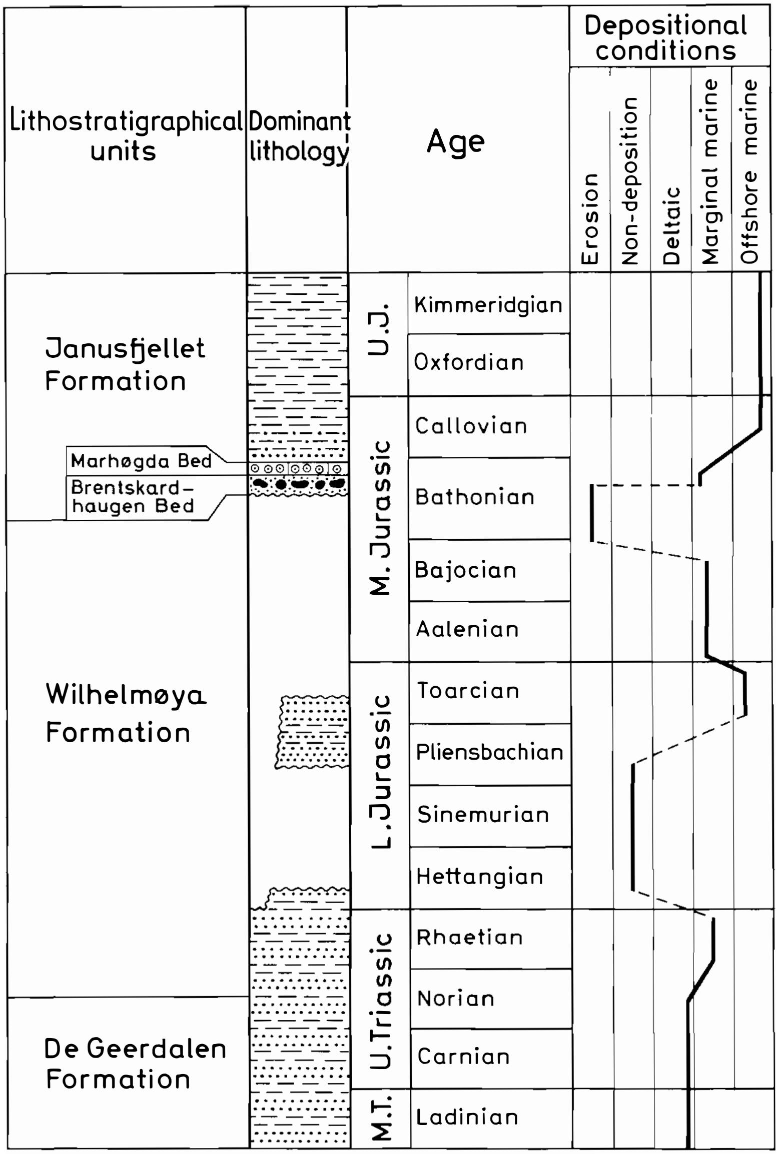

Fig. 23. Depositional history of central Spitsbergen from Middle Triassic to Upper Jurassic as reflected by the Brentskardhaugen conglomerate and adjacent strata.

was reduced in comparison to the eastern parts of the archipelago.

Shallow shelf conditions of a more normal marine character were introduced to central Spitsbergen during a transgression which probably started in the Norian and culminated in the Rhaetian. The lower part of the Wilhelmøya Formation has been deposited by this marine ingression as suggested by Bjærke & Dypvik (1977).

Regressive conditions started already in the late Rhaetian or early Hettangian and probably prevailed to the late Pliensbachian. These conditions seem to have resulted in a total or partial non-sequence corresponding to the Hettangian-Pliensbachian interval, which explains the absence of diagnostic fossils from this time period.

7.3. *The Toarcian-Bajocian interval*

A new transgression started probably in late Pliensbachian (T. Bjærke pers. comm.) and reached its maximum in the Toarcian. This event introduced shallow shelf to marginal marine conditions to Spitsbergen, with an extensive reworking of deltaic sediments, resulting in the deposition of the upper part of the Wilhelmøya Formation.

The Toarcian maximum of marine ingression is reflected by the fact that most of the ammonites found in the Brentskardhaugen Bed belong to this stage. The regional extent of the transgression must have been as large, or larger, than the present distribution of the Brentskardhaugen conglomerate which extends from Sørkapp Land through the western outcrop belt, the Isfjorden area and Agardhbukta to Wilhelmøya. This marine ingression appears to be time correlative with the global Toarcian transgression which reached its peak near the end of the stage.

The degree of open marine influence seems to have been reduced already in the Aalenian as this stage is represented by bivalves and only a few ammonites in the Brentskardhaugen Bed. The Bajocian is represented by bivalves but shows a total absence of ammonites suggesting a further reduced open marine tendency upwards in the Middle Jurassic.

The formation of phosphorite nodules seems to have been promoted by increasing marine influence as shown by the fact that the majority of the phosphorite pebbles apparently belongs to the Toarcian. The preceding chapters demonstrate that the pebbles were developed as concretions by precipitation of apatite commonly initiated by biogenic materials. The precipitation has taken place below the bottom surface, directly from the pore water of mineralogically mature, bioturbated sand deposits.

7.4. *The Bathonian-Callovian interval*

The Middle Jurassic regression seems to have culminated in the Bathonian. Absence of diagnostic marine fossils of Bathonian age from the Brentskardhaugen Bed suggests that the sea retreated at least from western and central Spitsbergen during this stage. (It must be noted here that two Bathonian bivalves are found in the uppermost part of the Wilhelmøya Formation on Hellwaldfjellet.) During this regression the shelf became exposed to coastal erosion with energy high enough to break up parts of the Wilhelmøya Formation and concentrate its coarse and resistant constituents, among these, the phosphorite pebbles.

A new transgression started probably near the end of the Bathonian contemporary with a global elevation of the sea level at the transition between the Bathonian and Callovian. This event led to renewed reworking and final deposition of the remanié sediments forming the Brentskardhaugen Bed. In eastern and central regions these Middle Jurassic reworking processes reached locally down at least to the Middle Toarcian bifrons Zone. The lower parts of the Toarcian remained undisturbed as shown by the relations found in the region between inner Isfjorden and Agardhfjellet, and further northeast.

In the western outcrop belt, e.g. in the Festningen area, the Brentskardhaugen conglomerate rests on Rhaetian deposits belonging to a very thin Wilhelmøya Formation. Thus, in western regions the Middle Jurassic erosion might have been more extensive, and removed a larger part of the Wilhelmøya Formation, than in eastern areas. In this connection it must be noted, however, that Mørk et al. (1982) suggest an originally thinner and more incomplete development of the Wilhelmøya Formation in areas west of the Billefjorden fault belt.

As energy decreased during the Bathonian-Callovian transgression, an essentially fining upwards sequence was developed in the Diabasodden and Brentskardet areas. It starts with the Brentskardhaugen conglomerate which has a transitional boundary towards the Marhøgda Bed. There is also a gradational contact between the Marhøgda Bed and the lowermost siltstones of the Agardhfjellet Member, as well as between these siltstones and the black shales higher up in the member. We can therefore conclude that the Brentskardhaugen Bed and the lower part of the Janusfjellet Formation have been deposited during a single, continuous, transgressive event.

In central Spitsbergen the lowermost siltstones of the Agardhfjellet Member contain a *Kepplerites* fauna of uppermost Bathonian-basal Callovian age. Based on the fact that the Brentskardhaugen conglomerate and these siltstones were deposited during the same transgressive event, we may assume that the final deposition of the Brentskardhaugen Bed has taken place not much before the end of the Bathonian Stage.

8. Paleontological part

8.1. *Introductory notes*

The synonymy lists given in this paper are not complete and include only the publications used when identifying the species. For more information about the morphology of the species and more detailed synonymy lists, the reader is referred to those publications. The classification of the brachiopods, bivalves and ammonites corresponds to the *Treatise on Invertebrate Paleontology,* edited by R.C. Moore (1957, 1965, 1969, 1971).

In the drawings illustrating the ammonites,

Table 7. *List of species with references to the localities where they were found.*

	SPECIES	LOCALITIES																	
		3	4	5	6	7	8	9	12	13	14	15	16	17	18	19	20	21	22
BRACH.	Lingula cf. beani		*	*															
	Lingula sp.			* *			*							*					
	Discinisca cf. reflexa			*		*													
BIVALVES	Buchia sp.																*		*
	Inoceramus sp.							*											
	Oxytoma (O.) inequivalvis				*														
	Oxytoma sp.																	*	
	Meleagrinella cf. echinata			*	*	*		* *											
	Propeamussium (Parvam.) cf. personatum						*												
	Chlamys (C.) sp.														*				
	Plagiostoma cf. subcardiiformis							* *											
	Gryphaea ? sp.																*		
	Liotrigonia lingonensis							* *											
	Trigonia sp.																		*
	Luciniola cf. pumila					*													
	Mactromya globosa																*		
	Astarte (A.) elegans																*		
	Tancredia (T.) donaciformis	*		*	*	***		*									*		
	Pholadomya (P.) cf. hemicardia			*															
	Pholadomya (P.) kingi															*			
	Pholadomya sp.							*											
	Goniomya literata																*		
	Homomya gibbosa					*													
	Pleuromya elongata													*			*		
	? Pleuromya marginata						*							*			*		
	Pleuromya subcompressa																		
	Pleuromya sp.																		*
AMMONITES	Dactylioceras toxophorum														*				
	Porpoceras polare					* *			*										
	Porpoceras spinatum													*					
	Porpoceras cf. spinatum										*								
	Brasilia aff. bradfordense			*															
	Pseudolioceras compactile						*			*		* *	*						
	Pseudolioceras gradatum			*		*						*							
	Pseudolioceras cf. gradatum						*			*					*				
	Pseudolioceras pumilum				* *														
	Pseudolioceras cf. pumilum									*									
	Pseudolioceras maclintocki					* *					*								
	Pseudolioceras rosenkrantzi													*					
	Pseudolioceras spp.											*		*					
	Pseudogrammoceras fallaciosum									*									
DECAP.	Hastites ? sp.							*											
	Belemnitidae genus indet.	*		* *	* *	***		*			*				*		*		

* One specimen
* * Few specimens
*** Several specimens

reconstructed parts of the sutures and whorl sections are indicated by dotted lines. Each suture is based on a single specimen, and for the reconstructions, adjacent sutures are used. On the suture drawings the middle of the venter is marked by a straight line with an arrow pointing adorally, while the umbilical seam is marked by a dashed arc. Small arrows indicate points where the figured suture is truncated by the preceding suture.

The distribution of the species at the investigated localities is summarized in Table 7.

The fossils figured in the present paper are deposited in the Paleontological Museum of the University of Oslo. The registration numbers of the specimens (e.g. A39420) refer to the collections of this museum.

8.2. *List of descriptions*

8.3. *Brachiopoda*

Lingula cf. *beani* Phillips 1829
Plate 1, Fig. 1

- □ 1829 cf. *Lingula Beanii* Phillips, p. 157, pl. 11, fig. 24.
- □ 1900 cf. *Lingula beani* Phillips — Pompeckj, p. 54, pl. 1, figs. 2—5.

Material and occurrence. — Internal and external molds, poorly preserved. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 5 and 7.

Remarks. — The Spitsbergen specimens resemble Pompeckj's (1900) *Lingula beani* in shape, size and ornamentation, although his specimens have weaker and more numerous radial striae. The specimens described by Phillips (1835) show more parallel lateral margins and a more stumpy area near the frontal margins.

Stratigraphical range. — Lower Bajocian (Pompeckj 1900).

Lingula sp.
Plate 1, Fig. 2

Material and occurrence. — Internal molds, often with attached shell fragments. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 5, 8 and 17.

Remarks. — The present specimens fully correspond in morphology to *Lingula* sp. described by Birkenmajer & Pugaczewska (1975). They can be separated from *Lingula* cf. *beani* by their smaller size and somewhat different ornamentation.

Discinisca cf. *reflexa* (Sowerby 1829)
Plate 1, Figs. 3—5

- □ 1829 cf. *Orbicula reflexa* Sowerby, p. 4, pl. 506, fig. 1.
- □ 1900 cf. *Discina reflexa* (Sowerby) — Pompeckj, p. 58, pl. 1, figs. 6—9.

Material and occurrence. — Internal and external molds, poorly preserved. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 5 and 7.

Remarks. — The present specimens are similar in shape and size to forms usually included in the family Discinidae. The morphology and stratigraphical distribution of the genus *Discinisca* recorded by Rowell (in Moore 1965) fit well with that of the Spitsbergen specimens. They are almost identical with *Discina reflexa* recorded by Pompeckj (1900), although poor preservation makes a detailed comparison somewhat difficult.

Stratigraphical range. — Lower Bajocian (Pompeckj 1900).

8.4. *Bivalvia*

Inoceramus sp.
Plate 1, Fig. 8

Material and occurrence. — Incomplete internal mold of a left valve. Phosphorite pebble of the Brentskardhaugen Bed at loc. 9.

Remarks. — Shape, ornamentation and fragments of a postero-dorsal auricle indicate that the specimen belongs to the genus *Inoceramus*. Among Lower Jurassic subgenera it corresponds most to *I. (Inoceramus)*.

Oxytoma (Oxytoma) inequivalvis (Sowerby 1819)
Plate 1, Fig. 9

- □ 1819 *Avicula inequivalvis* Sowerby, p. 78, pl. 244, fig. 2.
- □ 1840 *Avicula inaequivalvis* Sowerby — Goldfuss, p. 130, pl. 118, fig. 1.
- □ 1905 *Oxytoma inaequivalvis* (Sowerby) — Benecke, p. 91, pl. 4, fig 11.
- □ 1975 *Oxytoma inaequivalvis* (Sowerby) — Birkenmajer & Pugaczewska, p. 61, pl. 3, figs. 1—6.
- □ 1981 *Oxytoma (Oxytoma) inequivalvis* (Sowerby) — Wierzbowski et al., p. 219, pl. 7, figs. 5—7.

Material and occurrence. — Incomplete internal and external molds, all of left valves. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 6.

Stratigraphical range. — Sinemurian to Kimmeridgian (Birkenmajer & Pugaczewska 1975).

Oxytoma sp.
Plate 1, Fig. 10

Material and occurrence. — Several more or less complete internal molds. Lower part of the Wilhelmøya Formation at loc. 21.

Remarks. — The specimens have a greater size than *O. (Oxytoma) inequivalvis* and the ornamentation is somewhat different.

Meleagrinella cf. *echinata* (Smith 1817)
Plate 2, Fig. 1

- □ 1817 cf. *Avicula echinata* Smith, pl. 26, fig. 8.
- □ 1840 cf. *Monotis decussata* Goldfuss, p. 139, pl. 120, fig. 8.
- □ 1853 cf. *Avicula echinata* Smith — Morris & Lycett, p. 16, pl. 2, fig. 7.
- □ 1961 cf. *Meleagrinella echinata* (Smith) — Sibiriakova, p. 70, pl. 8, figs. 13—15.
- □ 1975 *Meleagrinella* cf. *echinata* (Smith) — Birkenmajer & Pugaczewska, p. 62, pl. 3, fig. 9.
- □ 1981 *Meleagrinella* cf. *echinata* (Smith) — Wierzbowski et al., p. 219, pl. 8, figs. 6—8.

Material and occurrence. — Several more or less complete internal molds, often with attached shell fragments. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 5, 6, 7 and 8.

Remarks. — Our specimens are closely similar to the specimens illustrated by Birkenmajer & Pugaczewska (1975) and Wierzbowski et al. (1981).

Stratigraphical range. — Bajocian to Callovian (Birkenmajer & Pugaczewska, op. cit.).

Propeamussium (Parvamussium) cf. *personatum* (Zieten 1830)

Plate 2, Fig. 2

- □ 1830 cf. *Pecten personatus* Zieten, p. 68, pl. 52, fig. 2.
- □ 1840 cf. *Pecten personatus* Zieten — Goldfuss, p. 75, pl. 99, fig. 5.
- □ 1905 cf. *Pecten (Variamussium) pumilus* (Lamarck) — Benecke, p. 112, pl. 3, figs. 20—22.
- □ 1961 cf. *Variamussium personatum* (Zieten) — Sibiriakova, p. 85, pl. 10, figs. 14—17.
- □ 1975 cf. *Variamussium personatum* (Zieten) — Birkenmajer & Pugaczewska, p. 63, pl. 3, fig. 8.
- □ 1981 cf. *Propeamussium (Parvamussium) personatum* (Zieten) — Wierzbowski et al., p. 220, pl. 7, fig. 10.

Material and occurrence. — Incomplete internal molds of two left valves. Phosphorite pebble of the Brentskardhaugen Bed at loc. 8.

Remarks. — Cox (in Moore 1969) included the genus *Variamussium* Sacco (1897) within *Propeamussium (Parvamussium)*, and this classification is followed in the present paper. *Pecten personatus* described by Goldfuss (1840) is ornamented with 12—14 radial ribs, while specimens referred to the same species by Birkenmajer & Pugaczewska (1975) have seven ribs. Our specimens are ornamented with 9 to 10 poorly visible ribs. They show no 2nd and 3rd order radial ribs which make their specific determination somewhat uncertain.

Stratigraphical range. — Upper Lias to Bajocian (Birkenmajer & Pugaczewska op. cit.).

Chlamys (Chlamys) sp.

Plate 2, Fig. 3

Material and occurrence. — External mold of one specimen with attached shell fragments. Phosphorite pebble of the Brentskardhaugen Bed at loc. 18.

Remarks. — Shape, ornamentation and fragment of an auricle together with stratigraphical occurrence indicate that the specimen belongs to the *Chlamys* group, and most probably to the subgenus *C. (Chlamys)*.

Buchia? sp.

Plate 1, Figs. 6, 7

Material and occurrence. — Several internal and external molds. Phosphorite pebbles from the uppermost part of the Wilhelmøya Formation at loc. 20 and 22.

Remarks. — Poor preservation does not allow determination at the specific level, but shape and rib pattern resemble the features characteristic of *Buchia*.

Plagiostoma cf. *subcardiiformis* (Greppin 1870)

Plate 2, Fig. 5

- □ 1853 cf. *Lima cardiiformis* Morris & Lycett, p. 27, pl. 3, fig. 2.
- □ 1853 cf. *Lima semicardiiformis* Morris & Lycett, p. 29, pl. 3, fig. 3.
- □ 1870 cf. *Lima subcardiiformis* Greppin, p. 44, 50.
- □ 1961 cf. *Lima (Plagiostoma) subcardiiformis* Greppin — Ronchetti & Sestini, p. 125, pl. 10, fig. 13.

Material and occurrence. — Three internal molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 9.

Remarks. — The Spitsbergen specimens mostly resemble Ronchetti & Sestini's (1961) specimens referred to *Lima (Plagiostoma) subcardiiformis* due to their shape, size and ornamentation. Cox & Hertlein (in Moore 1969) regarded *Plagiostoma* as an own genus, and this classification is followed here.

Stratigraphical range. — Bajocian to Bathonian (Ronchetti & Sestini 1961).

Gryhaea? sp.

Plate 2, Fig. 4

Material and occurrence. — An incomplete shell. Phosphorite pebble from the uppermost part of the Wilhelmøya Formation at loc. 20.

Remarks. — A large, almost circular muscle scar is situated in the central part of the shell, which is almost flat. These features are found in the families Gryphaeidae and Ostreidae. Shape of the shell and stratigraphical occurrence indicate that the specimen most probably belongs to the genus *Gryphaea.*

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Liotrigonia lingonensis (Dumortier 1869)
Plate 3, figs. 1—4

□ 1869 *Trigonia Lingonensis* Dumortier, p. 275, pl. 32, figs. 6—8.
□ 1952 *Liotrigonia lingonensis* (Dumortier) — Cox, p. 53, pl. 4, fig. 2.

Material and occurrence. — Four more or less complete internal molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 9.

Remarks. — The specimens are similar to Dumortier's (1869) *Trigonia lingonensis* which has a distinct ridge-like structure in its posterior part. In the present material this structure is best developed on the smallest specimen.

Stratigraphical range. — According to Dumortier (1869) the species occurs in the Pecten equivalvis Zone which corresponds to the Upper Pliensbachian — Lower Toarcian interval, as shown below. The oldest ammonite described by Dumortier from this zone was *Ammonites margaritatus* (margaritatus Zone, Upper Pliensbachian). The oldest ammonite described by the same author from the overlying zone was *Ammonites exaratus* (exaratum Subzone, lower part of falciferum Zone, Lower Toarcian).

Trigonia sp.
Plate 3, Figs. 5—6

Material and occurrence. — Two incomplete internal molds. Phosphorite pebbles from the upper part of the Wilhelmøya Formation at loc. 22.

Remarks. — A ridge-like structure runs from umbo towards the posterioventral portion of the shell. This, together with the general shape indicate that the specimens belong to the genus *Trigonia.*

Luciniola cf. *pumila* (Goldfuss 1840)
Plate 3, Fig. 7

□ 1840 cf. *Venus pumila* Goldfuss, p. 243, pl. 150, fig. 7.
□ 1975 *Luciniola* cf. *pumila* (Goldfuss) — Birkenmajer & Pugaczewska, p. 68, pl. 5, fig. 4.
□ 1981 *Luciniola* cf. *pumila* (Goldfuss) — Wierzbowski et al., p. 222, pl. 9, fig. 3.

Material and occurrence. — One external mold with attached shell fragments. Phosphorite pebble of the Brentskardhaugen Bed at loc. 7.

Remarks. — The specimen mostly resembles *Luciniola* cf. *pumila* described by Birkenmajer & Pugaczewska (1975) and Wierzbowski et al. (1981).

Stratigraphical range. — Upper Lias (Birkenmajer & Pugaczewska, op. cit.).

Mactromya globosa Agassiz 1845
Plate 3, Figs. 8—9

□ 1845 *Mactromyaglobosa* Agassiz, p. 200, pl. 9, figs. 9—14.

Material and occurrence. — Two internal molds with attached shell fragments. Phosphorite pebbles from the upper part of the Wilhelmøya Formation at loc. 20.

Remarks. — The specimens described by Agassiz (1845) show some variation in convexity. The specimen illustrated by him in Figs. 12—14 is most similar to the Spitsbergen specimens.

Stratigraphical range. — According to Agassiz (1845) the stratigraphical occurrence of *M. globosa* is confined to the Middle Jurassic, while the time range of the genus *Mactromya* is Bathonian — Portlandian. Consequently, the range of *M. globosa* must be within the Bathonian — Callovian interval.

Astarte (Astarte) elegans Sowerby 1816
Plate 3, Figs. 10—11

□ 1816 *Astarte elegans* Sowerby, pl. 137, fig. 3.
□ 1840 *Astarte elegans* Sowerby — Goldfuss, p. 191, pl. 134, fig. 12.

□ 1853 *Astarte elegans* Sowerby — Morris & Lycett, pl. 14, fig. 14.

□ 1905 *Astarte elegans* Sowerby — Benecke, p. 214, pl. 16, figs. 1—3.

Material and occurrence. — Two internal molds with attached shell fragments. Phosphorite pebbles from the uppermost part of the Wilhelmøya Formation at loc. 20.

Remarks. — Shavan (in Moore 1969) divided the genus *Astarte* into different subgenera. Shape and stratigraphical occurrence attribute the present specimens to *A. (Astarte).*

Stratigraphical range. — Erzformation, according to Benecke (1905). This unit contains in its lowermost part *Dumortiera levesquei* (representing the uppermost zone of the Toarcian), while in its upper part *Ludwigia murchisonae* occurs (representing the middle part of the Aalenian).

Tancredia (Tancredia) donaciformis Lycett 1850.

Plate 3, Fig. 12, Plate 4, Figs. 1—4

□ 1850 *Tancredia donaciformis* Lycett, p. 407, pl. 11, fig. 8.

□ 1905 *Tancredia donaciformis* Lycett — Benecke, p. 245, pl. 20, figs. 9—12.

□ 1969 *Tancredia (Tancredia) donaciformis* Lycett — Cox, in Moore, p. 640, pl. E 123, fig. 4.

□ 1981 *Tancredia (Tancredia)* cf. *donaciformis* Lycett — Wierzbowski et al., p. 225, pl. 12, fig. 6.

Material and occurrence. — Several more or less complete internal and external molds, often with attached shell fragments. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 3, 5, 6, 7 and 9; uppermost part of the Wilhelmøya Formation at loc. 20.

Remarks. — The present specimens are generally consistent with those referred to *Tancredia donaciformis* by Benecke (1905). The posterior part of the palial line is in Benecke's specimens inclined somewhat more anteriorly than on the specimens illustrated in the present paper.

Stratigraphical range. — Erzformation (Benecke 1905), corresponding in age to the Upper Toarcian — Middle Aalenian interval (discussed under *Astarte (Astarte) elegans*).

Pholadomya (Pholadomya) cf. *hemicardia* Roemer 1836.

Plate 4, Fig. 5

□ 1836 cf. *Pholadomya hemicardia* Roemer, p. 131, pl. 9, fig. 18.

□ 1840 cf. *Pholadomya hemicardia* Roemer — Goldfuss, p. 269, pl. 156, fig. 8.

□ 1945 cf. *Pholadomya* cf. *hemicardia* Roemer — Imlay, p. 268, pl. 40, figs. 22, 23, 25, 28, 29.

□ 1975 cf. *Pholadomya* cf. *hemicardia* Roemer — Birkenmajer & Pugaczewska, p. 74, pl. 6, fig. 3.

Material and occurrence. — External mold of one right valve. Phosphorite pebble of the Brentskardhaugen Bed at loc. 5.

Remarks. — Cox (in Moore 1969) divided the genus *Pholadomya* into three subgenera. Among these the present species is closest related morphologically to *P. (Pholadomya).* Shape and dimensions show great similarity to *Pholadomya* cf. *hemicardia* recorded in the papers listed above.

Stratigraphical range. — Callovian to Oxfordian (Birkenmajer & Pugaczewska 1975).

Pholadomya (Pholadomya) kingi Meek 1873.

Plate 4, Figs. 6—7

□ 1873 *Pholadomya Kingii* Meek, p. 473.

□ 1899 *Pholadomya kingi* Meek — Stanton, p. 624, pl. 74, figs. 1—3.

□ 1964 *Pholadomya kingi* Meek — Imlay, p. 36, pl. 4, fig. 36.

□ 1967 *Pholadomya kingi* Meek — Imlay, p. 86, pl. 5, figs. 36—38, 42.

Material and occurrence. — One incomplete internal mold. Phosphorite pebble from the Wilhelmøya Formation at loc. 19.

Remarks. — *P. (Pholadomya) kingi* differs from *P. (Pholadomya)* cf. *hemicardia* recorded above by its distinct radial ribbing. *P. (Pholadomya)* cf. *fidicula* figured by Wierzbowski et al. (1981, pl. 5, fig. 9) is morphologically close to the present specimen except for its shorter anterior part and a longer posterior portion.

Stratigraphical range. — Bajocian to Lower Callovian (Imlay 1964, 1967).

Pholadomya sp.
Plate 4, Fig. 8

Material and occurrence. — Incomplete external mold of a left valve. Phosphorite pebble of the Brentskardhaugen Bed at loc. 9.

Remarks. — Shape and ornamentation of the present specimen fit with the main features of *Pholadomya.* With its large height the specimen shows some similarity to the subgenus *P. (Bucardiomya)* defined by Cox (in Moore 1969).

Goniomya literata (Sowerby 1819)
Plate 5, Figs. 1—2

□ 1819 *Mya? literata* Sowerby, p. 45, pl. 224, fig. 1.
□ 1975 *Goniomya literata* (Sowerby) — Birkenmajer & Pugaczewska, p. 76, pl. 11, fig. 2.

Material and occurrence. — One internal mold. Phosphorite pebble from the uppermost part of the Wilhelmøya Formation at loc. 20.

Remarks. — Morphology of the present specimen fully corresponds to the description given by Birkenmajer & Pugaczewska (1975).

Stratigraphical range. — Bathonian to Kimmeridgian (Birkenmajer & Pugaczewska, op. cit.).

Homomya gibbosa (Sowerby 1813)
Plate 5, Figs. 3—6

□ 1813 *Mactra gibbosa* Sowerby, p. 91, fig. 42.
□ 1843 *Homomya gibbosa* (Sowerby) — Agassiz, p. 160, pl. 18, figs. 1—5.
□ 1863 *Homomya gibbosa* (Sowerby) — Lycett, p. 88, pl. 43, fig. 2.
□ 1969 *Homomya gibbosa* (Sowerby) — Cox (in Moore), p. 832, pl. F13, fig. 3.

Material and occurrence. — One incomplete internal mold. Phosphorite pebble of the Brentskardhaugen Bed at loc. 7.

Remarks. — The present specimen differs from *Pholadomya (Pholadomya)* cf. *nodosa* figured by Wierzbowski et al. (1981, pl. 10, fig. 2) by a more anteriorly situated umbo, concave posteriodorsal margin and absence of well defined radial ribs.

Stratigraphical range. — Lycett (1863) reported the species from the Cornbrash and Inferior Oolite in England, which corresponds to the Aalenian — Lower Callovian (Brinkmann 1959).

Pleuromya elongata (Goldfuss 1836)
Plate 5, Figs. 7—9

□ 1836 *Lutraria elongata* Goldfuss, p. 258, pl. 153, fig 4.
□ 1845 *Pleuromya elongata* (Goldfuss) — Agassiz, p. 244, pl. 26, figs. 1, 2, pl. 27, figs. 3—8.
□ 1905 *Pleuromya elongata* (Goldfuss) — Benecke, p. 279, pl. 24, fig. 2.
□ 1955 *Pleuromya elongata* (Goldfuss) — Ksiazkiewicz, p. 181, pl. 17, fig. 10.
□ 1961 *Pleuromya elongata* (Goldfuss) — Sibiriakova, p. 157, pl. 28, figs. 3, 4.

Material and occurrence. — Several more or less complete internal molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 17, and from the uppermost part of the Wilhelmøya Formation at loc. 20.

Stratigraphical range. — Bajocian (Ksiazkiewicz 1955).

? Pleuromya marginata (Agassiz 1845)
Plate 5, Figs. 10—13

□ 1845 ? *Myopsis marginata* Agassiz, p. 257, pl. 30, figs. 1, 2.
□ 1899 ? *Pleuromya marginata* (Agassiz) — Greppin, p. 60, pl. 7, fig. 5.
□ 1961 ? *Pleuromya marginata* (Agassiz) — Sibiriakova, p. 155, pl. 27, fig. 7.

Material and occurrence. — Several more or less complete internal molds, often with attached shell fragments. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 8 and 17, and from the uppermost part of the Wilhelmøya Formation at loc. 20.

Remarks. — Length of the anterior part is variable but less prominent than in *Pleuromya elongata.* Shape and size of the specimens show some similarity to *Pleuromya marginata,* but because of variable length of the anterior part and a somewhat too prominent umbo, both the generic and specific assignments are uncertain.

Stratigraphical range. — Bathonian (Sibiriakova 1961).

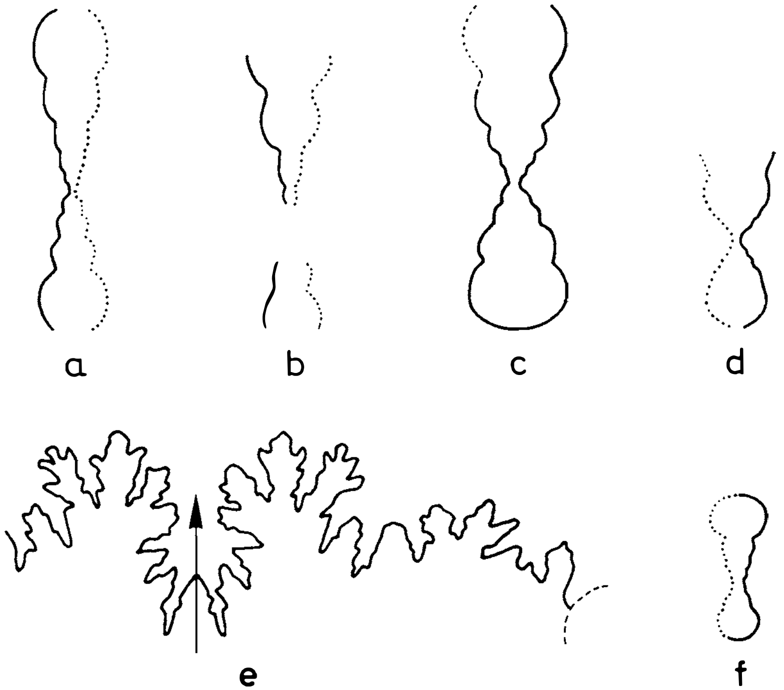


Fig. 24. Whorl sections and suture line of *Dactylioceras* and *Porpoceras.*
a-b. *Dactylioceras toxophorum* (Buckman). Whorl sections (× 1) of two specimens: a of A39453, b of A39454.
c-d. *Porpoceras polare* (Frebold). Whorl sections (× 0.8) of two specimens: c of A39456, d of A39455.
e. *Porpoceras polare* (Frebold). External suture (× 4) of A39455 at a whorl height of 11 mm.
f. *Porpoceras spinatum* (Frebold). Whorl section (× 0.8) of A39457.

Pleuromya subcompressa (Meek 1873)
Plate 6, Fig. 1

- ☐ 1873 *Myacites (Pleuromya) subcompressa* Meek, p. 472.
- ☐ 1899 *Pleuromya subcompressa* (Meek) — Stanton, p. 626, pl. 74, figs. 8—11.
- ☐ 1964 *Pleuromya subcompressa* (Meek) — Imlay, p. 35.
- ☐ 1967 *Pleuromya subcompressa* (Meek) — Imlay, p. 85, pl. 5, figs. 16—21.

Material and occurrence. — One internal mold and one external mold of a right valve with attached shell fragments. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 9.

Stratigraphical range. — Bajocian to Callovian (Imlay 1964, 1967).

Pleuromya sp.
Plate 6, Figs. 2, 3

Material and occurrence. — One incomplete internal mold. Phosphorite pebble from the upper part of the Wilhelmøya Formation at loc. 22.

Remarks. — The specimen resembles *Pleuromya* by its shape and ornamentation, but seems to be more inflated than is usual within this genus.

8.5. *Ammonoidea*

Dactylioceras toxophorum (Buckman 1928)
Plate 6, Figs. 4, 5, Text-fig. 24a—b

- ☐ 1928 *Toxodactylites toxophorus* Buckman, pl. 776.

Material and occurrence. — Internal and external molds with attached shell fragments. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 18.

Remarks. — The ribs of *Dactylioceras toxophorum* are somewhat less closely spaced than in *Dactylioceras anguiforme* (Buckman 1928), but denser spaced than in *Dactylioceras commune* (Sowerby 1815). The flanks of *D. toxophorum* seem to be slightly more flattened than in the two related species mentioned above.

Stratigraphical range. — Falciferum Zone (falciferum Subzone), Toarcian.

Porpoceras polare (Frebold 1929)
Plate 6, Figs. 6—9, Text-fig. 24c—e

- ☐ 1929b *Coeloceras polare* Frebold, p. 258, pl. 2(34), figs. 11—13.

□ 1930 *Coeloceras polare* Frebold — Frebold, p. 61, pl. 22, fig. 4.
□ 1975 *Catacoeloceras polare* (Frebold) — Birkenmajer & Pugaczewska, p. 81, pl. 10, figs. 2, 3.
□ 1975 *Peronoceras polare* (Frebold) — Frebold, p. 14, pl. 5, fig. 2.
□ 1981 *Porpoceras polare* (Frebold) — Wierzbowski et al., p. 208, pl. 1, figs. 5, 6.

Material and occurrence. — Two incomplete internal molds and one complete specimen. Phosphorite pebbles from the Brentskardhaugen Bed at loc. 7, and from a sandstone bench 4 metres below the Brentskardhaugen Bed at loc. 12 (A 39477).

The age of the Porpoceras — Pseudolioceras fauna. — The widespread arctic Porpoceras — Pseudolioceras fauna contains *Porpoceras polare*, *P. spinatum*, *Pseudolioceras compactile* and other representatives of *Pseudolioceras.* It is known from the Canadian Arctic, East Greenland, northern Sibiria and from the Brentskardhaugen Bed in Svalbard. The age of the fauna is discussed by several authors and diverging opinions are propounded, e.g. thouarsense Zone, striatulum Subzone (Frebold 1975); bifrons Zone, fibulatum Subzone (Howarth 1978); fibulatum Subzone to variabilis Zone (Wierzbowski et al. 1981). Conclusive evidence for a more precise zonal assignment is, however, not presented. We prefer therefore to place the Porpoceras — Pseudolioceras fauna of the Brentskardhaugen remanié bed provisionally within the total time interval suggested above, without closer age specification.

Porpoceras spinatum (Frebold 1958)

Plate 6, Figs. 10, 11, Text-fig. 24f

□ 1956 *Coeloceras* n. sp. Frebold (in Tozer), p. 21.
□ 1958a *Coeloceras spinatum* Frebold, p. 3, pl. 2, figs. 1—4.
□ 1975 *Peronoceras spinatum* (Frebold) — Frebold, p. 13, pl. 5, fig. 1.

Material and occurrence. — One external mold. Phosphorite pebble of the Brentskardhaugen Bed at loc. 17.

Remarks. — This species can be separated from *Porpoceras polare* by its thinner and higher ribs.

Stratigraphical range. — Bifrons Zone (fibulatum Subzone) — thouarsense Zone (striatulum Subzone), Toarcian; as discussed under *Porpoceras polare.*

Porpoceras cf. *spinatum* (Frebold 1958)

Plate 6, Figs. 12, 13

For synonyms, see under *Porpoceras spinatum.*

Material and occurrence. — Two incomplete external molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 14.

Remarks. — The general shape of the shell and its ribbing pattern with high and thin ribs, show a close similarity to *P. spinatum.*

Pseudolioceras compactile (Simpson 1855)

Plate 7, Fig. 3

□ 1855 *Ammonites compactilis* Simpson, p. 75.
□ 1889 *Pseudolioceras compactile* (Simpson) — Buckman, p. 85.
□ 1904 *Pseudolioceras compactile* (Simpson) — Buckman, p. 159 suppl.
□ 1911 *Pseudolioceras compactile* (Simpson) — Buckman, p. 41b, pl. 41a, b.
□ 1929a *Pseudolioceras* cf. *compactile* (Simpson) — Frebold, p. 9, pl. 1, fig. 3.
□ 1929b *Pseudolioceras* cf. *compactile* (Simpson) — Frebold, p. 261, pl. 2(34), figs. 1—4.
□ 1958a *Pseudolioceras* aff. *compactile* (Simpson) — Frebold, p. 5, pl. 3, figs. 3—6.
□ 1968 *Pseudolioceras compactile compactile* (Simpson) — Kopik, p. 46, pl. 2, fig. 3, 4.

Material and occurrence. — Incomplete internal and external molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 8, 13, 15 and 16.

Stratigraphical range. — Bifrons Zone (fibulatum Subzone) — thouarsense Zone (striatulum Subzone), Toarcian; as discussed under *Porpoceras polare.*

Pseudolioceras gradatum Buckman 1904

Plate 7, Fig. 4, Text-fig. 25c—e

□ 1889 *Pseudolioceras compactile* Buckman, p. 85, pl. 20, figs. 3—4.
□ 1904 *Pseudolioceras gradatum* Buckman, p. 158 suppl.

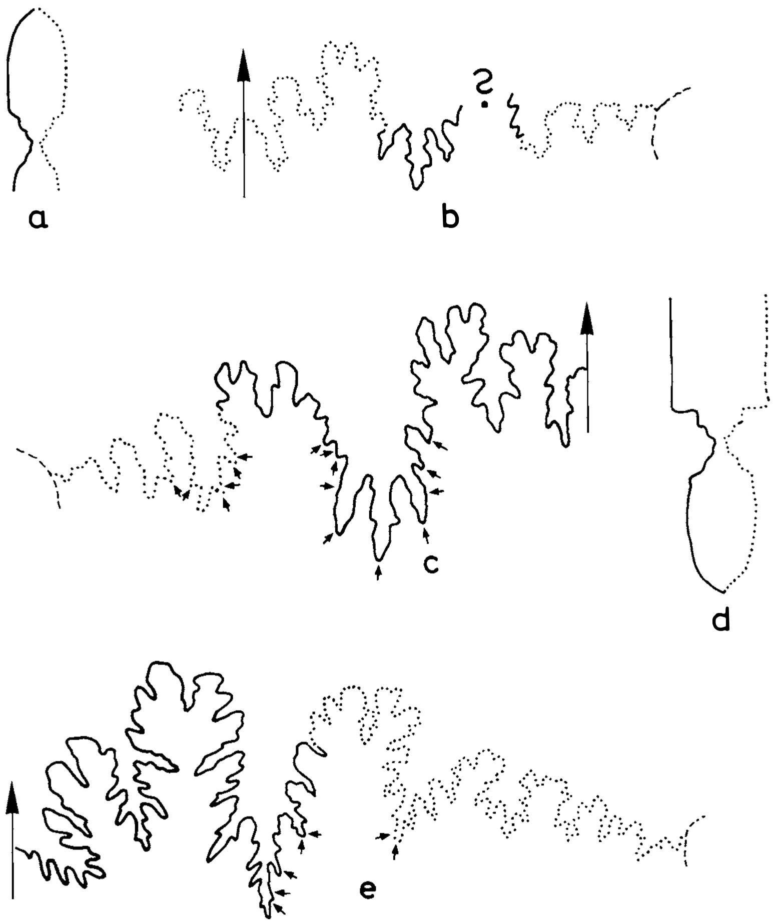


Fig. 25. Whorl sections and suture lines of *Brasilia* and *Pseudolioceras*.
a-b. *Brasilia* aff. *bradfordense* (Buckman): a. whorl section (× 0.8); b. external suture (× 3) of A39460.
c-e. *Pseudolioceras gradatum* (Buckman): c. external suture (× 3) of A39462 at a whorl height of 22 mm; d. whorl section (× 0.8); of A39462; e. external suture (× 2.4) of A39478 at a whorl height of 29 mm.

□ 1929b *Pseudolioceras* cf. *compactile* Buckman — Frebold, p. 261, pl. 2(34), figs. 1—4.
□ 1968 *Pseudolioceras compactile gradatum* Buckman — Kopik, p. 43, pl. 2, fig. 2.

Material and occurrence. — Three more or less complete internal molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 5, 7 and 11.

Remarks. — This species can be separated from *Pseudolioceras pumilum* by a somewhat broader umbilicus and a more dominating keel. Kopik (1968) classified his specimen as a sub-species of *Pseudolioceras compactile.* The material treated in the present paper show, however, marked differences between the two forms indicating that the classification of Buckman (1904) should be preferred.

Stratigraphical range. — Close morphological relation between *Pseudolioceras compactile* and *Pseudolioceras gradatum* suggests a similar stratigraphical occurrence, i.e. bifrons Zone (fibulatum Subzone) — thouarsense Zone (striatulum Subzone), Toarcian.

Pseudolioceras cf. *gradatum* Buckman 1904
Plate 7, Fig. 5, Text-fig. 27c

For synonyms, see under *Pseudolioceras gradatum.*

Material and occurrence. — An incomplete mold, an external mold, and cross section of an internal mold belonging to three different specimens. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 8, 13 and 18.

Remarks. — Shape of umbilicus, rib pattern and cross section of the internal mold show close similarity to *Pseudolioceras gradatum.* Rib pattern and a rather high keel of the external mold also resemble that species.

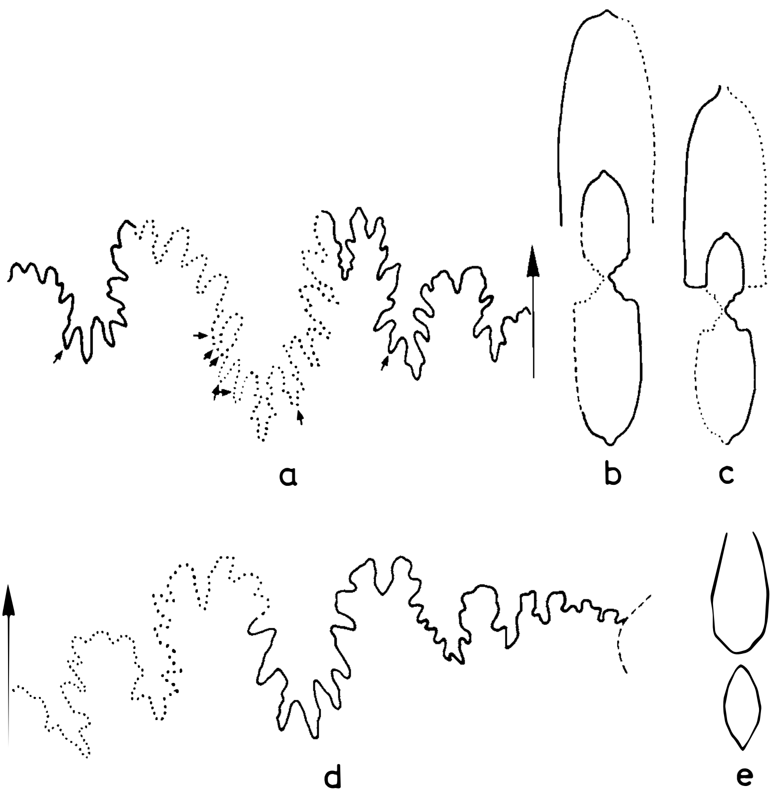


Fig. 26. Suture lines and whorl sections of *Pseudolioceras*.
a-c. *Pseudolioceras pumilum* (Buckman): a. external suture (× 2.2) of A39465 at a whorl height of 14 mm; b. whorl section (× 0.8) of A39465; c. whorl section (× 0.8) of A39464.
d-e. *Pseudolioceras maclintocki* (Haughton): d. external suture (× 5.3) of A39466 at a whorl height of 14 mm; e. whorl section (× 0.8) of A39466.

The cross section of the internal mold shows a rather wide umbilicus with perpendicularly bent walls, and a distinct peripheral keel, all features characteristic for *Pseudolioceras gradatum*. The whorls, however, seem somewhat more inflated than in the illustrations published by Buckman (1904).

Pseudolioceras pumilum Buckman 1902
Plate 7, Figs. 6—9, Text-fig. 26a—c

- □ 1889 *Pseudolioceras compactile* (Simpson) — Buckman, p. 85, pl. 20, figs. 5, 6.
- □ 1902 *Pseudolioceras pumilum* Buckman, p. 159, suppl.
- □ 1930 *Pseudolioceras pumilum* Buckman — Frebold, p. 28, pl. 6, fig. 1.
- □ 1981 *Pseudolioceras compactile* (Simpson) — Wierzbowski et al., pl. 2, fig. 3 only.

Material and occurrence. — Two almost complete specimens. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 6.

Remarks. — The two specimens show minor differences in the development of the ventral area (Text-fig. 26b, c) which may be due to different growth stages. The present species can be separated from *Pseudolioceras compactile* by its less distinct ribs which are narrower in the ventral area. One of the ammonites referred to *P. compactile* by Wierzbowski et al. (1981, pl. 2, fig. 3) is here included in *P. pumilum* because it shows a close similarity to the present specimens by its rib pattern and umbilical area.

Stratigraphical range. — Close morphological relation between *Pseudolioceras compactile* and *Pseudolioceras pumilum* suggests a similar stratigraphical occurrence, i.e. bifrons Zone (fibulatum Subzone) — thouarsense Zone (striatulum Subzone), Toarcian.

Pseudolioceras cf. *pumilum* Buckman 1902

For synonyms, see under *Pseudolioceras pumilum*.

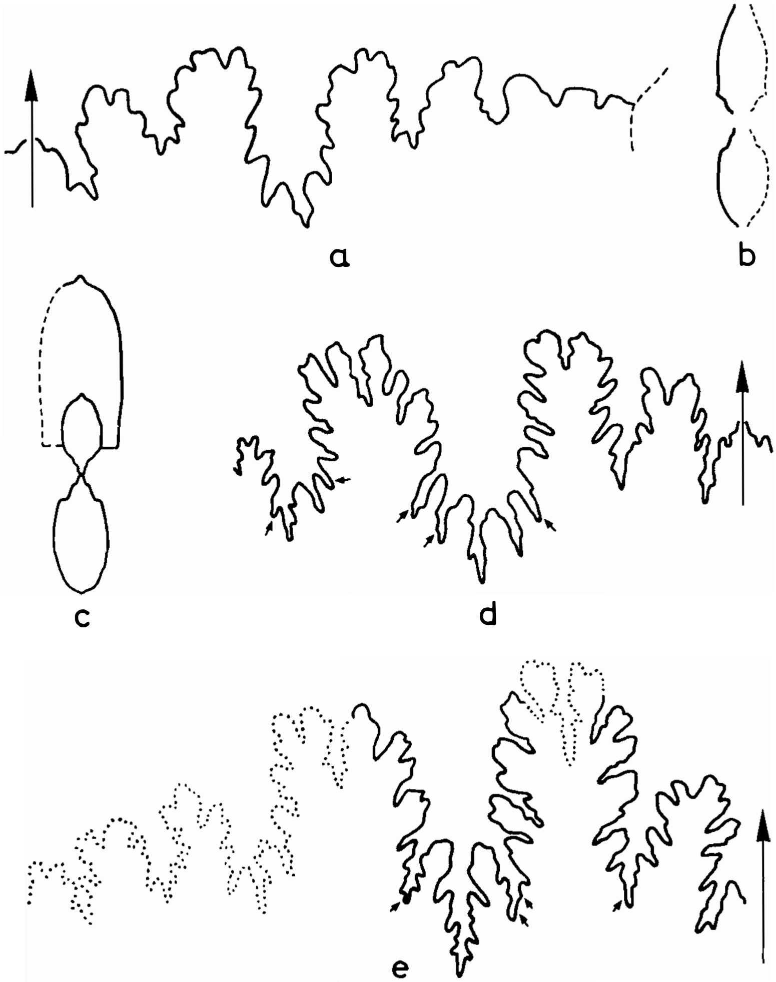
Material and occurrence. — One incomplete internal mold. Phosphorite pebble of the Brentskardhaugen Bed at loc. 15.

Fig. 27. Suture lines and whorl sections of *Pseudolioceras.*

a-b. *Pseudolioceras rosenkrantzi* (Dagis): a. external suture (× 8) of A39467 at at whorl height of 10 mm; b. whorl section (× 0.8) of A39467.

c. *Pseudolioceras* cf. *gradatum* (Buckman). Whorl section (× 0.8) of A39476.

d-e. *Pseudolioceras* spp. External sutures (× 3) of two specimens: d. of A39474, e. of A39475.



Remarks. — This specimen is similar to *Pseudolioceras pumilum* with regard to cross section, ventral margin and umbilicus. It differs in having somewhat higher ribs.

Pseudolioceras maclintocki (Haughton 1858)

Plate 7, Fig. 10, Text-fig. 26d-e

□ 1858 *Ammonites m'clintocki* Haughton, p. 244, pl. 9, figs. 2—4.

□ 1885 *Harpoceras m'clintocki* (Haughton) — Neumayr, p. 85, figs. 5—8.

□ 1958a *Ludwigia m'clintocki* (Haughton) — Frebold, p. 7, pl. 5, figs. 3, 4.

□ 1960 *Pseudolioceras m'clintocki* (Haughton) — Frebold, p. 20, pl. 8, figs. 1—9, pl. 9, figs. 1—4, pl. 10, fig. 1, pl. 11, figs. 1—3, pl. 12, fig. 1.

Material and occurrence. — Two more or less complete internal molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 7 and 14.

Stratigraphical range. — Opalinum Zone, Lower Aalenian (Frebold 1958a).

Pseudolioceras rosenkrantzi Dagis 1965

Plate 7, Fig. 11, Text-fig. 27a, b

□ 1929 *Pseudolioceras* cf. *wuerttenbergeri* (Denckmann) — Frebold, p. 262, pl. 2, fig. 5.

□ 1965 *Pseudolioceras rosenkrantzi* A.A. Dagis (in Dagis & Dagis), p. 23, pl. 1, figs. 1—3.

□ 1974 *Pseudolioceras rosenkrantzi* Dagis — Dagis, p. 52, pl. 18, figs. 2—7, Text-fig. 18, ? pl. 14, fig. 4.

□ 1981 *Pseudolioceras rosenkrantzi* Dagis — Wierzbowski et al., p. 213, pl. 2, fig. 6, pl. 3, figs. 1, 2.

Material and occurrence. — One incomplete internal mold with attached shell fragments. Phosphorite pebble of the Brentskardhaugen Bed at loc. 17.

Remarks. — The Spitsbergen specimen is similar to *Pseudolioceras wuerttenbergeri* (Denckmann 1887) in its general appearance. It differs, however, from that species in having slightly backward bent ribs instead of the falcoid or almost straight ribs seen on the illustrations given by Denckmann. Another distinguishing feature of *Pseudolioceras rosenkrantzi* is its comparatively inflated whorl section.

Stratigraphical range. — *Pseudolioceras rosenkrantzi* indicates the rosenkrantzi Zone in accordance with Dagis (1974). This zone is correlated by Russian geologists with the thouarsense and levesquei Zones which form the Upper Toarcian in northwestern Europe. Frebold (1975) tentatively considers the rosenkrantzi Zone as an equivalent to the striatulum Subzone (thouarsense Zone) only. This approach is regarded to be disputable by Wierzbowski et al. (1981), who share the opinion of Dagis (1974) and other Russian geologists.

Pseudolioceras spp.
Text-fig. 27d, e

Material and occurrence. — Two incomplete internal molds. Phosphorite pebbles of the Brentskardhaugen Bed at loc. 15, and 17.

Remarks. — Rib pattern and suture lines of both specimes show diagnostic features of the genus *Pseudolioceras.*

The sutures preserved in one of the specimens resemble those found in *P. gradatum.* The other specimen shows more complicated sutures, resembling those of *P. pumilum.* Differences are, however, observed in both cases and more certain specific determinations require additional material.

Pseudogrammoceras fallaciosum (Bayle 1878)
Plate 8, Fig. 1

□ 1878 *Grammoceras fallaciosum* Bayle, pl. 78, figs. 1, 2.

Material and occurrence. — One incomplete internal mold. Phosphorite pebble of the Brentskardhaugen Bed at loc. 13.

Stratigraphical range. — Thouarsense Zone (fallaciosum Subzone), Toarcian.

Brasilia aff. *bradfordense* (Buckman 1887)
Plate 7, Figs. 1, 2, Text-fig. 25a—b

□ 1887 aff. *Lioceras bradfordense* Buckman, p. 22, pl. 4, figs. 5—8, pl. 5.

□ 1905 aff. *Harpoceras (Ludwigia) bradfordense* (Buckman) — Benecke, p. 423, pl. 57, figs. 2, 3.

Material and occurrence. — One almost complete internal mold. Phosphorite pebble of the Brentskardhaugen Bed at loc. 7.

Remarks. — The present specimen resembles specimens of *Lioceras bradfordense* illustrated by Buckman (1887 pl. 4, fig. 7) and Benecke (1905, pl. 57, figs. 2, 3). It differs, however, from those forms by its somewhat narrower umbilicus, and by its ribs which are pointed slightly more forwards in the ventral area. *Harpoceras kopiki* Wierzbowski & Kulicki described from the Brentskardhaugen Bed (in Wierzbowski et al. 1981) differs from the present specimen by its bisulcate venter.

Lioceras bradfordense is referred to *Brasilia* and is chosen as the type species of that genus (Arkell et al., in Moore 1957). This generic assignment is followed in this paper.

Stratigraphical range. — Murchisonae Zone (bradfordense Subzone), Middle Aalenian.

8.6. *Decapoda*
Hastites? sp.

Plate 8, Fig. 4

Material and occurrence. — One nearly complete rostrum. Phosphorite pebble of the Brentskardhaugen Bed at loc. 9.

Remarks. — Without having seen the specimen in cross section, attribution to the genus *Hastites* is somewhat doubtful.

Belemnitidae genus indet.

Plate 8, Figs. 2, 3

Material and occurrence. — Several incomplete internal molds of phragmocones, often with attached shell fragments. Phosphorite pebbles of the Brentskardhaugen bed at loc. 3, 5, 6, 7, 9, 14, 18 and in the uppermost part of the Wilhelmøya Formation at loc. 20.

Remarks. — These internal molds are considered to be indeterminable pieces of belemnite phragmocones with no closer age significance.

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PLATES 1—8

PLATE 1

Fig. 1. Lingula cf. *beani* Phillips. Internal mold (A39420) from phosphorite pebble of the Brentskardhaugen Bed at localitly 4; x 1.5.

Fig.2. Lingula sp. Numerous internal molds in phosphorite pebble (A39421) of the Brentskardhaugen Bed at locality 5; x 1.

Fig. 3—5. Discinisca cf. *reflexa* (Sowerby). Internal molds (A39422-Fig. 3 and A39424-Fig. 5) and external mold (A39423-Fig. 4) in phosphorite pebbles of the Brentskardhaugen Bed at locality 7; x 1.5.

Fig. 6—7. Buchia? sp. Internal molds (A39425-Fig. 6 and A39426-Fig. 7) in two phosphorite pebbles of the Wilhelmøya Formation at locality 20; Fig. 6, x 1.5; Fig. 7, x 1.

Fig. 8. Inoceramus sp. Internal mold (A39427, right hand specimen) from phosphorite pebble of the Brentskardhaugen Bed at locality 9; x 1.

Fig. 9. Oxytoma (O.) inequivalvis (Sowerby). Internal mold (A39428) from phosphorite pebble of the Brentskardhaugen Bed at locality 6; x 1.5.

Fig. 10. Oxytoma sp. Internal mold (A39429) from phosphorite pebble of the Wilhelmøya Formation at locality 21; x 1.

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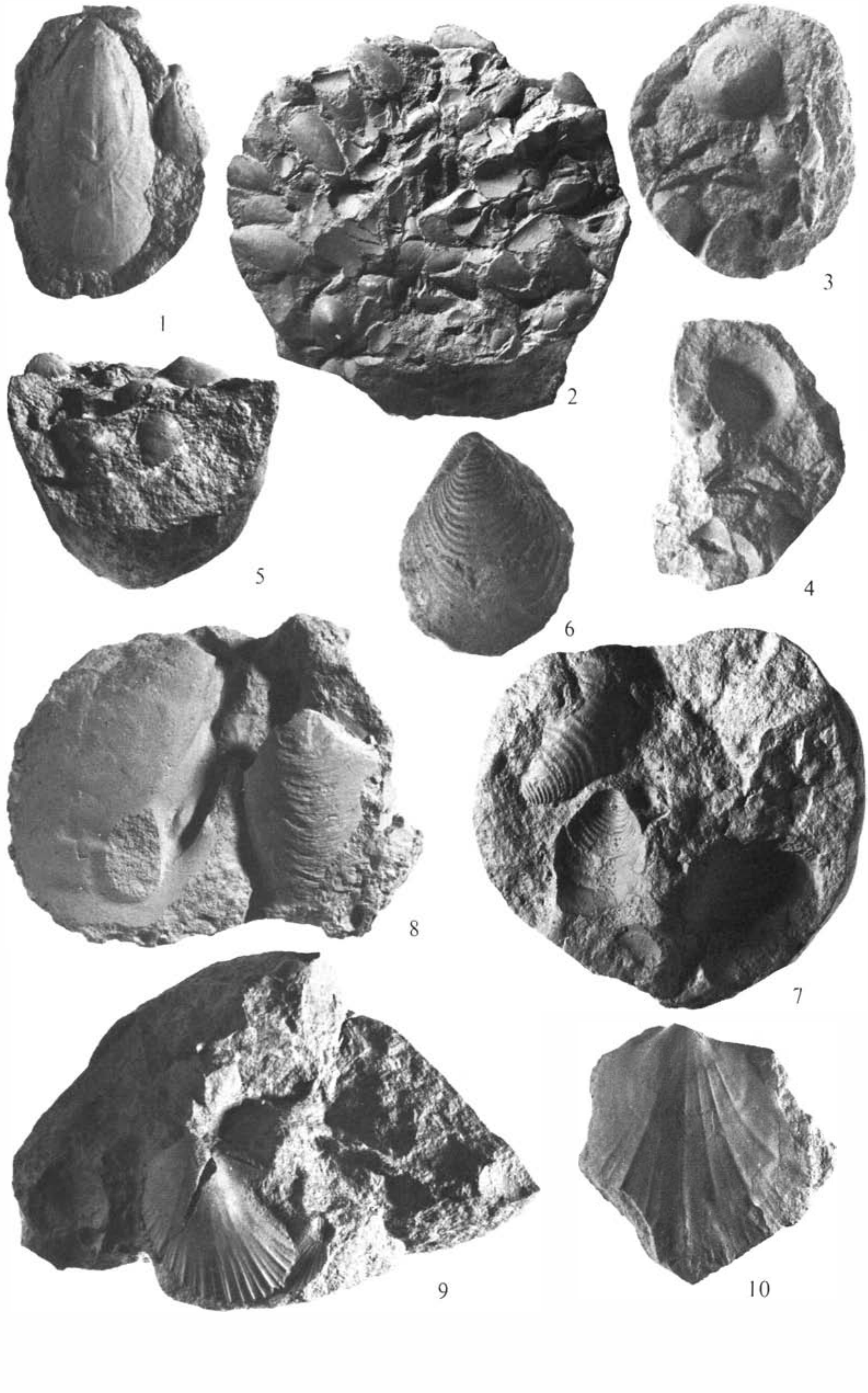

PLATE 2

Fig. 1. Meleagrinella cf. *echinata* (Smith). Internal mold (A39430) with parts of the shell preserved; in phosphorite pebble with numerous crinoide fragments; from the Brentskardhaugen Bed at locality 5; x 1.5.

Fig. 2. Propeamussium (Parvamussium) cf. *personatum* (Zieten). Internal mold (A39431) from phosphorite pebble of the Brentskardhaugen Bed at locality 8; x 2.

Fig. 3. Chlamys (C.) sp. Internal mold (A39432) with most of the shell preserved; phosphorite pebble of the Brentskardhaugen Bed at locality 18; x 1.

Fig. 4. Gryphaea? sp. Part of a shell with muscle scar (A39433); phosphorite pebble of the Wilhelmøya Formation at locality 20; x 1.

Fig. 5. Plagiostoma cf. *subcardiiformis* (Greppin). Internal mold (A39434) from phosphorite pebble of the Brentskardhaugen Bed at locality 9; x 1.

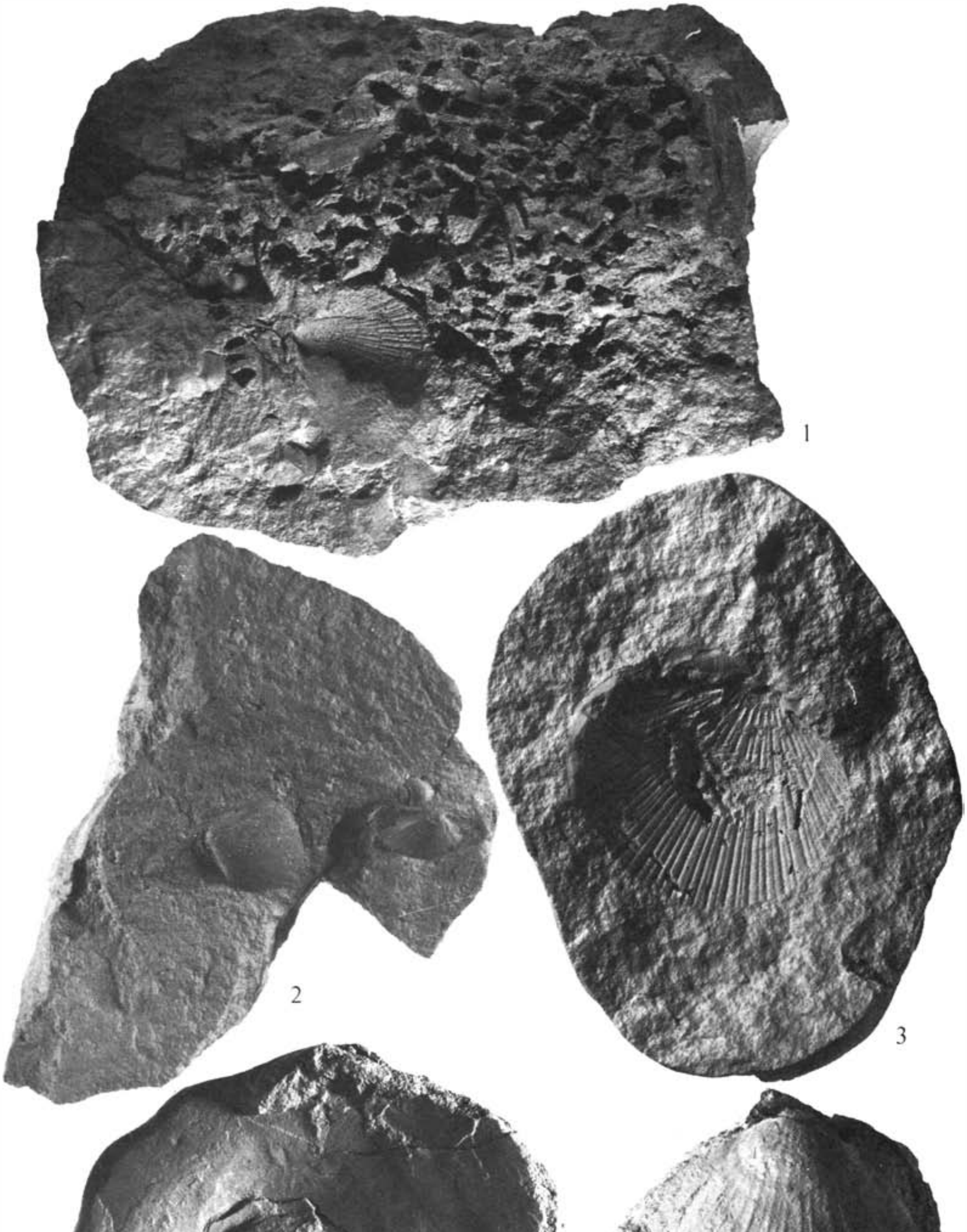
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PLATE 3

Fig. 1—4. Liotrigonia lingonensis (Dumortier). Internal mold (A39435-Figs. 2, 3, 4) and its latex replica (Fig. 1); phosphorite pebble of the Brentskardhaugen Bed at locality 9; x 1.

Fig. 5—6. Trigonia sp. Internal mold (A39436) from phosphorite pebble of the Wilhelmøya Formation at locality 22; x 1.

Fig. 7. Luciniola cf. *pumila* (Goldfuss). Internal mold (A39437) with parts of the shell preserved; phosphorite pebble of the Brentskardhaugen Bed at locality 7; x 1.5.

Fig. 8—9. Mactromya globosa Agassiz. Internal mold (A39438) with large parts of the shell preserved; phosphorite pebble of the Wilhelmøya Formation at locality 20; x 1.5.

Fig. 10—11. Astarte (A.) elegans Sowerby. Internal mold (A39439) with parts of the shell preserved; phosphorite pebble of the Wilhelmøya Formation at locality 20; x 1.5.

Fig. 12. Tancredia (T.) donaciformis Lycett. Internal mold (A39440) with the shell preserved; phosphorite pebble of the Brentskardhaugen Bed at locality 6; x 1.

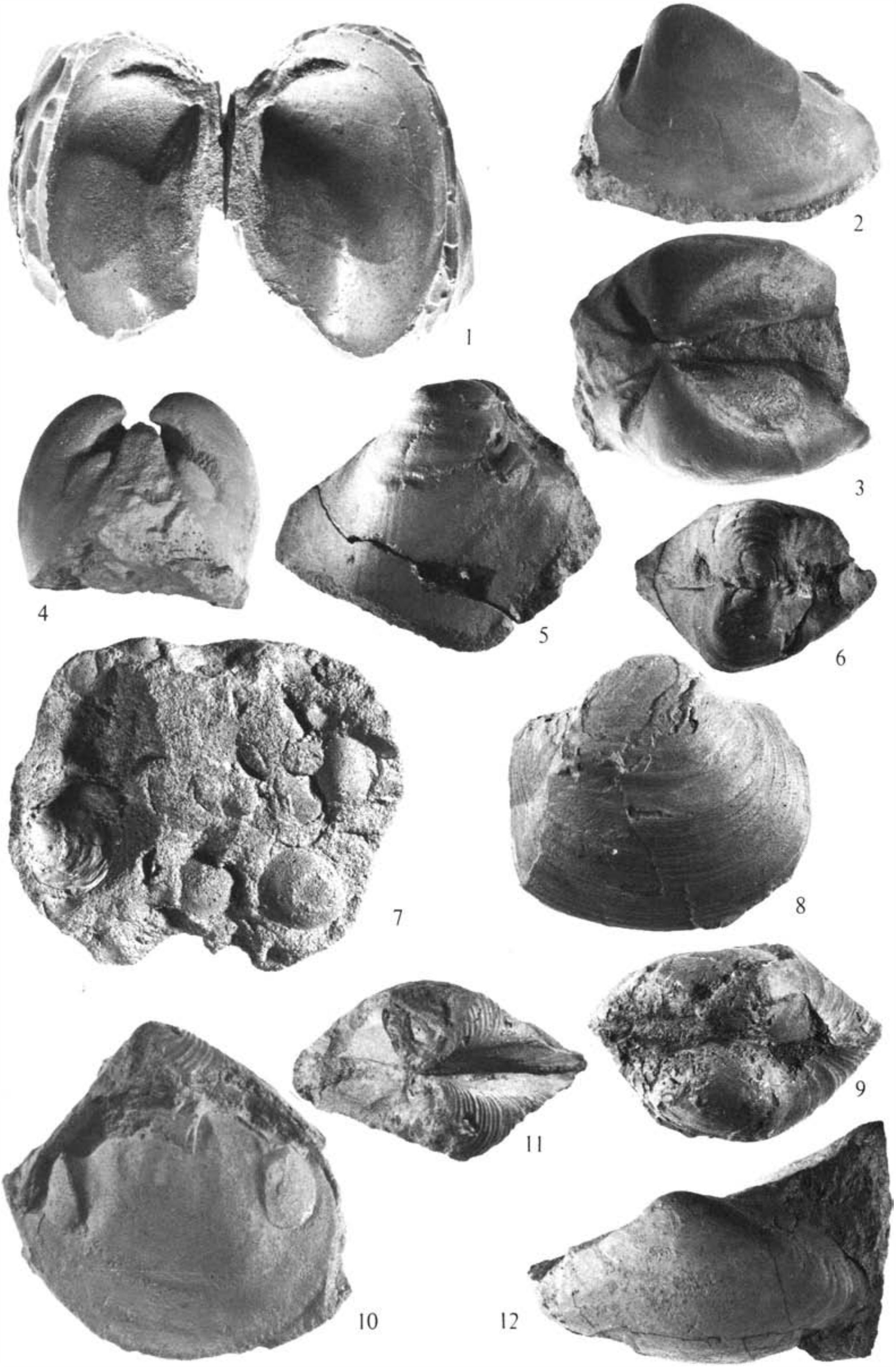
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PLATE 4

Fig. 1—4. Tancredia (T.) donaciformis Lycett. One specimen showing the inside of valves (A39441-Fig. 1), internal molds (A39442-Fig. 2, A39444-Fig. 4) and latex cast of internal mold (A39443-Fig. 3); phosphorite pebbles of the Brentskardhaugen Bed at locality 7; x 1.

Fig. 5. Pholadomya (P.) cf. *hemicardia* Roemer. Internal mold (A39445) with parts of shell preserved; phosphorite pebble of the Brentskardhaugen Bed at locality 5; x 1.

Fig. 6—7. Pholadomya (P.) kingi Meek. Internal mold (A39446) from phosphorite pebble of the Wilhelmøya Formation at locality 19; x 1.

Fig. 8. Pholadomya sp. External mold (A39447) in phosphorite pebble of the Brentskardhaugen Bed at locality 9; x 1.

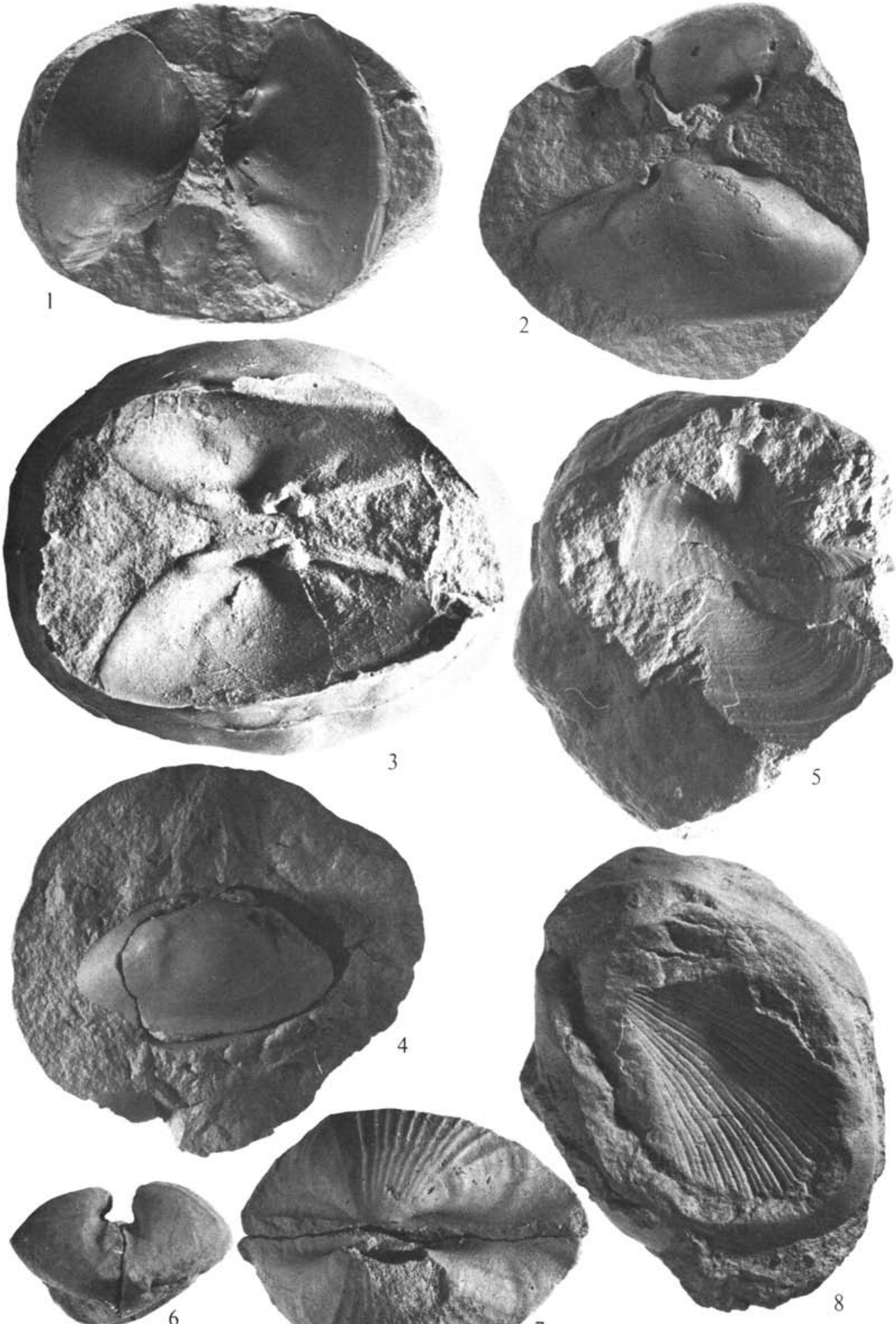
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PLATE 5

Fig. 1—2, Goniomya literata (Sowerby). Internal mold (A39437) from phosphorite pebble of the Wilhelmøya Formation at locality 20; x 1.5.

Fig. 3—6. Homomya gibbosa (Sowerby). Internal mold (A39448-Figs. 3, 4, 5) and its latex cast (Fig. 6); from phosphorite pebble of the Brentskardhaugen Bed at locality 7; x 1.

Fig. 7—9. Pleuromya elongata (Goldfuss). Internal mold (A39449) from phosphorite pebble of the Brentskardhaugen Bed at locality 17; x 1.

Fig. 10—13. ? Pleuromya marginata (Agassiz). One specimen (A39450) represented by an internal mold (Figs. 10, 12, 13) and an external mold (Fig. 11) with parts of shell preserved; phosphorite pebble of the Wilhelmøya Formation at locality 20; x 1.

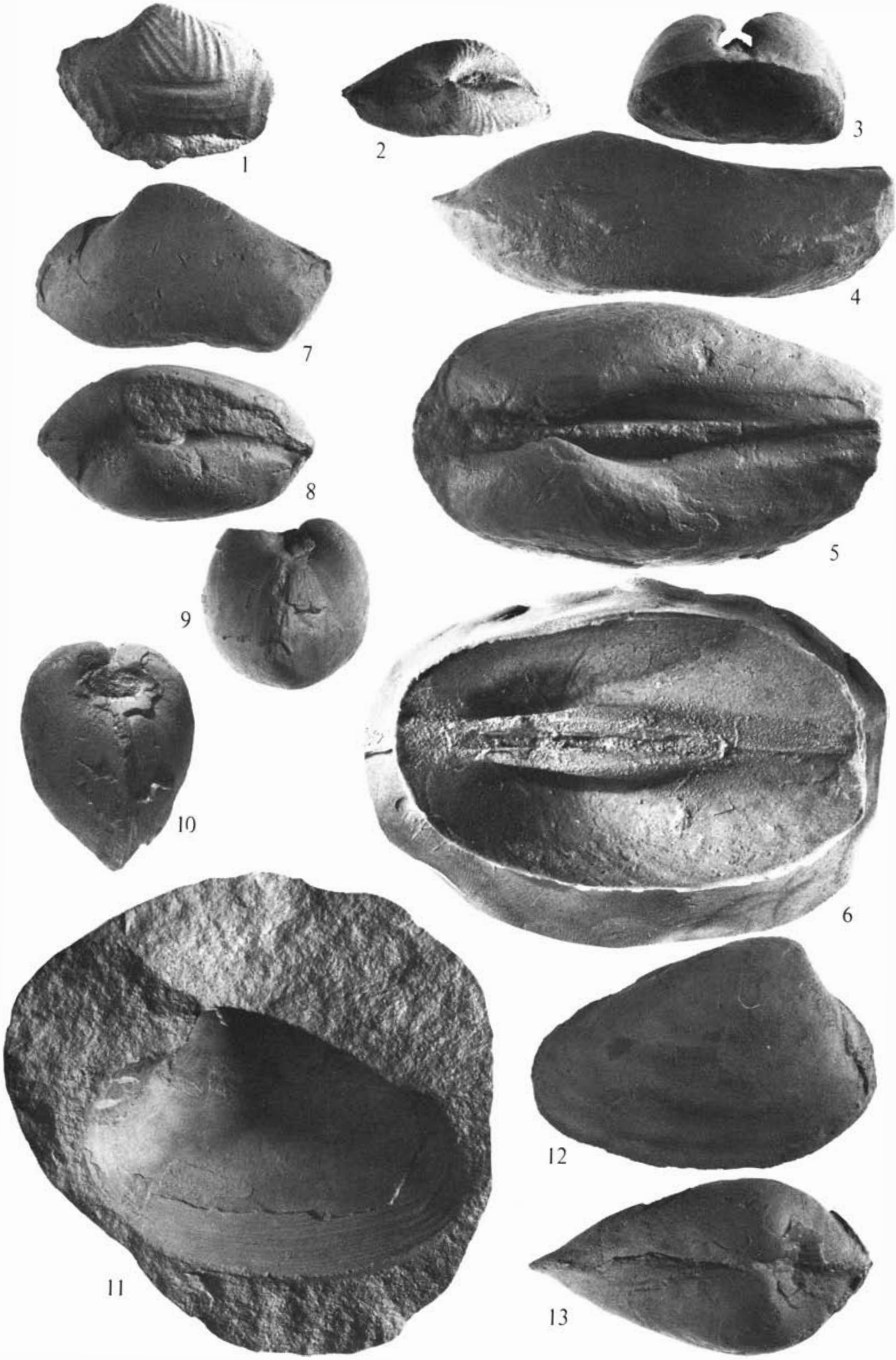
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PLATE 6

Fig. 1. Pleuromya subcompressa (Meek). External mold (A39451) from phosphorite pebble of the Brentskardhaugen Bed at locality 9; x 1.

Fig. 2—3. Pleuromya sp. Internal mold (A39452) from phosphorite pebble of the Wilhelmøya Formation at locality 22; x 1.

Fig. 4—5. Dactyliocers toxophorum (Buckman). Two specimens represented by internal mold (A39453-Fig. 4) and latex cast of external mold (A39454-Fig. 5); phosphorite pebbles of the Brentskardhaugen Bed at locality 18; x 1.

Fig. 6—9. Porpoceras polare (Frebold). Internal mold (Fig. 6) and latex cast of external mold (Fig. 7) of A39455; latex casts (Figs. 8, 9) of external mold (A39456). Phosphorite pebbles of the Brentskardhaugen Bed at locality 7; Figs. 6 and 7, x 1.5; Figs. 8 and 9, x 1.

Fig. 10—11. Porpoceras spinatum (Frebold). Latex casts of an external mold (A39457); phosphorite pebble of the Brentskardhaugen Bed at locality 17; x 1.5.

Fig. 12—13. Porpoceras cf. *spinatum* (Frebold). Latex casts of two external molds (A39458-Fig. 12 and A39459-Fig. 13); phosphorite pebbles of the Brentskardhaugen Bed at locality 14; x 1.5.

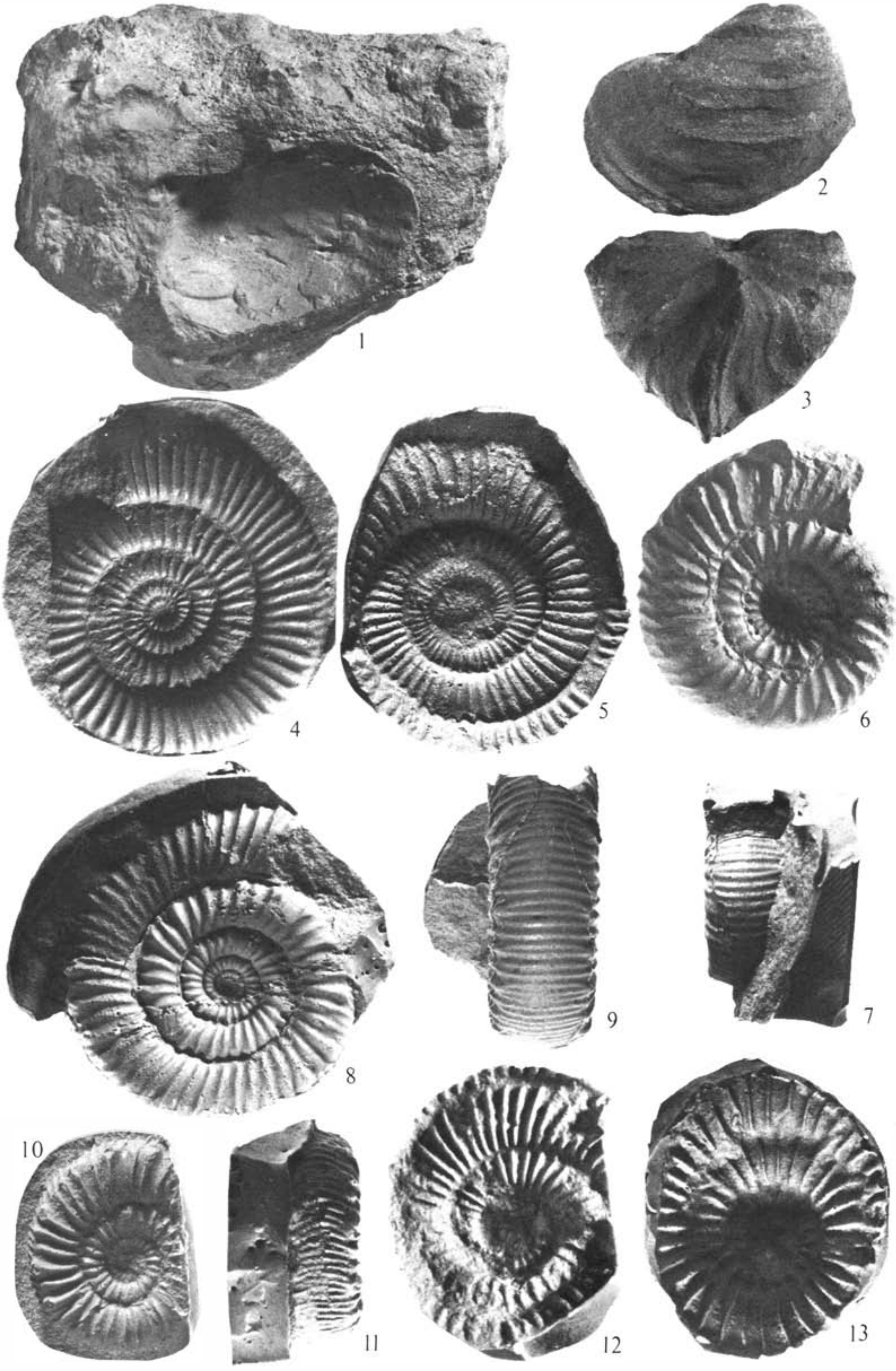
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PLATE 7

Fig. 1—2. Brasilia aff. *bradfordense* Buckman. Internal mold (A39460) from phosphorite pebble of the Brentskardhaugen Bed at locality 7; x 1.

Fig. 3. Pseudolioceras compactile (Simpson). Internal mold (A39461) from phosphorite pebble of the Brentskardhaugen Bed at locality 13; x 1.

Fig. 4. Pseudolioceras gradatum Buckman. Internal mold (A39462) in phosphorite pebble of the Brentskardhaugen Bed at locality 5; x 1.

Fig. 5. Pseudolioceras cf. *gradatum* Buckman. Latex cast of an external mold (A39463); phosphorite pebble of the Brentskardhaugen Bed at locality 18; x 1.

Fig. 6—9. Pseudolioceras pumilum Buckman. Latex cast of two natural molds (A39464-Figs. 6, 7 and A39465-Figs. 8, 9); phosphorite pebbles of the Brentskardhaugen Bed at locality 6; Figs. 6 and 7, x 1.2, Fig. 8, x 1, Fig. 9, x 0.8.

Fig. 10. Pseudolioceras maclintocki (Haughton). Internal mold (A39466) with shell fragments; phosphorite pebble of the Brentskardhaugen Bed at locality 7; x 1.

Fig. 11. Pseudolioceras rosenkrantzi Dagis. Partly internal mold (lower left) and latex cast (A39467); phosphorite pebble of the Brentskardhaugen Bed at locality 17; x 1.

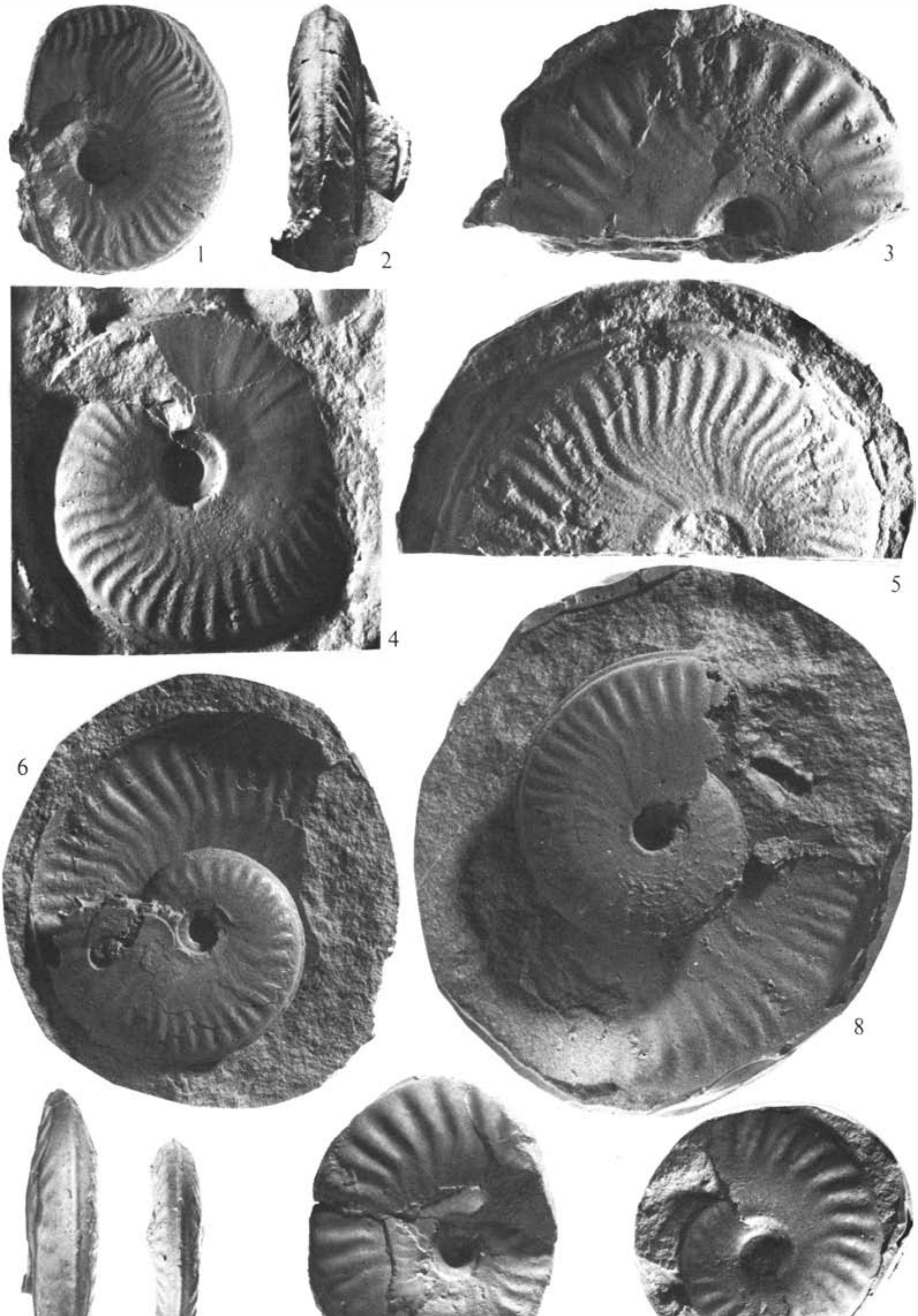
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PLATE 8

Fig. 1. Pseudogrammoceras fallaciosum (Bayle). Internal mold (A39468) from phosphorite pebble of the Brentskardhaugen Bed at locality 13; x 0.75.

Fig. 2—3. Belemnitidae genus indet. Two internal molds of phragmocone (A39469-Fig. 2 and A39470-Fig. 3) with parts of shell preserved; phosphorite pebble of the Brentskardhaugen Bed at locality 14 (Fig. 2) and locality 7 (Fig. 3); x 1.

Fig. 4. Hastites? sp. Rostrum (A39471) from phosphorite pebble of the Brentskardhaugen Bed at locality 9; x 1.

Fig. 5. Saurian vertebra (A39472) in phosphorite pebble of the Brentskardhaugen Bed at locality 8; x 1.

Fig. 6. Piece of wood in phosphorite pebble (A39473) collected 25 m below the top of the Wilhelmøya Formation on Wilhelmøya; x 1.

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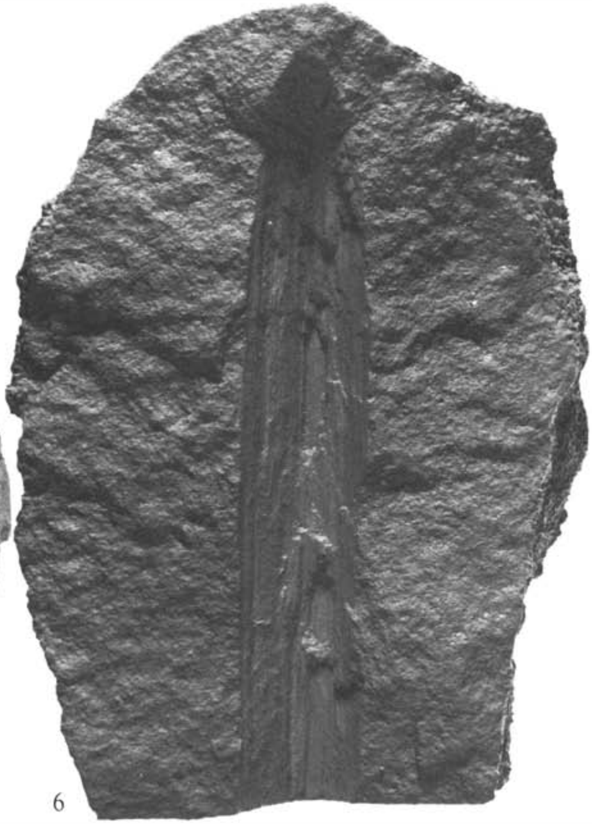

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