

JURASSIC-CRETACEOUS BIOSTRATIGRAPHY OF NORWAY, WITH COMMENTS ON THE BRITISH *RASENIA CYMODOCE* ZONE

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ABSTRACT. Extensive collections from exposed and mechanically excavated sections permit the recognition of Middle Jurassic to Neocomian deposits in Andøya, northern Norway. Non-marine Bajocian-Bathonian is recognized by an assemblage of spores and pollen showing a close resemblance to that from the Middle Jurassic of Trøndelag, Scania, and the Netherlands, but with some differences from Middle Jurassic assemblages from Britain. Marine Upper Jurassic sediments contain ammonites and dinocysts that permit the recognition of the *Rasenia cymodoce* Zone of the Lower Kimmeridgian, and the *Pavlovia rotunda-Progalbanites albani* zones of the Middle Volgian. The Upper Ryazanian *Surites spasskensis* Zone is the only zone recognized in the Neocomian sequence, but dinocysts, buchias, and ammonites suggest the presence of Valanginian beds above the *S. spasskensis* Zone. The boreal fauna shows close affinities with faunas from England, East Greenland, and Siberia. Similarly, dinocyst assemblages are comparable with those from other areas in north-west Europe and the Arctic, but the Ryazanian-Valanginian dinocyst assemblage shows closer links with boreal assemblages from Spitsbergen, the Moscow Basin, and the North Slope of Alaska. On the basis of material from Market Rasen (England) and Andøya the subdivision of the *R. cymodoce* Zone is discussed.

OUTCROPS of *in situ* Mesozoic rocks in Norway are known only from the island of Andøya, located just north of the Lofoten Islands (text-fig. 1). The great distances that isolate Andøya from other exposures of the same age render the island a vital link in palaeogeographic reconstruction. There are in addition Jurassic erratics in the Trøndelag area (text-fig. 1).

Andøya

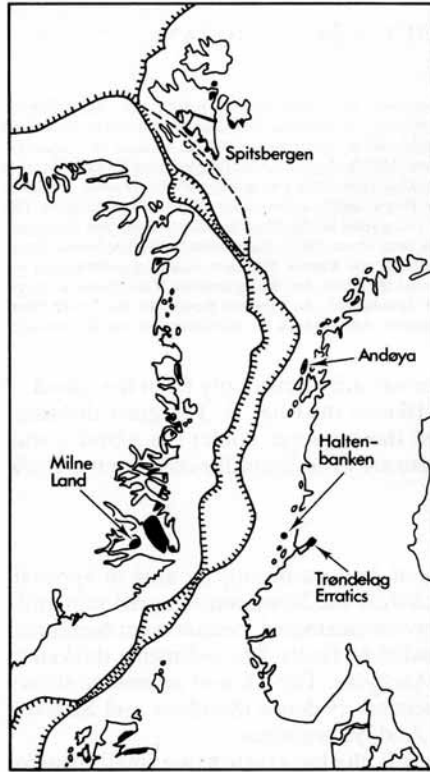
The Jurassic and Lower Cretaceous rocks of Andøya occupy an area of approximately 8 km². The sequence is some 650 m thick (text-fig. 2) and consists predominantly of sandstone and shale resting unconformably on weathered Precambrian basement. Except to the south, the outcrop area is bounded by faults. The sediments thicken to the east and appear to extend offshore into Andfjord. The 5 km of sediments shown to occur in the outer part of the fjord by seismic evidence (Sundvor and Sellevoll 1969) may, in part, be a continuation of the Andøya sequence.

The tight pattern of post-Lower Cretaceous faults has created two small troughs, one in the north and one in the south. The southern trough contains rocks of mainly Middle and late Jurassic age, whereas Lower Cretaceous rocks make up the bulk of the sequence in the northern trough. Both troughs are connected by a thin sedimentary cover across a basement high.

Previous lithostratigraphic and palaeontological work has been carried out mainly by Vogt (1905), Sokolov (1912), and Ørving (1953, 1960), and a number of other early works containing important stratigraphic information are listed in text-fig. 2. Recently Dalland (1975) established a new stratigraphic nomenclature on the basis of surface and mechanically excavated sections (text-fig. 2). The present paper is

based on samples collected by Dalland during extensive sedimentological and stratigraphic studies.

The Jurassic rocks include the Ramså Formation and the main part of the Dragneset Formation (text-fig. 2). The Ramså Formation consists of sandstone, shale, siltstone, and coal layers. The lower part of the overlying Dragneset Formation consists of medium- to fine-grained sandstone, and the middle part is a monotonous sequence of siltstone and fine-grained sandstone, while the upper beds are predominantly shale.



TEXT-FIG. 1. Map of the northern Atlantic area prior to the opening of the Ocean. Jurassic outcrops of Norway, Spitsbergen, East Greenland, and northern Scotland indicated. Ticked lines denote margins of continental blocks. Palinspastic reconstruction after Birkenmajer (1975).

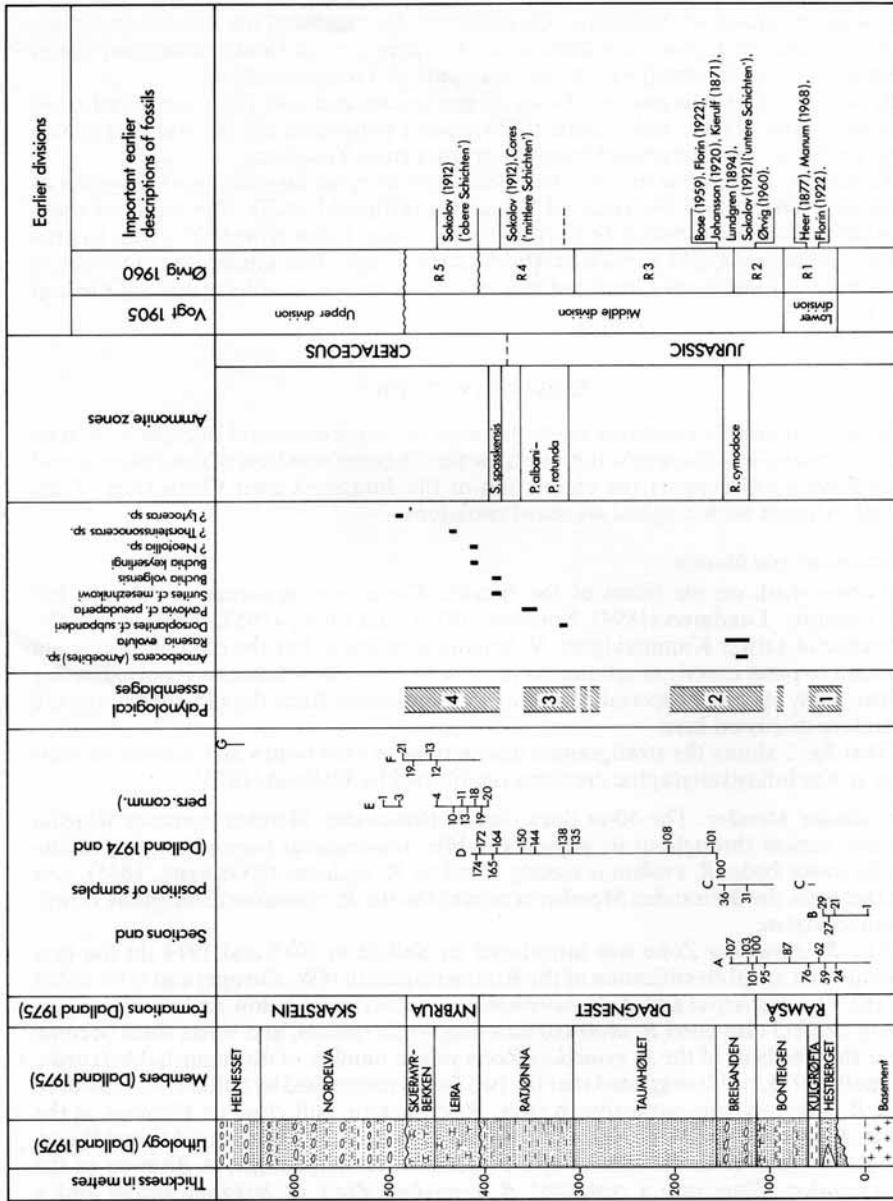
sandstone of Middle Jurassic age are found in the Trøndelag area (text-fig. 1). In a detailed study Oftedahl (1972) found sideritic ironstone boulders confined mainly to the stony beaches along the inner western shores of Trondheimsfjord. Plant

The Cretaceous rocks include the uppermost part of the Dragneset Formation, and the Nybrua and Skarstein formations (text-fig. 2). The Nybrua Formation consists of calcareous sandstone and siltstone, and according to Dalland (1975) the boundary with the Dragneset Formation appears to be an unconformity. The Skarstein Formation, which probably lies unconformably on the Nybrua Formation, comprises siltstone and silty shale in the lower part, and mudstone, shale, and thin beds of sandstones in the upper part. The sandstone layers show graded bedding and other structures commonly found in turbidites.

Dalland (1975) considered the lower, coal-bearing part of the sequence to be a fresh- to brackish-water deposit, while most of the overlying Jurassic sequence was referred to littoral environments, shallow, brackish-water lagoons, or mud flat deposits. However, no lithological evidence of littoral or lagoonal environments was given, and the fossil content indicates a sublittoral origin for considerable parts of the sequence. The Cretaceous sequence was considered by Dalland to be marine, the early part being deposited in shallow, sublittoral environments, and the later part in deeper water.

Trøndelag

Locally derived glacial erratics composed of sideritic ironstone and calcareous



TEXT-FIG. 2. Jurassic and Lower Cretaceous succession of Andøya.

cuticles described from this material (Vigran 1970) closely resemble those present in the Middle Jurassic of Yorkshire. Oftedahl (1972) considered the sideritic ironstone to be a lacustrine deposit, and that the erratics were derived from a Mesozoic, down-faulted basin in Beitstadfjord, in the inner part of Trondheimsfjord.

Grabs and core samples consisting of sandstones and soft clays recovered from Haltenbanken (Thusu and Vigran 1975) yielded palynomorphs of Middle Jurassic age, similar to those recovered from the erratics from Trøndelag.

Calcareous sandstone erratics have been recorded so far only from a group of islands, Froøyene, off the coast of Trøndelag (Oftedahl 1972). The fauna of these sandstones has been studied by J. Nagy (pers. comm.) who reports bivalves, gastropods, cephalopods, and anellids of Middle Jurassic age. This sandstone is thought to have been derived from a local sedimentary basin off the Trøndelag coast (Oftedahl 1975).

BIOSTRATIGRAPHY

The biostratigraphy presented below is based on ammonites and buchias as well as pollen, spores, and dinocysts. It is our hope that the combined use of macrofossils and microfossils will support the correlation of the Jurassic-Lower Cretaceous of the North Atlantic with classical standard zonations.

Ammonites and buchias

Earlier work on the fauna of the Jurassic-Cretaceous sequence of Andøya by, for example, Lundgren (1894), Sokolov (1912), and Ørvig (1953, 1960) shows the presence of Lower Kimmeridgian-Valanginian deposits, but the old collections are difficult to place exactly in relation to the new bed-by-bed collections reported in this paper. Only species of special stratigraphic importance from the old collections are therefore discussed here.

Text-fig. 2 shows the stratigraphic distribution of ammonites and buchias in relation to the lithostratigraphic divisions established by Dalland (1975).

Breisanden Member. The 40-m thick, sandy Breisanden Member contains *Rasenia evoluta* almost throughout its sequence, while *Amoeboceras (Amoebites)* sp. occurs in the lower beds. *R. evoluta* is closely allied to *R. uralensis* (d'Orbigny, 1845), and on this basis the Breisanden Member is referred to the *R. cymodoce* Zone of the Lower Kimmeridgian.

The *R. cymodoce* Zone was introduced by Salfeld in 1913 and 1914 (in the first attempt at a zonal classification of the Kimmeridgian in NW. Europe) and is bounded by the *Pictonia baylei* and *Aulacostephanus mutabilis* zones below and above respectively. Salfeld also cited *R. uralensis* as a diagnostic species, and it has since become clear that the beds of the *R. cymodoce* Zone yield a number of distinguishable faunas.

Spath (1935, p. 72) suggested that the two forms recognized by Salfeld, *R. cymodoce* and *R. uralensis*, are successive in time. *R. cymodoce*, still close to *Pictonia*, is the older. *R. uralensis* (here included in *R. evoluta*), typical of the sequence at Market Rasen (England), and never associated with *Prorasenia*, is the younger. A division of the *R. cymodoce* Zone into a restricted *R. cymodoce* Zone or Subzone below and a

R. uralensis Zone or Subzone above has been used more or less informally since 1935 by a number of authors. Besides the Market Rasen fauna from Lincolnshire, a Scottish fauna from Eathie, Ross-shire, has also been referred to the *R. uralensis* Zone by Waterston (1951) and Ziegler (1963). This fauna is, however, clearly distinguishable from the Market Rasen fauna. It is characterized by *R. (Semirasenia) askepta* Ziegler, 1963 (M) and *R. (Rasenioides) spp. (m)*, all closely allied to *Aulacostephanus*.

Since Salfeld's accounts, no proper revision of the stratigraphy of this part of the succession has been published, and neither has a systematic description been made of the genus *Rasenia* since Spath's notes of 1935. The critical successions are those in Britain and the coast of Normandy, and a monographic treatment is badly needed. Some progress could be made by a brief examination of some of the more readily accessible English collections and exposures, although this is far beyond the scope of the present work. Good material is housed in the British Museum (Natural History), the Institute of Geological Sciences (London), and the Sedgwick Museum (Cambridge); and we have examined sections at the Blue Circle Portland Cement Group's clay-pit at Westbury, Wiltshire, and the foreshore of the Fleet south-west of Wyke Regis, Weymouth, Dorset (map of Arkell *et al.* 1947, fig. 2, p. 14). The Westbury section shows Kimmeridge Clay with abundant ammonites from the *R. cymodoce* to *A. eudoxus* zones, and has not yet been described. The Fleet section is badly slumped, and the beds must be exposed by digging. The dip is gently and steadily to the south so that the sequence of faunas follows simply from their position along the beach. The *R. cymodoce* Zone appears to be largely complete and in clays except for a prominent siltstone near the base, perhaps a metre thick, current-bedded, and packed in its lower part with bivalves (at least seventeen species), gastropods, and occasional ammonites. This bed was mentioned by Arkell (1947, p. 88) and may be called the Wyke Siltstone.

Taking the evidence together, it seems that the following four horizons with different *Rasenia* faunas can be distinguished in the *R. cymodoce* Zone. From below:

Horizon I. Rasenia cf. cymodoce (d'Orbigny, 1850) (M) and *R. (Prorasenia) cf. triplicata* (Sowerby) Spath, 1935 (m). Occurrence: Wyke Siltstone, the Fleet shore, Wyke Regis, Dorset.

Horizon II. R. (Rasenia) involuta Spath, 1935 (m) and *R. (Eurasenia) spp. (M)*: Market Rasen fauna A. The famous fauna of splendidly preserved and iridescent shells, found in collections all over the world, is known only from museum material since the clays at Market Rasen are no longer exposed. A brief description of the former section was given by Woodward (1895, p. 175), who distinguished essentially 4-5 m of upper clays with small calcareous and pyritic concretions, resting on an unspecified thickness of lower, dark clays. Examination of the material in all three museum collections mentioned above, however, allows one to distinguish systematically two faunas differing in forms and preservation: fauna 1, consisting of involute adult and complete microconchs and nearly complete but always immature medium-sized macroconchs; and fauna 2, consisting of evolute mature and complete microconchs together with large, complete, and mature macroconchs. The shells of fauna 1 have the characteristic violet iridescence of the nacreous layer and lack the prismatic outer layer; the gas chambers of the phragmacone are still empty; and the body chambers are filled with a soft, buff, and probably somewhat phosphatic marly limestone. The shells of fauna 2 are only partly iridescent if at all, with a whitish layer, often encrusted with pyrite, and frequently embedded in septarian calcareous concretions. The differences in evoluteness were noted by Salfeld, who attached the MS names *involuta* and *evoluta* to specimens in the British Museum. Further descriptions are given below. Occurrence: (a) Market Rasen; (b) Wyke Regis, Fleet shore, in clays, with *R. cf.* and aff. *involuta* and *R. (Eurasenia) sp.*, all crushed.

Horizon III. R. (Zonovia) evoluta. (M) and (m) (previously referred partly to *R. (Z.) uralensis* (d'Orbigny, 1845)): Market Rasen fauna **B**. Occurrence: (a) Market Rasen. The relative positions of faunas **A** and **B** have not been demonstrated at Market Rasen, but on morphological grounds there seems little doubt that **B** (*evoluta*) occurs above **A** (*involuta*); the *R. involuta* fauna still resembles older assemblages, whereas the *R. evoluta* fauna is already intermediate on the path to the *Reineckeia*-like genus *Xenostephanus* of the lower *A. mutabilis* Zone. (b) This conclusion has been confirmed by a short re-examination of Westbury pit, Wiltshire, by J. H. Callomon (1976, pers. comm.). An unusually low water-level revealed layers containing *R. evoluta* (M)+(m), 0–50 cm below a marker layer of septarian concretions, and *R. involuta* (M), 1 m below the concretions.

Horizon IV. R. (Semirasenia) askepta Ziegler, 1963 (M) and associated *R. (Rasenioides) lepidula* (Oppel) and spp. (m). Neither *R. (Zonovia)* nor *Xenostephanus* have so far been recorded from this horizon. The appearance of the fauna as a whole is that of small, fine-ribbed species which are difficult to distinguish when crushed from those of the *A. mutabilis* Zone above; the distinctions lie in the venter, which the secondary ribs cross without interruption in *Rasenia* but which shows a smooth band or groove in *Aulacostephanus* (see Ziegler 1963, p. 769). The boundary between the *R. cymodoce* Zone (top of fauna IV) and the base of the *A. mutabilis* Zone is therefore dictated largely by historical circumstance rather than striking faunal differences. Occurrence: (a) Eathie, Scotland (Ziegler 1963); (b) Westbury pit, Wiltshire, 2–3 m above the marker layer of septarian concretions as mentioned above; (c) Wyke Regis, Fleet shore, southernmost end, 100 m W. of boathouse at Small Mouth, with *R. askepta* and *R. lepidula* in clays.

In addition to these faunas there are yet others in museums awaiting clarification. One includes *R. similis* Spath, 1935 (p. 46, pl. 14, fig. 2 showing only the nucleus of a much larger specimen), a form developing the straight but irregular ribbing reminiscent of the 'degenerate' forms illustrated by Tornquist (1896) from Le Havre, Normandy. Another is the fauna of the Abbotsbury Ironstone, a ferruginous oolitic siltstone equivalent of the Kimmeridge Clay which occurs only some 10 km NW. of Wyke Regis (Brookfield 1973). It appears to contain at least the faunas of horizons II–IV.

The closest resemblance of the Andøya fauna is to that of horizon III, suggesting that the *R. evoluta* fauna from Andøya represents a level high in the *R. cymodoce* Zone.

It is more difficult to place the Andøya forms stratigraphically in relation to *Rasenia*-bearing beds of other northern localities, e.g. East Greenland and the U.S.S.R. In East Greenland Spath (1935, p. 74) subdivided the *Rasenia* beds of Milne Land into a lower horizon containing *R. orbigny* Spath (*non* Tornquist) and a higher horizon containing *R. borealis* Spath. The latter was assigned to the *R. uralensis* Zone. All the material came from concretions of indurated siltstone. New collections made in 1957–1958 by Lauge Koch's expeditions (J. H. Callomon) and in 1968 (E. Håkansson, C. Heinberg) have shown, however, that these concretions occur in layers, of which there are at least four. Three successive faunas can be recognized: (a) a lower one with *R. orbigny* Spath (*non* Tornquist) and ?*Pictonia* sp.; (b) one with typical *R. cymodoce* (d'Orbigny); and (c) one with *R. borealis* Spath, 1935 (holotype only, pl. 7), which has been rediscovered in association with typical *Aulacostephanus mutabilis* and is hence younger than any of the forms discussed here from the *R. cymodoce* Zone. The Andøya fauna is not included in any of these.

A subdivision of *Rasenia*-bearing horizons given by Mesechnikov from the Kheta River Basin (*in* Saks 1969) is not comparable with the horizons described from England, except that there also *R. orbigny* (Tornquist) occurs in the lowermost part.

R. borealis (non Spath) *bojarkensis* Mesezhnikov may indicate the *R. uralensis* or *R. evoluta* horizon.

Taumhølet Member. No ammonites were collected from the c. 150-m thick Taumhølet Member. The sandy facies of the Breisanden and Taumhølet members, together with the considerable thickness of the *R. evoluta* horizon, indicates a high rate of sedimentation. It is therefore probable that the Taumhølet Member still belongs to the Lower Kimmeridgian and that the Middle Kimmeridgian and the lower part of the Upper Kimmeridgian represent a period of non-deposition.

Ratjønn Member. The 100-m thick, silty Ratjønn Member can be referred to the Middle Volgian-Ryazanian. Ammonites from the lower part of the sequence, *Dorsoplanites* cf. *subpanderi* and *Pavlovia* (*Epipallasiceras*) cf. *pseudaperta*, are comparable with boreal Middle Volgian species. *D. subpanderi* occurs in the *P. rotunda-Progalbanites albani* zones of the Glauconitic Series of Milne Land, East Greenland (Spath 1936; Håkansson *et al.* 1971; Surlyk *et al.* 1973) and is also known from a similar level in Siberia (Mikhailov 1966). *Pavlovia* (*Epipallasiceras*) *pseudaperta* is found at one sharply defined level in the upper part of the Glauconitic Series of Milne Land (Callomon 1961). It occurs above faunas of *Pavlovia* that can be readily equated with those of the *P. rotunda* and *P. pallasioides* zones of England and hence in a similar position to the basal *Progalbanites albani* Zone of Dorset, which also yields the subgenus (Buckman 1926, pl. 693; as *Virgatites pallasianus* d'Orbigny, from Dorset, basal *P. albani* Zone; Callomon 1961; and Cope *et al.* 1969, p. A49). The subgenus *Epipallasiceras* was previously thought to be endemic to East Greenland.

The '*Virgatosphinctes*' sp. figured by Sokolov (1912, p. 10, pl. 1, fig. 6), which he himself compared to *Epivirgatites nikitini* (Michalski, 1890), was referred by Saks (1972, p. 96) to ?*Chetaites* sp. This genus occurs immediately below and above the Volgian-Ryazanian boundary in northern Siberia (see Basov *et al.* 1970) and is also known from the Upper Volgian of Greenland (Surlyk *et al.* 1973). The specimen may belong to a level in the Ratjønn Member not represented by ammonites in the collection described here.

The uppermost part of the Ratjønn Member contains *Surites* (*Bojarkia*) cf. *mesezhnikowi* and *Buchia volgensis*. *S. (B.) mesezhnikowi* characterizes the youngest zone of the Ryazanian in northern Siberia (Basov *et al.* 1970), which according to Casey (1973) can be correlated with the *Surites* (*Bojarkia*) *stenomphalus* and *Peregrinoceras albidum* zones of eastern England and with the upper part of the *S. spasskensis* Zone of the Russian platform (see also Saks 1972). *B. volgensis* was reported by Lahusen (1888) from the Ryazanian as well as from the Upper Volgian, but Upper Volgian representatives were not figured. Pavlov (1907) and most later Russian workers have indicated the species only from the lowermost Cretaceous. Jeletzky (1966, p. 33), moreover, stated that the Upper Volgian representatives may either belong to or be related to *B. richardsonensis* Jeletzky, 1966. However, new investigations seem to show that *B. volgensis* did have a long range. Thus, Zakharov (*in* Saks 1972) indicates *B. volgensis* from the Upper Volgian as well as from the Lower and Upper Berriasian of the Khatanga Depression, and in East Greenland (Wollaston Forland) where *Surites* (*Bojarkia*) and *B. volgensis* also occur together, *B. volgensis* has similarly been shown to have a long range (F. Surlyk, pers. comm. 1975). The

Upper Ryazanian *Surites* (*Bojarkia*)–*Buchia* level is also represented by identical or closely related species in eastern England (see Pavlov 1896; Casey 1973) and in Arctic Canada (see Jeletzky 1965, 1973).

Leira Member. The 50-m thick Leira Member of the Nybrua Formation, consisting of calcareous sandstones, siltstones, and marls, contains *B. keyserlingi* s.l. and ?*Neotollia* sp. in the lowermost part and ?*Thorsteinssonoceras* sp. in the upper part. Sokolov (1912) further mentions *Bochianites* cf. *neocomiensis* (d'Orbigny, 1842) in addition to belemnites and *Buchia* species that are not contained in the collection described here. *Buchia keyserlingi* s.l. has a wide circumpolar distribution in the Valanginian and ranges, at least in certain areas, from the Upper Ryazanian to the Upper Valanginian (Jeletzky 1965, 1973). *Neotollia* also has a circumpolar distribution, but is restricted to the Lower Valanginian (Saks 1972). *Thorsteinssonoceras* is known from Arctic Canada (Ellesmere Island) and Spitsbergen (Jeletzky 1965) and seems also to be restricted to the Lower Valanginian (Jeletzky 1973). An early Valanginian age for the Leira Member may thus be inferred.

Skarstein Formation. Apart from one poor fragment, identified as ?*Lytoceras* sp., the present collection contains no fossils from the Skarstein Formation. Spath (1947, p. 62) recorded the occurrence of a '*Crioceras*' sp. from these beds.

The Jurassic flora

Remains of plants occur throughout the sequence, but well-preserved macrofossils are confined to the bituminous shales of the Kullgrøfta Member, and to some sandstone layers of the Breisanden Member (text-fig. 2).

Fossil plants from these strata have been described by Heer (1877), Johansson (1920), Florin (1922), Bose (1959), and Manum (1968) (text-fig. 2). According to Manum (pers. comm.) the fossils from Andøya include seven or eight conifers, two ginkgophytes, one cycad, three bennettites, and two or three ferns, but Manum considers that the entire flora is in need of revision. Fragments of conifers dominate; especially common are leaves assigned to the genus *Sciadopityes*. So far, none of the plants recorded have proved useful for detailed correlations with other areas.

The pollen and spores recorded in the Jurassic sequence on Andøya are characterized by long-ranging Mesozoic taxa (Vigran and Thusu 1975, table 2) and indicate the existence of a rich flora adjacent to the depositional basin. The abundance of bivecculate and araucariacean pollen, together with *Cerebropollenites mesozoicus*, *Concentrisporites hallei*, and *Perinopollenites elatoides*, suggest that a coniferous vegetation was dominant on Andøya.

The *Classopollis* complex (including *Corollina meyeriana*) in well-preserved assemblages never exceeds 1% of the identified species. Such rarity of *Classopollis* is recorded previously in Arctic Canada (Pocock 1970) and Siberia (Vakhrameev 1970). According to Hughes (1973) this rarity of *Classopollis* in the Arctic region, in contrast to its abundance in north-west Europe, may be a function of latitude.

Palynostratigraphy

Four palynological assemblages are recorded from the Jurassic and Cretaceous sequence. Only selected taxa from assemblages 1 and 4 are illustrated here. Readers

should refer to Vigran and Thusu (1975, pls. 1–20, tables 2 and 3) for illustrations and complete lists of taxa with their stratigraphic distribution.

Assemblage 1. A rich, non-marine assemblage of pollen and spores is recorded from the Hestberget Member and, with reduced diversity, from the Kullgrøfta Member (Pl. 6). Although coniferous pollen grains dominate the assemblage, spores are strikingly well represented in the Hestberget Member. The onset of brackish conditions is recorded by the appearance of acritarchs (*Leiofusa jurassica*, *Metaleiofusa diagonalis*, *Micrhystridium* spp.) in the middle part of the Kullgrøfta Member.

The assemblage is assigned a Bajocian–Bathonian age because of its similarity with Scanian assemblages (Guy 1971; Mahin 1968; Tralau 1967, 1968; Tralau and Artursson 1972). Text-fig. 3 shows twenty-four selected taxa of which eighteen have been reported from other Scanian assemblages. Similar, but less diverse assemblages from the Netherlands have been reported by Hergreen and de Boer (1974). Comparison with British assemblages shows that *Foveotriletes microreticulatus* and *Leptolepidites equatibossus*, restricted respectively to the Bathonian and Bajocian in Britain (Couper 1958; Neves and Selley 1975), are present in Assemblage 1 together with *Clavatipollenites hughesii*, *Crybelosporites vectensis*, and *Kuylisporites lunaris*, which first appear in Britain in the Lower Cretaceous (Couper 1958; Kemp 1971).

In spite of the long-ranging nature of Jurassic palynomorphs and the strong sedimentary control over their distribution in north-west Europe, Assemblage 1 has proved useful for correlations of Middle Jurassic rocks from the Norwegian continental shelf.

Assemblage 2 is recorded from the Breisanden Member and in immediately over- and underlying beds (text-fig. 2). The Breisanden Member is placed in the *R. cymodoce* Zone of the Lower Kimmeridgian and contains dinocysts marking the onset of normal marine conditions on Andøya.

Many of the long-ranging spore and pollen taxa present in Assemblage 1 continue to dominate. A single diagnostic spore, *Cicatricosisporites sternum* Amerom, 1965 (*Schizaeoisporites heintzii* Bose, 1959) has been recorded. Dinocysts include *Gonyaulacysta jurassica*, *Cannosphaeropsis pulchra*, *Chlamydothorella wallala*, *Crassosphaera concinna*, *Oligosphaeridium anthophorum*, *O. dictyophorum*, *Scriniodinium crystallinum*, *Sirimiodinium grossi*, *Systematophora fasciculigera*, and *Systematophora* sp. (*Perisseiasphaeridium pannosum* of Vigran and Thusu, 1975). The assemblage is comparable with that reported by Neves and Selley (1975) from the Lower Kimmeridgian Allt-na-cuile Sandstone in north-east Scotland and also with assemblages from England (Gitmez 1970; Gitmez and Sarjeant 1972), although the Andøya assemblage shows lower diversity.

Assemblage 3 is restricted mainly to the lower and middle part of the Ratjønna Member (text-fig. 2). Most of the Taumhølet Member between assemblages 2 and 3 is essentially barren. The lower part of the Ratjønna Member, placed in the *Pavlovia rotunda*–*Progalbanites albani* zones of the boreal Middle Volgian, contains poorly preserved palynomorphs. Of note is *Classopollis echinatus*, which is also known from the 'higher Upper Malm' of the Netherlands (Burger 1966) and in the Upper Kimmeridgian and Portlandian of southern England (Norris 1969).

Dinocyst species, poorly preserved but fairly common, include *Gonyaulacysta* spp. (*G. cladophora*–*G. perforans* complex), *Dingodinium* sp. (*Netrelytron* cf. *stegastum* of Vigran and Thusu 1975), *Pareodinia ceratophora*, *Prolixosphaeridium granulosum*, and *Sirimiodinium grossi*. The assemblage differs from Assemblage 2 by the incoming of the *Gonyaulacysta* complex in abundance.

Assemblage 4. This is the youngest recorded assemblage (text-figs. 2, 4). The uppermost part of the Ratjønna Member, placed in the youngest Ryazanian ammonite Zone (*Surites* (*Bojarkia*) *mesezhnikovi*) contains a few dinocysts including *Pareodinia dasyforma* and *Oligosphaeridium* complex. *P. dasyforma*, a characteristic boreal form, is restricted to Neocomian strata on Spitsbergen (Bjærke et al. 1975), North Slope of Alaska (Wiggins 1975) and the Canadian Arctic (Pocock 1976); but this species has also been reported from the Kimmeridgian and Upper Volgian in England (Gitmez and Sarjeant 1972) and Russia (Vozzhennikova 1967). *O. complex* is cosmopolitan and ranges from the Valanginian to Middle Miocene. Since Upper Volgian strata are not represented in our sample collection, we tentatively suggest that *P. dasyforma* and *O. complex* appear for the first time in Ryazanian beds on Andøya.

The Lower Valanginian Leira Member of the Nybrua Formation contains *P. ceratophora*, *P. dasyforma*, *Mudrongia tetraacantha*, *O. complex*, *Scriniodinium apatelum*, *S. grossi* and *Systematophora* sp. Dating of the Skjermyrbekken Member on a megafaunal basis is lacking, but a late Valanginian age is

TOTAL RANGES OF SELECTED PALYNOMORPHS FROM ASSEMBLAGE 1		JURASSIC										
		HETTANGIAN	SINEMURIAN	PIEENSCHACHIAN	TOARCIC	AALENIAN	BAJOCIAN	BATHONIAN	CALLOVIAN	OXFORDIAN	KIMMERIDGIAN	VOLGIAN
<i>Auritulinaspores intrastriatus</i>	★											
<i>A. scanicus</i>	★											
<i>Chasmatosporites apertus</i>	★											
<i>Classopollis simplex</i>												
<i>Clavatipollenites hughesii</i>	★											→
<i>Contignisporites glebulentus</i> ¹⁾												→
<i>C. dunrobinensis</i> ¹⁾	★											→
<i>Corrugatisporites amplexiformis</i>	★											→
<i>Crybelosporites vectensis</i>												→
<i>Dictyophyllidites mortoni</i>												→
<i>Foveotriletes microreticulatus</i>	★											→
<i>Ischyosporites variegatus</i>	★											→
<i>Kuylisporites lunaris</i>												→
<i>Leptolepidites equatibossus</i>	★											→
<i>L. rotundus</i>	★											→
<i>Lycopodiacidites rugulatus</i>	★											→
<i>Manumia irregularis</i> (ident? <i>Triletes minutus</i>)												→
<i>Monosulcites cotidianus</i>	★											→
<i>Neoraistrickia truncatus</i>	★											→
<i>Ovalipollis limbata</i>	★											→
<i>Perotriletes zonatoides</i>	★											→
<i>Polycingulatisporites triangularis</i>	★											→
<i>Retitriletes concavus</i>	★											→
<i>Sestrosporites pseudoalveolatus</i>	★											→

TEXT-FIG. 3. Total known ranges of selected palynomorphs from Assemblage 1, Andøya. ¹ indicates probably conspecific taxa. * indicates palynomorphs reported from Bajocian-Bathonian assemblages in Scandinavia.

suggested by the presence of *Gardodinium trabeculosum*, *Pseudoceratium pelliferum*, and *Pterodinium magnoserratum*.

The Skarstein Formation lacks a megafauna, but sparse dinocysts include *Aptea polymorpha*, *Cyclonephelium distinctum*, and *Phoberocysta neocomica*. These are present in the lowermost beds of the Nordelva Member and indicate an early Cretaceous (Aptian?) age.

This assemblage is similar to those reported from other areas in north-west Europe and the Arctic, but some forms are largely dominant in boreal areas. Of note is the concurrence of *Pareodinia dasyforma* and *Scrinioidinium* (? = *Tubotuberella*) *apatehum*. Both these species are abundant in Ryazanian sediments on Spitsbergen (Thusu, unpublished data) and are also reported in early Neocomian sediments from the North Slope of Alaska (Wiggins 1975 and unpublished data from the Jurassic-Cretaceous Boundary Circular). Furthermore, Vozzhennikova (1967) reports *P. dasyforma* and species of *Tubotuberella* from the Upper Volgian of the Moscow Basin. These occurrences suggest close links of dinocyst assemblages in boreal areas.

The Jurassic of Trøndelag

The glacial erratics of sideritic ironstone and coal, which were collected along Trondheimsfjord, are non-marine deposits with fossil plants. A Middle Jurassic age for these deposits is suggested by a small collection of leaf cuticles which are related to the Middle Jurassic flora of Yorkshire (Vigran 1970). Palynomorphs from the same rocks include the following important taxa also present in Assemblage 1 of Andøya: *Chasmatosporites apertus*, *Clavatipollenites hughesii*, *Contignisporites glebulentus*, *Corrugatisporites amplexiformis*, *Crybelosporites vectensis*, *Dictyophyllidites mertonii*, *Foveotriletes microreticulatus*, *Gleicheniidites granulatus*, *Ischyosporites variegatus*, *Kuylisporites lunaris*, *Leptolepidites equatibossus*, *Lycopodiadites rugulatus*, *Monosulcites cotidianus*, *Neoraistrickia truncatus*, *Ovalipollis limbata*, *Polycingulatisporites triangularis*, and *Retitriletes concavus*.

The dominance of the *Cycadopites* complex together with the coniferous pollen grains is in marked contrast to Andøya where conifers are singularly dominant. The *Classopollis* complex is infrequent as on Andøya.

Calcareous sandstones, dated as Middle Jurassic from the associated fauna (Nagy in Thusu and Vigran 1975), were collected off the coast of Trøndelag (Oftedahl 1975). The assemblage contains the following taxa which are common with Assemblage 1: *Contignisporites glebulentus*, *Corrugatisporites amplexiformis*, *Crybelosporites vectensis*, *Ischyosporites variegatus*, *Neoraistrickia truncatus*, and spore sp. A.

Furthermore, the assemblage is characterized by the presence of typical Middle Jurassic dinoflagellates including *Chytroeisphaeridia chytroeides*, *C. cf. pococki*, *Gonyaulacysta* sp., *Nannoceratopsis gracilis*, *Pareodinia ceratophora*, and *Valensiella ovulum* (as *V. ovalum* in Vigran and Thusu 1975). This assemblage is similar to the Bajocian assemblage recorded from the North Sea (Thusu and Vigran 1975).

Core and grab samples recovered from Haltenbanken (Thusu and Vigran 1975), and from deposits south of Trøndelag (unpublished data), contain the following species: *Acanthotriletes varispinosus*, *Chasmatosporites* sp. cf. *C. major*, *Corrugatisporites amplexiformis*, *Foveosporites canalis*, *Ischyosporites variegatus*, *Kuylisporites lunaris* and spore sp. A. This assemblage, although reduced, is similar to Assemblage 1 of Andøya.

CONCLUSIONS

The stratigraphy established here allows comparison of the geological evolution of the Andøya basin with other marginal areas of the northernmost Atlantic Ocean.

The Middle Jurassic faulting, and initiation of deposition of non-marine Bajocian–Bathonian sediments is contemporaneous with widespread transgressions across the marginal areas of East Greenland (Birkelund 1975) and Spitsbergen (Parker 1967). At the same time the northern North Sea was marked by the ‘Great Estuarine’ regression causing separation of the ‘Tethyan’ and Boreal Seas (see Callomon 1975).

In Scotland transgressive pulses occurred in Callovian and Oxfordian times and further deepening apparently took place during the early Kimmeridgian (Sykes 1975). East Greenland is also characterized by Callovian and Oxfordian transgressions, and in late Oxfordian–early Kimmeridgian time marked subsidence occurred. The Lower Kimmeridgian transgression of Andøya may be related to the widespread subsidence of the North Atlantic area, marked by widespread unconformities and facies changes.

The late Kimmerian phase of faulting in late Jurassic–early Cretaceous time, prominent over the whole northern Atlantic area, is indicated by an unconformity at the Ryazanian–Valanginian boundary (between Dragneset and Nybrua formations) in the Andøya sequence, while sedimentation appears to be continuous across the Jurassic–Cretaceous boundary.

Boreal Bajocian–Bathonian ammonites are not known south of the Shetlands (Callomon 1975). As a consequence of the Callovian transgression the sharp faunal break disappeared during the late Jurassic, but boreal elements were still persistent. This is demonstrated by the known southernmost extension of ammonite taxa from Andøya as far as Dorset, England.

Four diagnostic assemblages of palynomorphs are reported from Andøya. Non-marine, spore and pollen Assemblage 1 of Bajocian–Bathonian age shows close resemblance to those from the Middle Jurassic of Trøndelag, Haltenbanken, Sweden

TEXT-FIG. 4. Selected taxa from dinocyst Assemblage 4, Lower Cretaceous, Andøya.

1, *Pareodinia dasyforma* Wiggins, 1975. Specimen illustrating distal bifurcation of processes, $\times 650$. Sample E-18, slide 75-23/5, co-ord. 23·2–103. Nybrua Formation, Leira Member.

2, *Gonyaulacysta serrata* (Cookson and Eisenack) Sarjeant, 1969. Specimen showing helicoid cingulum and a short, blunt, apical prominence, $\times 400$. Sample F-21, slide 76-26/1, co-ord. 16·8–98·6. Skarstein Formation, Nordelva Member.

3, *Phoberocysta neocomica* (Gocht) Millioud, 1969. Complete specimen with operculum, $\times 400$. Sample E-11, slide E-11/5, co-ord. 32–112. Nybrua Formation, Leira Member.

4, *Cyclonephelium distinctum* Deflandre and Cookson, 1955. Specimen illustrating a bald central part, processes confined to periphery, $\times 750$. Sample F-21, slide F-21/1, co-ord. 47·6–98. Skarstein Formation, Nordelva Member.

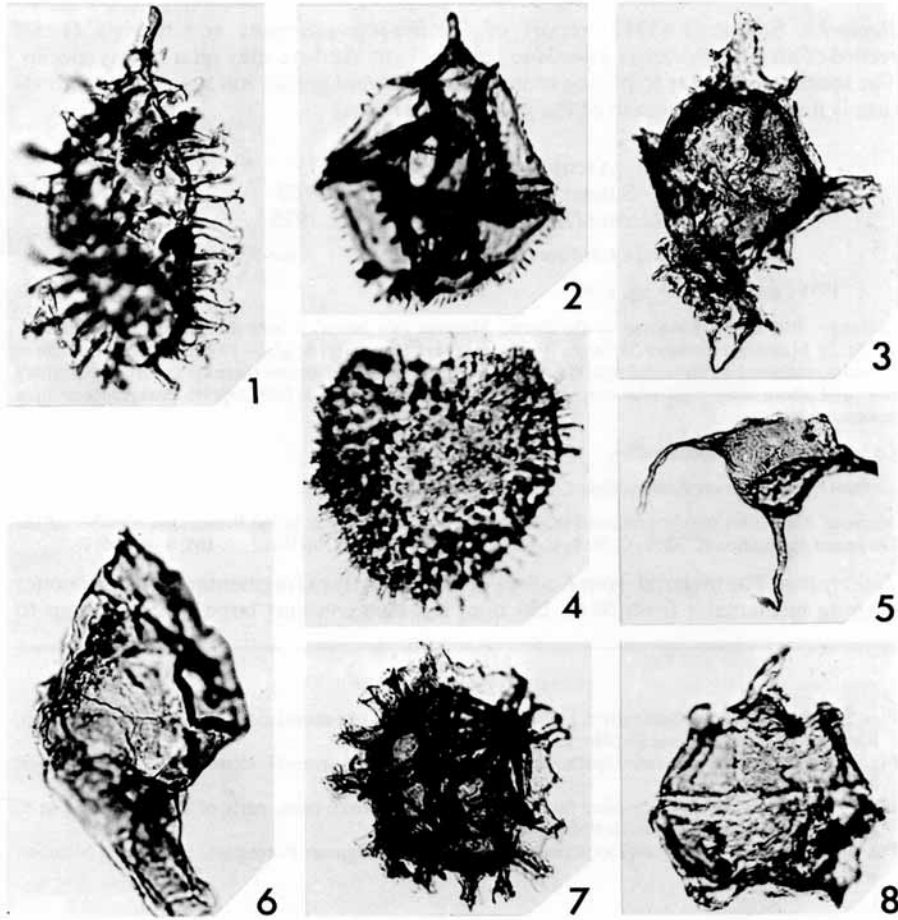
5, *Muderongia tetracantha* (Gocht) Alberti, 1961. Specimen without operculum, ventral view, $\times 350$. Sample F-21, slide 75-26/6, co-ord. 42·8–111·2. Skarstein Formation, Nordelva Member.

6, *Scriniodinium apatelum* Cookson and Eisenack, 1960. Specimen illustrating elongated tubular antapical pericoel, $\times 650$. Sample E-18, slide 75-23/2, co-ord. 14·9–101·9. Nybrua Formation, Leira Member.

7, *Pterodinium magnoserratum* Cookson and Eisenack, 1962. Specimen illustrating fields bordered by relatively high, coarsely serrated wing-like membrane, $\times 600$. Sample F-19, slide F-19/1, co-ord. 43–112·6. Nybrua Formation, Skjermvækket Member.

8, *Sirmiodinium grossi* (Alberti) Warren, 1973. Specimen showing surface features and cingulum, dorsal view, $\times 450$. Sample E-13, slide 75-22/4, co-ord. 21·5–111·4. Nybrua Formation, Leira Member.

and the Netherlands; however, there are certain differences, mainly involving the ranges of taxa, in comparison with Middle Jurassic assemblages from Great Britain. The rarity of the *Classopollis* complex in Andøya and Trøndelag agrees with similar records from Arctic Canada and Siberia. Marine dinocyst Assemblages 2 and 3 of Upper Jurassic age, and Assemblage 4 of Neocomian age, although showing a lower diversity are comparable with those reported from other areas in north-west Europe and the Arctic. The presence of *Pareodinia dasyforma* together with *Scriniodinium* (? = *Tubotuberella*) *apatelum* in Assemblage 4 on Andøya suggests closer links with boreal dinocyst assemblages from Spitsbergen, the Moscow Basin, and the North Slope of Alaska. However, further detailed regional investigation will be the subject of a future publication.



SYSTEMATIC DESCRIPTIONS

Unless otherwise indicated, all figured specimens are in Paleontologisk Museum, University of Oslo.

Genus AMOEOCERAS Hyatt, 1900

Amoeboceras (*Amoebites*) sp.

Plate 1, fig. 6

?1912 *Cardioceras alternans* v. Buch; Sokolov, p. 6.

?1953 *Amoeboceras* (*Amoebites*) sp.; Ørvig, p. 20.

Material. Two specimens from level A-103, two from level A-104, and two from level A-106, Breisanden Member of Dragneset Formation.

Remarks. Sokolov's (1912) report of *Cardioceras alternans* and Ørvig's (1953) record of an *Amoeboceras* (*Amoebites*) species from Andøya may refer to this species. The specimens appear to belong to the *A. (A.) kitchini* group, but specific determination is not possible because of the poor preservation.

Genus RASENIA Salfeld, 1913

Subgenus ZONOVIA Sazonov, 1960

Rasenia (*Zonovia*) *evoluta* Spath, 1935

Plate 1, figs. 4, 5; Plate 2, figs. 7-10; Plate 3, figs. 1-5; text-figs. 5, 6

1953 *Rasenia* sp.; Ørvig, p. 19.

Lectotype. BM 39801, a syntype in the British Museum (see below) is here designated lectotype (text-fig. 5a, b). Maximum diameter 59.7 mm. At 58.6 mm diameter, whorl height = 19.1 mm, whorl breadth = 21.9 mm, umbilical width = 25.2 mm. On the outer whorl at 60 mm diameter there are twenty-two primary ribs, and about sixty-eight ribs cross the venter. The specimen is a fully septate phragmocone of a macroconch.

Locus typicus. Brigg, Lincolnshire.

Stratum typicum. Lower Kimmeridgian, *R. cymodoce* Zone, upper part.

Material. Numerous poorly preserved internal casts of *Rasenia* occur in the Breisanden Member of the Dragneset Formation (C-32:1; C-33:7; C-34:6; C-36:55; A-103:2; A-104:2; A-105:6; A-106:1).

Description. The material from Andøya consists mostly of fragmentary phragmocones ranging in diameter from 50 to 150 mm, but also contains large specimens, up to

EXPLANATION OF PLATE I

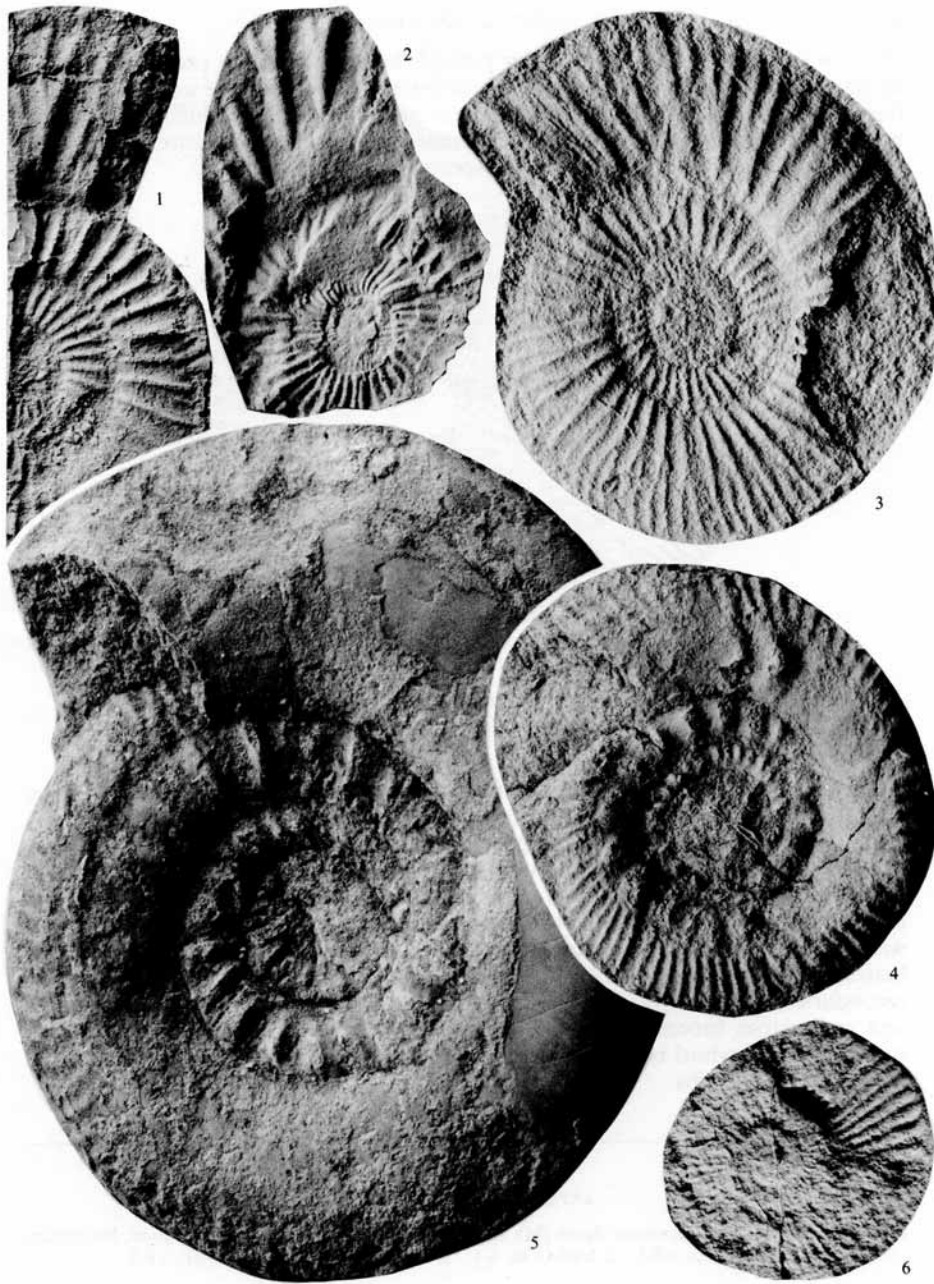
Figs. 1, 2. *Pavlovia* (*Epipallasiceras*) cf. *pseudaperta* Spath. Casts of external moulds. Dragneset Formation, Ratjønn Member. 1, level D-144. 2, level D-150.

Fig. 3. *Dorsoplanites* cf. *subpanderi* Spath. Cast of external mould. Dragneset Formation, Ratjønn Member, level D-138.

Figs. 4, 5. *Rasenia* (*Zonovia*) *evoluta* Spath (M). Crushed internal casts, parts of shell preserved in 5. Dragneset Formation, Breisanden Member, level C-36.

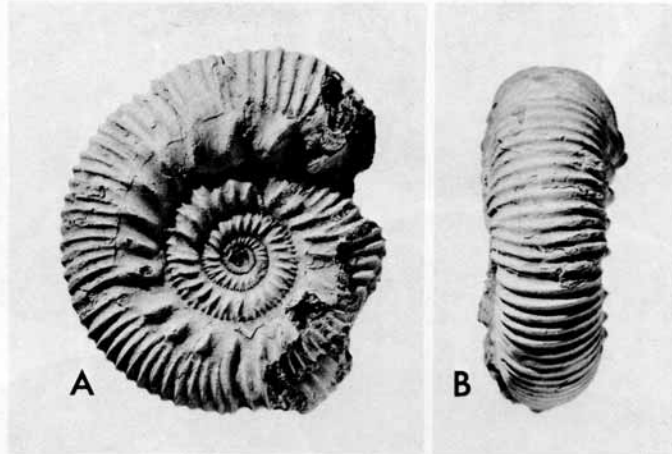
Fig. 6. *Amoeboceras* (*Amoebites*) sp. Crushed internal cast. Dragneset Formation, Breisanden Member, level A-104.

All $\times 1$.



BIRKELUND, THUSU and VIGRAN, ammonites from Norway

250 mm in diameter, with the greater part of the body chamber preserved. Nearly all specimens are badly crushed and only one side is preserved. The umbilicus ranges from 42 to 49% of the shell diameter in nineteen specimens. The umbilical ratio shows no obvious ontogenetic or stratigraphic variation. However, the measurements should be viewed with reservation because the specimens are crushed.



TEXT-FIG. 5. *Rasenia (Zonovia) evoluta* Spath (M), lateral and ventral view of nucleus, lectotype, BM 39801. Brigg, Lincolnshire, $\times 1$.

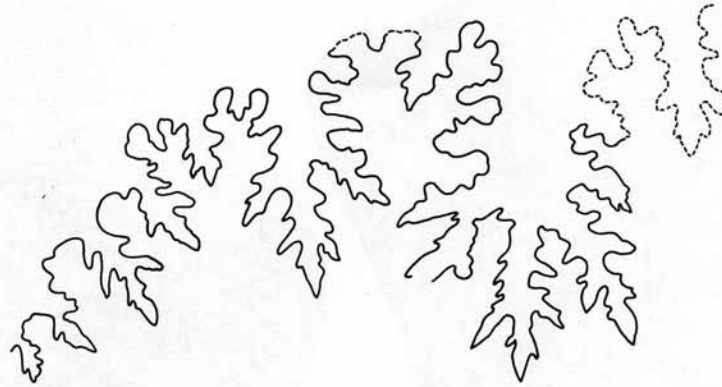
The sculpture of the innermost whorls is poorly preserved. From a shell diameter of *c.* 30 mm a rasenid ribbing pattern can be seen. The primary ribs are usually very strong and bullate. The relationship between primaries and secondaries is 1:3-4, but in certain cases the primaries are very irregularly developed and may be completely missing on parts of the shell; in such cases counts of primaries and secondaries become meaningless (Pl. 1, fig. 4). The secondaries appear to pass over the venter without interruption. The ornament disappears at very variable diameters, usually between 110 and 130 mm. In some specimens the primaries disappear before the secondaries, in other specimens it is the opposite, and in still others both primaries and secondaries become reduced simultaneously. Most specimens are completely smooth for $\frac{1}{2}$ - $\frac{3}{4}$ whorl before sculpture reappears as straight, blunt single, or occasionally bifurcate ribs.

EXPLANATION OF PLATE 2

Figs. 1-4. *Rasenia (Zonovia) evoluta* Spath (M). Crushed internal casts. Dragneset Formation, Breisanden Member. 1, level A-105, $\times 0.5$. 2, level C-36, $\times 1$. 3, level C-36, $\times 1$. 4, level C-31, $\times 0.5$.



BIRKELUND, THUSU and VIGRAN, ammonites from Norway



TEXT-FIG. 6. Suture-line of *Rasenia (Zonovia) evoluta* Spath. Dragneset Formation, Breisanden Member, level C-36, $\times 3$.

Sutures are occasionally preserved and show a rather finely incised pattern (text-fig. 6).

Discussion. The *Rasenia* species from Andøya shows a strong resemblance to a species from Market Rasen, referred to *R. uralensis* (d'Orbigny, 1845) or to *R. evoluta* by Salfeld (1913, 1914, MS), Spath (1935), and others.

The *Rasenia* species from Market Rasen have never been properly described. According to Spath (1935, p. 48) the fauna contains *R. uralensis* (d'Orbigny, 1845), *R. involuta*, and *R. evoluta* (Salfeld MS) Spath, 1935, and a number of undescribed species, some of which are perfectly smooth while others resemble *R. borealis* Spath, 1935 from East Greenland. In addition Spath (1935, p. 46, pl. 14, fig. 2a, b) established a *R. similis* on the basis of material found in drift at Norton Wood, Norfolk.

Study of material in the British Museum (Natural History), Institute of Geological Sciences, London, and Sedgwick Museum (Cambridge) allows the following brief descriptions to be made:

(a) *Rasenia uralensis* (d'Orbigny, 1845): The largest specimen figured by d'Orbigny (1845, pl. 32, figs. 6, 7, 10) was designated lectotype of *R. uralensis* by Salfeld (1913, p. 429), but is now presumed lost. A smaller syntype was figured by Douvillé (1911,

EXPLANATION OF PLATE 3

Figs. 1-3. *Rasenia (Zonovia) evoluta* Spath? 1, 2, (M), lateral and ventral view of nucleus, SM J29109, $\times 1$. 3, (m), SM J29115, $\times 1$.

Figs. 4, 5. *Rasenia (Zonovia) evoluta* Spath. 4, (M), fully grown, SM J62725, $\times 0.5$. 5, (M), nucleus, SM J29090, $\times 1$.

Fig. 6. *Rasenia (Eurasenia) involuta* Spath (M), with part of body chamber preserved, SM J29081, $\times 1$.

All specimens from Market Rasen, Lincolnshire, housed in the Sedgwick Museum, Cambridge.



BIRKELUND, THUSU and VIGRAN, *Rasenia* from Norway

pl. 210^a, figs. C¹, C^{1A}), and designated as 'lectotype' by Ziegler (1962, p. 26). This specimen was collected by de Verneuil in Russia (Kineshima on the Volga) and formed part of d'Orbigny's type material; it appears to accord fairly well with the larger lectotype figured by d'Orbigny. It shows the moderately evolute inner whorls (umbilical ratio 42%) with depressed whorl section and rather strong bullate primaries. The relation between primaries and secondaries on the last whorl preserved is 1:4. The secondaries seem to cross the venter uninterrupted although they may be slightly weaker on that part of the shell. Outer whorls and body chamber are not known from type material.

Many septate nuclei from Market Rasen, fauna **B**, are rather similar to the lectotype and the syntype figured by Douvillé, but are generally more evolute and less inflated; the primary ribs are more coarse, and the fasciculate secondary ribbing of the inner whorls is usually clearly exposed in the umbilicus. The Market Rasen specimens are therefore here referred to *R. evoluta* Spath (see below).

(b) *Rasenia evoluta* Spath, 1935: This species, used as a manuscript name by Salfeld, was formalized by Spath (1935, pp. 48-49). Spath stated that *R. evoluta* was a large species, but figured only a small, wholly septate, and barely interpretable nucleus (1935, pl. 14, fig. 6a, b; BM C8046). This specimen was therefore considered as the holotype by Arkell and Callomon (1963, p. 223). Because of its close similarity to the lectotype of *R. involuta* Spath, 1935 the name *R. evoluta* was placed in subjective synonymy by these authors.

Since then it has become clear that the type series of *R. evoluta* must be regarded as more extensive than previously thought, and hence that there is no holotype. Following Spath's description the types must include at least all the specimens labelled *R. evoluta* by Salfeld in the British Museum. Besides the small nucleus figured in 1935, there is one other specimen (M. K. Howarth pers. comm.). It is also a wholly septate nucleus, 60 mm in diameter, but determinable, for it closely resembles other, abundant nuclei at similar diameters in collections from Market Rasen, fauna **B**, in which the ontogeny can be reconstructed up to the final adult stage of what is clearly a macroconch. Spath's reference to large specimens suggests that the type series of his species includes additional specimens, but labels in his handwriting may not be reliable evidence as they could include metatypes (topotypes subsequently identified by the original author).

To settle this problem finally and at the same time to attach a firm name to the Market Rasen fauna **B**, the second syntype of *R. evoluta*, BM 39801, is now designated lectotype. It is illustrated in text-fig. 5. In the adult, as is usual in perisphinctid macroconchs, the last whorl or so shows a wide range of variation in ribbing, which may disappear completely and reappear again as straight, blunt single or bifurcating ribs. Five complete, mature specimens in the Sedgwick Museum range from 150 to 220 mm in diameter. One of these is shown in Plate 3, fig. 4.

(c) *Rasenia involuta* Spath, 1935 (p. 48, pl. 10, fig. 5a, b): Arkell and Callomon (1963, p. 221) pointed out that the lectotype (BM 50629b) is a nearly complete specimen and that it seems to be a microconch, as the body chamber gives the impression near the end of slight contraction indicating maturity. The specimen is slightly more involute than the type of *R. uralensis* and the whorls are more compressed. It is considerably

more involute than *R. evoluta*, and a number of similar microconchs in the collections bear out the point to which Spath drew attention, that in *R. involuta* the secondary ribs on the inner whorls are always covered and hence not visible in the umbilicus. In addition, the collections contain many macroconchs in the Market Rasen fauna A, almost all juveniles having some body chamber preserved, in which the whorl section of the intermediate whorls becomes notably compressed and oval, and the primary ribbing becomes subdued and only moderately flexuous, not strongly bullate, most of the secondaries being intercalatories (Pl. 3, fig. 6). These specimens are here considered to be the macroconchs of *R. involuta*. A subgeneric name for them could be *Eurasenia* Geyer, 1961 (type species *R. rolandi* (Oppel 1863)).

(d) *Rasenia similis* Spath, 1935 (p. 46, pl. 14, fig. 2a, b): Spath figured only the inner whorls of the holotype, although outer whorls are partly preserved (BM C36504). The specimen is almost as involute as *R. involuta* macroconchs and is also similar to *R. involuta* in cross-section of the whorls. It differs in having straighter, non-bullate primary ribs that branch indistinctly and irregularly, with many intercalatories, as in *Pictonia normandiana* Tornquist (1896, p. 20, pl. 5, fig. 1; pl. 6, fig. 2) from the *P. baylei* Zone of Normandy. Although Spath thought it transitional between *R. cymodoce* and the *R. uralensis* group, it might in fact be earlier than either, transitional even between *Pictonia* and *Rasenia*. Another specimen, in the Institute of Geological Sciences (No. 30740), is still septate at a diameter of 18 cm. Both specimens are from glacial drift, so nothing can be said about their precise ages.

Among the Market Rasen species the Andøya material is clearly most closely related to *R. evoluta*, from which it seems to differ only in a more irregular spacing of the primary ribs, and in being slightly more involute. Typical *R. evoluta* is also known from glacial erratics in northern Jutland.

The Andøya material has also been compared with the *R. cymodoce* group as described by Spath from Milne Land, East Greenland (Spath 1935) under the name *R. orbignyi* (Tornquist, 1896) and varieties.

R. orbignyi Spath (*non* Tornquist) shows an extremely wide range of variation, both in umbilical ratio and in ornamentation, but this may be due in part to slight differences in age. The species is similar to the material from Andøya in umbilical ratio (38–50%) and in the disappearance of ribbing on later parts of the shell. Also the wide variation in the degeneration of the ribs on the outer whorls is similar. However, it seems to differ in having a smaller size and weaker and straighter primaries. *R. borealis* Spath, 1935, as represented by the holotype, is from a higher level than *R. orbignyi* in Milne Land. It is similar to the Andøya material in size and the style of ribbing on the mature body chamber, but differs in the inner whorls, which are very evolute and densely ribbed with straight primaries that furcate visibly in the umbilicus, rather as in *Aulacostephanus*, and suggest affinity with *A.* (?) (*Xenostephanoides?*) *groenlandicus* Ravn, 1911 (pl. 37, fig. 3a–c, from Store Koldewey; and Frebold 1930, pl. 9, figs. 3, 4; pl. 22, fig. 2), as already suggested by Spath.

Genus DORSOPLANITES Semenov, 1898
Dorsoplanites cf. *subpanderi* Spath, 1936

Plate 1, fig. 3

- 1936 *Dorsoplanites subpanderi* Spath, p. 76, pl. 27, fig. 5a, b; pl. 31, fig. 1a, b (holotype).
 1966 *Dorsoplanites subpanderi* Spath; Mikhailov, p. 28, pl. 6, fig. 3; text-fig. 10.

Material. Two specimens from level D-138, Ratjøna Member of Dragneset Formation.

Remarks. The figured specimen is close to *Dorsoplanites subpanderi* Spath in coiling and ribbing pattern, with the ribs fairly regularly bifurcate as in that species. The ribs differ in having slightly closer spacing and the primaries may be less blunt, being more similar to *D. jamesoni* Spath (1936, pl. 29, fig. 3; pl. 30, fig. 1) in these characters. However, *D. jamesoni* differs distinctly in having a greater number of single ribs, especially near the aperture.

The figured specimen shows a change in ribbing pattern close to the aperture as seen in other representatives of this genus. A final specific determination is not possible because of the poorly preserved cross-section.

Genus PAVLOVIA Ilovaisky, 1917
Pavlovia (*Epipallasiceras*) cf. *pseudaperta* Spath, 1936

Plate 1, figs. 1, 2

- 1936 *Pavlovia* (*Epipallasiceras*) *pseudaperta* Spath, p. 56, pl. 8, fig. 1; pl. 9, figs. 3, 4; pl. 11, fig. 5; pl. 16, figs. 1 (holotype), 4; pl. 20, fig. 1; pl. 39, fig. 2.

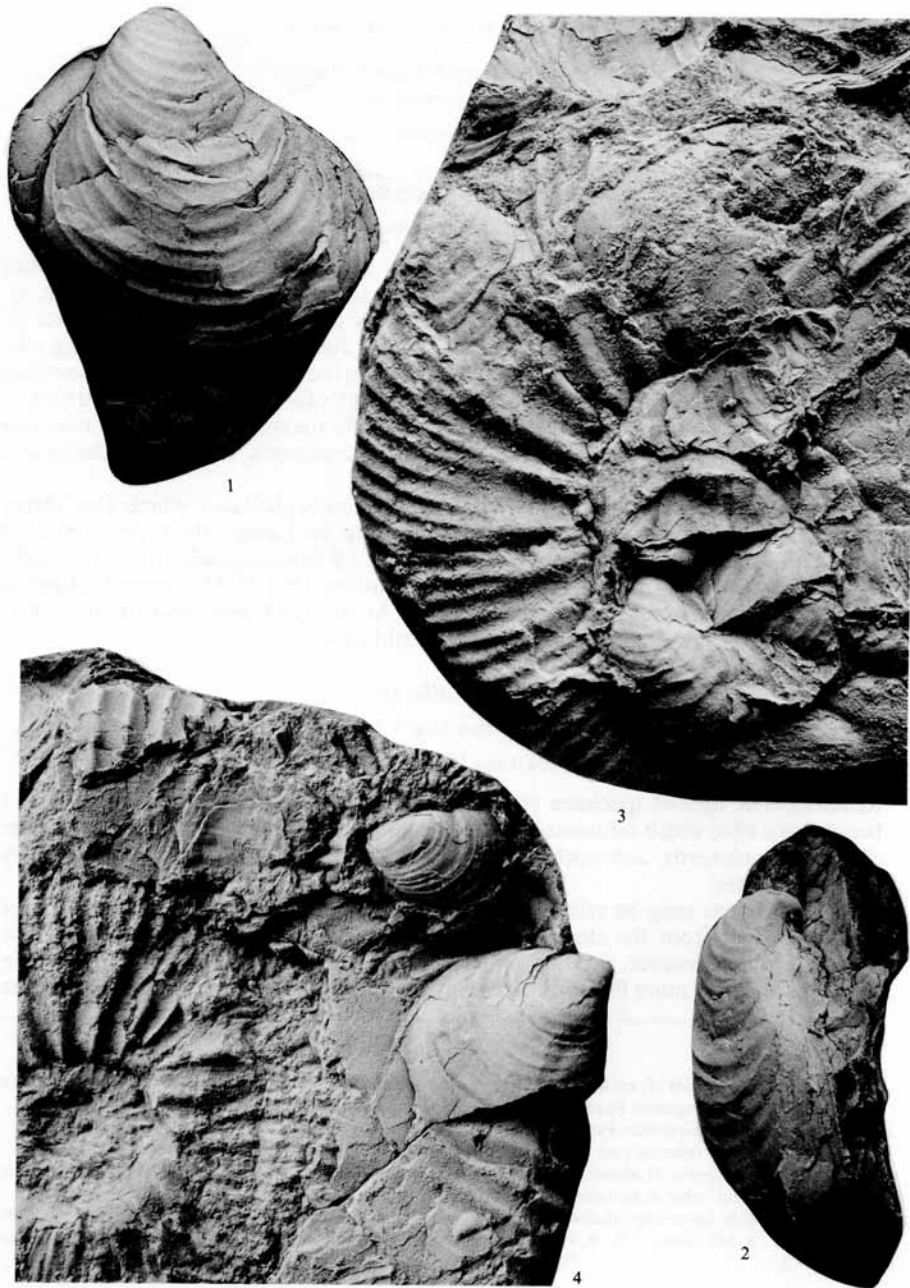
Material. One specimen from level D-144 and one from level D-150. In addition a number of fragments, mostly nuclei, from levels D-144, D-145, D-149, and D-150, which may belong to the same subgenus. Ratjøna Member of Dragneset Formation.

Remarks. The subgenus *Epipallasiceras* contains among the most easily recognizable of the enormous spectrum of forms included in the genus *Pavlovia*. The characteristic features are the densely and finely ribbed involute inner whorls, shared with *P. (Pallasiceras)*, flat whorl sides, straight, sharp regular primary ribs bifurcating high on the whorl side into almost equally strong and sharp closely spaced secondaries just exposed in the umbilicus, all illustrated in Plate 1, fig. 1. The Andøya forms are very similar to the holotype of *P. (E.) pseudaperta* itself, but the crushing makes definite identification impossible.

EXPLANATION OF PLATE 4

- Figs. 1, 2. *Buchia volgensis* (Lahusen). Left valve, and posterior view, $\times 1$.
 Figs. 3, 4. *Surites* (*Bojarkia*) cf. *mesezhnikovi* (Shulgina). Crushed internal casts preserved together with fragmentary *Buchia volgensis*, $\times 1$.

All from Dragneset Formation, Ratjøna Member, level D-164.



BIRKELUND, THUSU and VIGRAN, ammonites and bivalves from Norway

Genus *SURITES* Sazonov, 1951
Surites (*Bojarkia*) cf. *mesezhnikowi* (Shulgina, 1969)

Plate 4, figs. 3, 4; Plate 5, fig. 1

1969 *Bojarkia mesezhnikowi* Shulgina in Saks and Shulgina, p. 46, pl. 1, figs. 1 (holotype), 2, 3.

1972 *Bojarkia mesezhnikowi* Shulgina; Shulgina in Saks, p. 158, pl. 14, figs. 1, 2.

Material. Five crushed specimens from level D-164, Dragneset Formation, Ratjønna Member.

Remarks. The specimens show a very narrow range of variation. All are rather involute, the umbilical ratio being about 30% at a shell diameter of 9 cm (Pl. 5, fig. 1). The ribbing changes from a fine to a considerably coarser pattern at a diameter of about 2 cm. From a diameter of 8 cm to 10 cm trifurcating ribs or bifurcating ribs with one intercalatory rib dominate. After branching the ribs bend slightly backwards, and towards the ventral side they seem to bend slightly forwards. From a diameter of about 10 cm further secondaries are intercalated. On the outermost whorl preserved of the wholly septate specimens the sides become smooth, while secondaries are preserved on the ventral side.

The specimens are similar to *Surites* (*Bojarkia*) *mesezhnikowi*, which also seems to grow large and somewhat smooth. According to Casey (1973, pp. 250-252) *S. (B.) mesezhnikowi* is very closely related to *S. (B.) stenophalus* (Pavlov, 1889), if not conspecific. Sazonova (1971, p. 72) mentions that *S. (B.) mesezhnikowi* is a subjective synonym of *Pavlovites krestnensis* Aristov (in Ivanov and Aristov 1969) which, however, appears to remain strongly ribbed.

?*Neotollia* sp.

Plate 5, fig. 3

Material. Two fragments from level D-174, Leira Member of Nybrua Formation.

Remarks. The figured specimen shows the inner crushed whorls; it is involute and bears sharp ribs, which bifurcate close to the middle of the sides. After branching the ribs bend backwards, and ventrally they have a distinct forward projection as they cross the venter.

The specimens may be related to *Neotollia* Shulgina, 1969. The inner whorls of *Neotollia* differ from the closely related genus *Tollia* in having bifurcate and not trifurcate ribs. However, the ribs are sharper and more distant than usually seen in *Neotollia* and also more flexuous on the lateral sides (compare, for example, with the

EXPLANATION OF PLATE 5

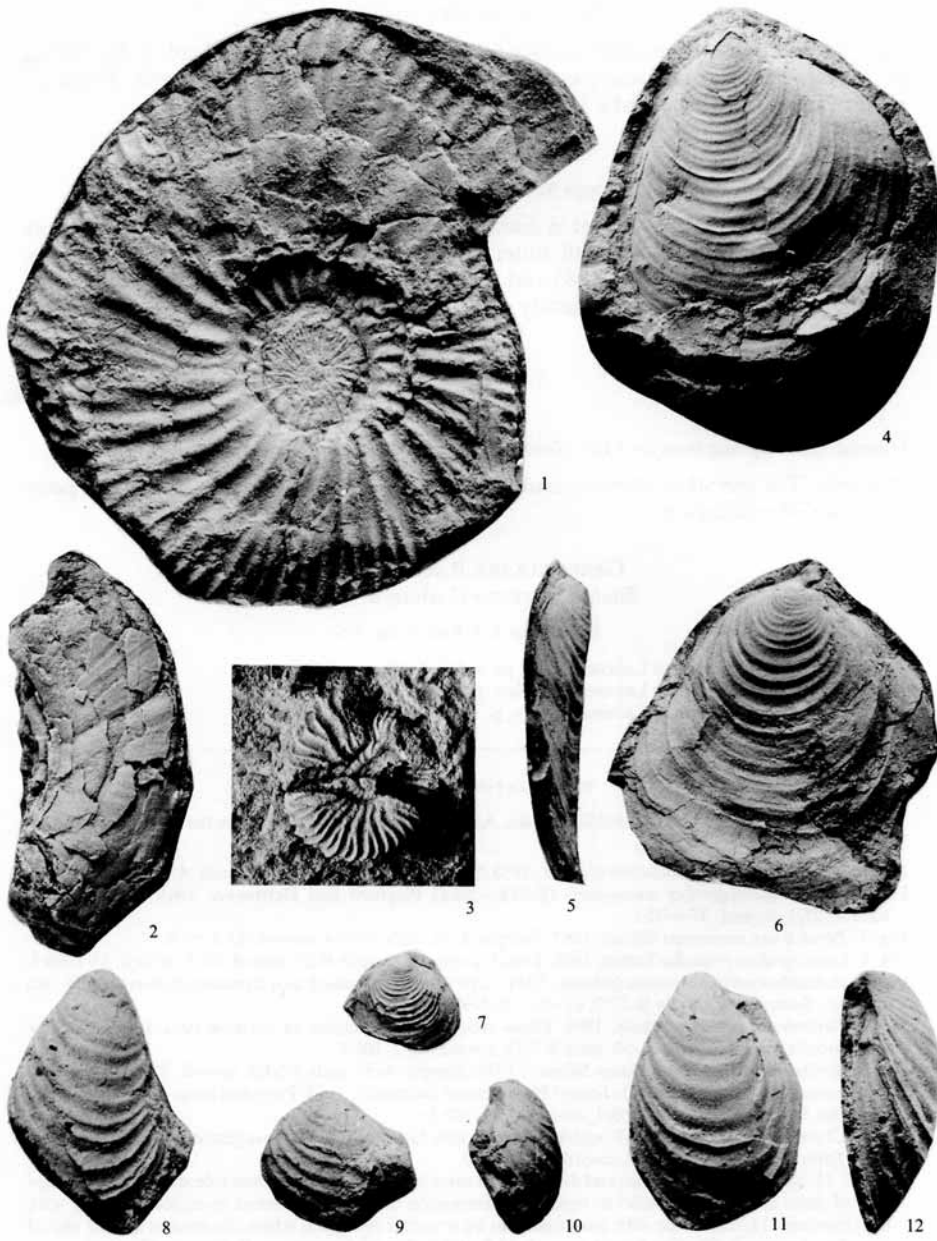
Fig. 1. *Surites* (*Bojarkia*) cf. *mesezhnikowi* (Shulgina). Cast of external mould preserved in sample with *Buchia volgensis*. Dragneset Formation, Ratjønna Member, level D-164, $\times 1$.

Fig. 2. ?*Lytoceras* sp. Skarstein Formation, Nordelva Member, level E-3, $\times 1$.

Fig. 3. ?*Neotollia* sp. Internal cast. Nybrua Formation, Leira Member, level D-174, $\times 1$.

Figs. 4-6. *Buchia volgensis* (Lahusen). Dragneset Formation, Ratjønna Member, level D-164, $\times 1$. 4, right valve. 5, 6, right valve in anterior and lateral view.

Figs. 7-12. *Buchia keyserlingi* (Lahusen) s.l. Nybrua Formation, Leira Member, level D-174. 7, right valve, $\times 1$. 8, left valve, $\times 2$. 9, 10, left valve and posterior view, $\times 1$. 11, 12, left valve and anterior view, $\times 2$.



BIRKELUND, THUSU and VIGRAN, ammonites and bivalves from Norway

inner whorls of *N. klimovskiensis* (Krimholz), figured in Saks 1972, pl. 5, fig. 5a, b; pl. 18, fig. 3a, b). A flexuous pattern may be seen in *Tollia* (for example, *Tollia* cf. *payeri* (Toula) figured in Saks 1972, pl. 37, fig. 5).

?*Thorsteinssonoceras* sp.

Material. One poorly preserved specimen from level E-10, Leira Member of Nybrua Formation.

Remarks. The specimen is 16 cm in diameter and wholly septate. It has a polyptychid shape and a completely smooth outer whorl, and may be referred to the genus *Thorsteinssonoceras* Jeletzky, 1965 and not to *Polyptychites* because it grows smooth, but the suture line is not sufficiently well preserved to make a final determination possible.

?*Lytoceras* sp.

Plate 5, fig. 2

Material. One fragment from level E-3, Nordelva Member of Skarstein Formation.

Remarks. The specimen shows a sculpture comparable to *Lytoceras*, but is too poor for closer identification.

Genus BUCHIA Rouillier, 1845
Buchia volgensis (Lahusen, 1888)

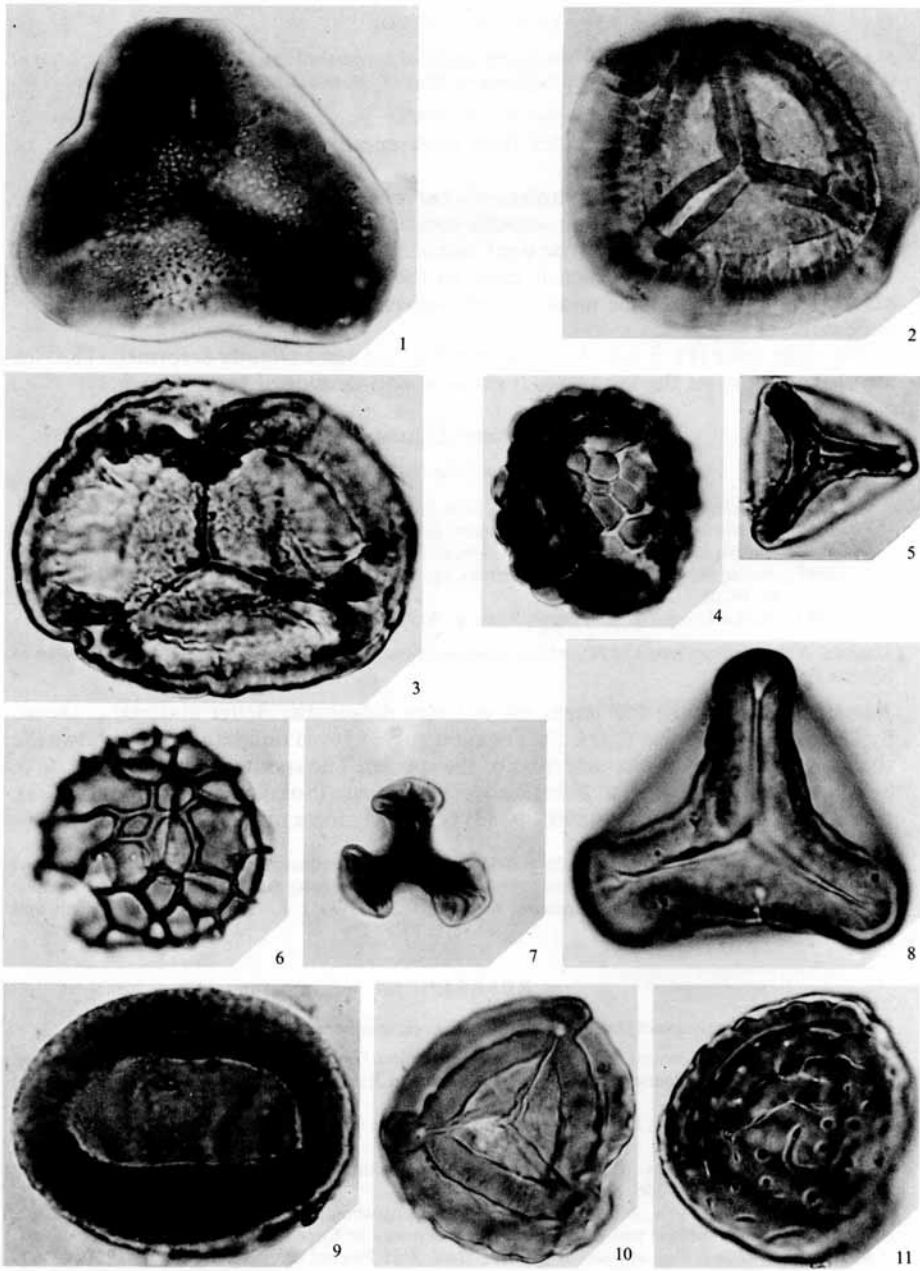
Plate 4, figs. 1-4; Plate 5, figs. 4-6

- 1888 *Aucella volgensis* Lahusen, p. 38, pl. 3, figs. 1-16.
1912 *Aucella volgensis* Lahusen; Sokolov, p. 9, pl. 1, fig. 2.
1959 *Aucella volgensis* Lahusen; Imlay, p. 160, pl. 18, figs. 7, 8, 12-14.

EXPLANATION OF PLATE 6

Selected taxa from Assemblage 1, Middle Jurassic, Andøya, all except figs. 10, 11 from the Ramså Formation, Hestberget Member. All $\times 1000$.

- Fig. 1. *Foveotrites microreticulatus* Couper, 1958. Sample B-27, slide R-27/4, co-ord. 45-0-95-3.
Fig. 2. *Polycingulatisporites triangularis* (Bolkhovitina) Playford and Dettmann, 1965. Sample B-27, slide R-27/1, co-ord. 37-6-95-1.
Fig. 3. *Perotrites zonatoides* Schulz, 1967. Sample A-59, slide S-59/4, co-ord. 35-3-95-6.
Fig. 4. *Leptolepidites rotundus* Tralau, 1968. Distal sculpture. Sample B-27, slide R-27/2, co-ord. 33-1-96-3.
Fig. 5. *Auritulinasporites scanicus* Nilsson, 1958. Lips thickened, raised as a kytome, and emerging into a flange. Sample B-27, slide R-27/2, co-ord. 39-7-99-9.
Fig. 6. *Retitrites concavus* Schulz, 1966. Distal reticulum with lumina of variable sizes, formed by low and smooth ridges. Sample A-59, slide S-59/2, co-ord. 43-2-106-7.
Fig. 7. *Auritulinasporites intrastriatus* Nilsson, 1958. Sample A-59, slide S-59/2, co-ord. 32-0-98-9.
Fig. 8. *Dictyophyllidites mortoni* (De Jersey) Playford and Dettmann, 1965. Proximal focus of well developed kytome. Sample A-59, slide S-59/1, co-ord. 43-3-103-3.
Fig. 9. *Chasmatosporites apertus* (Rogalska) Pocock and Jansonius, 1969. Invaginated, supposed sulcoid area. Sample A-37, slide S-37/5, co-ord. 39-2-106-0.
Figs. 10, 11. Spore sp. A. Proximal and distal foci of same specimen. 10, proximal side smooth with exception of three crassituda parallel to equator. Termination of laesurae widened as auriculae fusing with the cingulum. 11, distal side with muri fusing to an irregular reticulum where the meshes are the size of foveolae. Sample A-69, slide S-69/4, co-ord. 33-8-104-6. Ramså Formation, Kullgrøfta Member.



BIRKELUND, THUSU and VIGRAN, Middle Jurassic spores

Material. A few samples from level D-164 consist largely of *Buchia* shells packed closely together. Most of the shells are fragmentary and crushed. Ratjonna Member of Dragneset Formation.

Remarks. Some of the specimens attain a very large size, as does typical *Buchia volgensis*, but appear to be wider than representatives of that species because of deformation (Pl. 4, fig. 1).

The left valve has a slightly anteriorly curved beak (Pl. 4, fig. 2). The sculpture consists usually of fairly regular, smooth, concentric ribs as in typical representatives of *B. volgensis*, but in a single case weak radial ribs can be distinguished (Pl. 4, fig. 3). The sculpture of that specimen is close to the specimen figured by Pavlov (1896, pl. 27, fig. 2a-b) under the name *Aucella volgensis* var. *radiolata* from the Spilsby Sandstone of England.

The right valve (Pl. 5, figs. 4-6) is nearly flat, but again slightly deformed. The ribs are sharper than on the left valve. It shows a well-developed byssal notch.

Buchia keyserlingi (Lahusen, 1888) *s.l.*

Plate 5, figs. 7-12

- 1888 *Aucella keyserlingi* Lahusen, p. 40, pl. 4, figs. 18-23.
 1894 *Aucella keyserlingi* Lahusen; Lundgren, p. 9; text-figs. 1-2.
 1912 *Aucella keyserlingi* Lahusen; Sokolov, p. 14.
 1965 *Buchia keyserlingi* (Lahusen); Jeletzky, pp. 31, 33, pl. 10, fig. 1; pl. 11, fig. 1; pl. 12, figs. 1, 2; pl. 19, figs. 1, 2, 5, 7.
 1969 *Buchia keyserlingi* (Lahusen); Jones, p. A14, pl. 5, figs. 12-15, 18-33.

Material. A sample from level D-174 contains a few fragmentary shells, mostly juveniles. Leira Member of Nybrua Formation.

Remarks. The juvenile specimens are not very diagnostic. Better material is shown by Lundgren (1894, text-figs. 1, 2). The right valve figured on Plate 5, fig. 7 shows the sharp, high, dense ribs characteristic of the species. The specimen shown on Plate 5, figs. 9, 10 seems to be close to *B. keyserlingi* var. *sibirica* (Sokolov 1908, pl. 3, figs. 1-3), which according to Jeletzky (1965, p. 33) is an early form of *B. keyserlingi s.l.*

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