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Ammonite succession in the Kimmeridgian of southwestern Barents Sea, and the *Amoeboceras* zonation of the Boreal Kimmeridgian

ABSTRACT: Shallow cores drilled in the southwestern Barents Sea have revealed Kimmeridgian strata with a fairly complete succession of species of the ammonite genus *Amoeboceras*. The taxonomical problems of these ammonites are discussed, and the new species *Amoeboceras (Euprionoceras) norvegicum* WIERZBOWSKI, sp.n., is established. The recognized ammonite succession is compared with these described previously from East Greenland and Spitsbergen, and the new zonal scheme based entirely on the representatives of the genus *Amoeboceras* is proposed for the Boreal Kimmeridgian. In this scheme four zones are distinguished: the Bauhini Zone, the Kitchini Zone (with the Subkitchini horizon, and the Modestum horizon), the Kochi Zone (with the Norvegicum horizon, and the Kochi horizon), and the Elegans Zone.

INTRODUCTION

In the western Barents Sea, the Upper Jurassic ammonite faunas have previously been well documented from Svalbard. Lower Oxfordian *Cardioceras* ammonite faunas have been recorded from Southern Spitsbergen (PCHELINA 1967, PARKER 1967) and Kong Karls Land (LØFALDLI & NAGY 1980). Upper Oxfordian and Kimmeridgian *Amoeboceras* — *Rasenia* faunas have been documented from several areas, *i.a.* by FREBOLD (1930), SOKOLOV & BODYLEVSKY (1931), PCHELINA (1967, 1983), YERSHOVA (1983), WIERZBOWSKI (1989) and BIRKENMAJER & WIERZBOWSKI (1991). In the upper parts of the Agardhfjellet Formation, *Dorsoplanites* faunas have been recovered from several localities (PCHELINA 1967, 1983; PARKER 1967; NAGY *& al.* 1990 and earlier papers cited therein); they include species which offer a correlation with the Middle Volgian D. panderi Zone of the Volga Basin (PCHELINA 1967) and the D. maximus Zone of Siberia (YERSHOVA 1983, NAGY *& al.* 1990). In addition to these two zones, YERSHOVA (1983) also recognized faunas assigned to the Laugeites groenlandicus Zone in the Middle Volgian of Spitsbergen. The Jurassic strata overlying the Middle Volgian yielded ammonites of the Upper Volgian, including the diagnostic *Craspedites* which enable a full correlation with the Upper Volgian zones of Rusia (YERSHOVA 1983).

Jurassic ammonite faunas from the southwestern Barents Shelf have been described only from the shallow core *7227/08-U-03* in the Nordkapp Basin (WIERZBOWSKI & ÅRHUS 1990). This core revealed a fairly complete succession of species of the ammonite genus *Amoeboceras*, enabling an identification of the standard Boreal ammonite zones and some informal ammonite horizons of the Upper Oxfordian and Kimmeridgian, recognized in East Greenland.

Upper Jurassic ammonite faunas have also been encountered in the IKU shallow cores *7230/05-U-02* and *7231/01-U-01* drilled in the Nordkapp Basin (*see* Text-fig. 1). Based on the new information obtained from these cores and from the previous studies in the western Barents Sea area, as well as some other areas of the Arctic, mostly East Greenland, a new ammonite zonal scheme

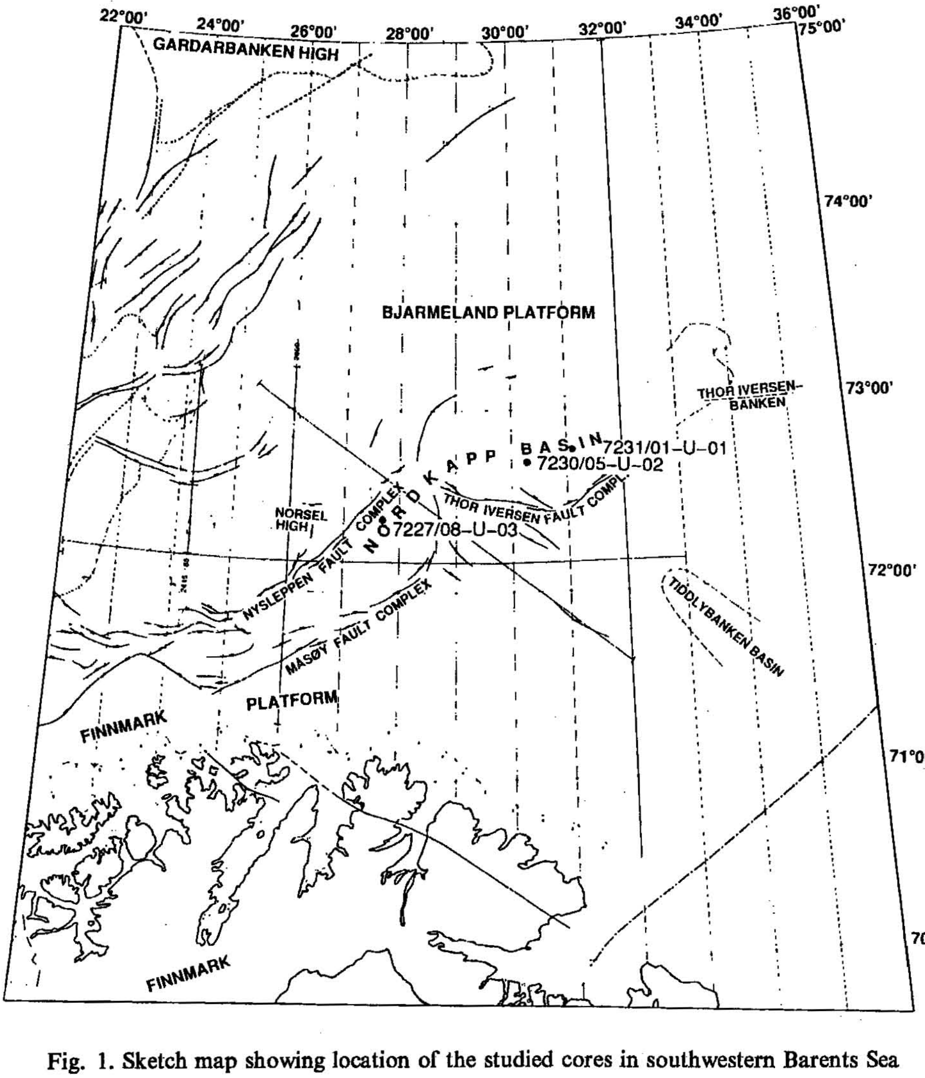


Fig. 1. Sketch map showing location of the studied cores in southwestern Barents Sea

based entirely on the representatives of the genus *Amoeboceras* is proposed herein for the Boreal Kimmeridgian.

The figured ammonites are housed in Paleontologisk Museum, Oslo (PMO).

CORE DESCRIPTIONS

The Upper Jurassic succession of the shallow core *7227/08-U-03* in the Nordkapp Basin has previously been described by WIERZBOWSKI & ÅRHUS (1990).

In the following the Upper Jurassic deposits of the two other cores treated in this paper are briefly described (*see* Text-fig. 2).

Core *7230/05-U-02*

At this site Upper Jurassic strata (Unit *B*) rest unconformably on the Late Bathonian/earliest Callovian. The oldest Upper Jurassic deposit is Late Oxfordian dark gray shale with glauconite pebble laminae (up to 1.5 cm in diameter) in the lower meter. The lower part of the core consists of black, fossiliferous shale. Pyritic and calcareous (shell fragments) laminae occur below 40 m. Siltstone laminae occur, particularly in the uppermost meter, giving it a coarsening-upward grain-size trend. Cone-in-cone calcite concretions are common in the black shales. The bivalve *Buchia* as well as ammonites are the dominant fossils in this part, while cephalopod hooks and other cephalopod fragments, fish remains, and belemnite fragments have also been found. The upper part of the core consists of a more massive, black claystone with *Inoceramus* fragments as well as one ammonite fragment. This part is far less rich in fossil than the underlying unit.

Core *7231/01-U-01*

The Upper Jurassic strata (Unit *B*) occur from the base of the core up to 64.4 m and consist of thinly laminated black shale. In the lower part (up to ca 75 m) ammonites, as well as bivalves, are abundant. Cephalopod hooks are also common. Besides, only a few specimens of a benthic microfauna (foraminifera) are found, and there are no trace fossils. A calcitic nodule occurs at 78.40 m, and at 66.22 m a thin lamina with glauconite grains is present. The dark shale continues to the top of the unit and has a sharp boundary to the overlying Hauterivian unit (*see* ÅRHUS 1991).

AMMONITES OF THE GENUS *AMOEBOCERAS*

Nearly all the Kimmeridgian ammonites discovered in the studied cores belong to the genus *Amoeboceras*. The taxonomic relations between the ammonites of this genus have been discussed in details by BIRKELUND & CALLOMON (1985), and thus only new observations are presented. As the evolution of the family Cardioceratidae (and hence of the genus *Amoeboceras*) was with minor exceptions monophyletic, the occurrence of the monospecific assemblages at the succeeding stratigraphic levels has been the common feature of this lineage (Callomon 1985). This indicates the importance of the following the "horizontal" classification, instead of "vertical" one, when studying the

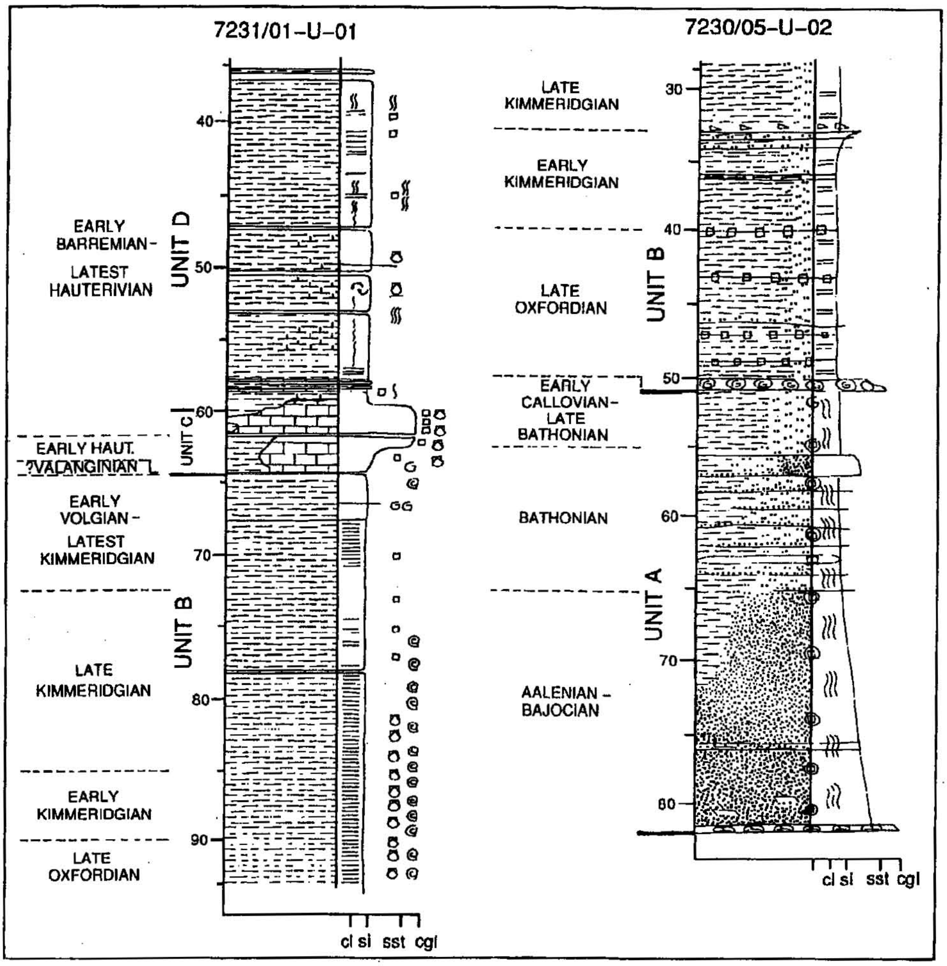


Fig. 2. Lithological logs and stratigraphic interpretation of cores *7230/05-U-02* and *7231/01-U-01*

Lithologies of the rock-units are as follows:

unit **A** — glauconitic sandstones in a lower part, and clayey siltstones above, with the phosphorate conglomerate at the base of the unit,

unit **B** — black fossiliferous organic rich shales discussed in the text,

unit **C** — green clays and nodular limestones, also conglomerates of limestone and claystone clasts,

unit **D** — dark-gray claystones.

Variation in maximum grain size, and explanations of lithology and the fauna content are given in right-sides of logs; these include the occurrence of bivalves, ammonites, bioturbations (vertical flexuosus lines), glauconite grains (G), calcareous nodules (white squares), and horizontal lamination (horizontal lines) succession of the *Amoeboceras* faunas. This is also an approach accepted in the present paper.

In the uppermost Oxfordian of the studied cores there occur two well known *Amoeboceras* faunas following each other in the succession (*cf.* SYKES & SURLYK 1976, SYKES & CALLOMON 1979; *see also* WIERZBOWSKI & ÅRHUS 1990). These are: the older fauna (Pl. 1. Fig. 1) with *Amoeboceras regulare* SPATH, and very close, if not conspecific, *Amoeboceras freboldi* SPATH, and the younger one (Pl. 1, Fig. 2) with *Amoeboceras rosenkrantzi* SPATH (Text-figs 3—5). The latter needs some discussion, as its occurrence directly precedes the appearance of the Kimmeridgian faunas in the cores.

In the fauna with *A. rosenkrantzi*, the most common are moderately ribbed, medium-sized specimens associated with some more coarsely ribbed ones (*e.g.* at 42.47 m in core *7230/05-U-02*). The latter may be compared with a coarse ribbed variant of *A. rosenkrantzi* presented by SYKES & CALLOMON (1979, Pl. 120, Fig. 1), but on the other hand, they show also a similarity to *Amoeboceras leucum* (*see* MESEZHNIKOV 1967, Pl. 1, Fig. 3, and Pl. 3, Figs 2—3). The material from the cores is however, too poorly preserved to allow a closer comparison between *A. rosenkrantzi* and *A. leucum*. In any case, it confirms a very wide range of variability of forms attributed to *A. rosenkrantzi* by SYKES & CALLOMON (1979).

The studied cores have also yielded small microconchs partly associated with much more larger specimens of *A. rosenkrantzi* — *A.* cf. *rosenkrantzi* (see WIERZBOWSKI & ÅRHUS 1990). Of the former, the most interesting are specimens showing a very characteristic extension of the secondary ribs up into the crenulae on the keel. This appears to be a diagnostic feature of the subgenus *Plasmatites* BUCKMAN, 1925, whose separation "*may become useful for members of the bauhini group when better understood*" (SYKES & CALLOMON 1979, p. 859). The specimens studied, although poorly preserved, show mostly a presence of fairly dense ribs projected evenly on the whorl side. This suggests their relation to *Amoeboceras crenulatum* (BUCKMAN), the type species of the subgenus *Plasmatites*. However, as the name *Amoeboceras praebauhini* (SALFELD) appears to be the older synonym of *A. crenulatum*, what has been indicated by BIRKELUND & CALLOMON (1985; *cf. also* MATYJA & WIERZBOWSKI 1988), the poorly preserved specimens from the cores are referred to as *Amoeboceras* cf. *praebauhini* (SALFELD) (*see* Text-figs 3—4 and Pl. 1, Figs 3—5).

It is noteworthy that the most complete material from core *7230/05-U-02* shows a marked overlapping of the stratigraphic range of *Amoeboceras rosenkrantzi* and that of *A.* cf. *praebauhini* (from 42.92 m to 40.80 m, and from 41.93 m to 40.53 m, respectively; *see* Text-fig. 4). This suggests a possible dimorphic relation at least between some forms of *A. rosenkrantzi* and *A.* cf. *praebauhini.*

The first Kimmeridgian fauna discovered in the cores (*see* Text-figs 3–5) is composed mostly of small specimens assigned to the species *Amoeboceras*

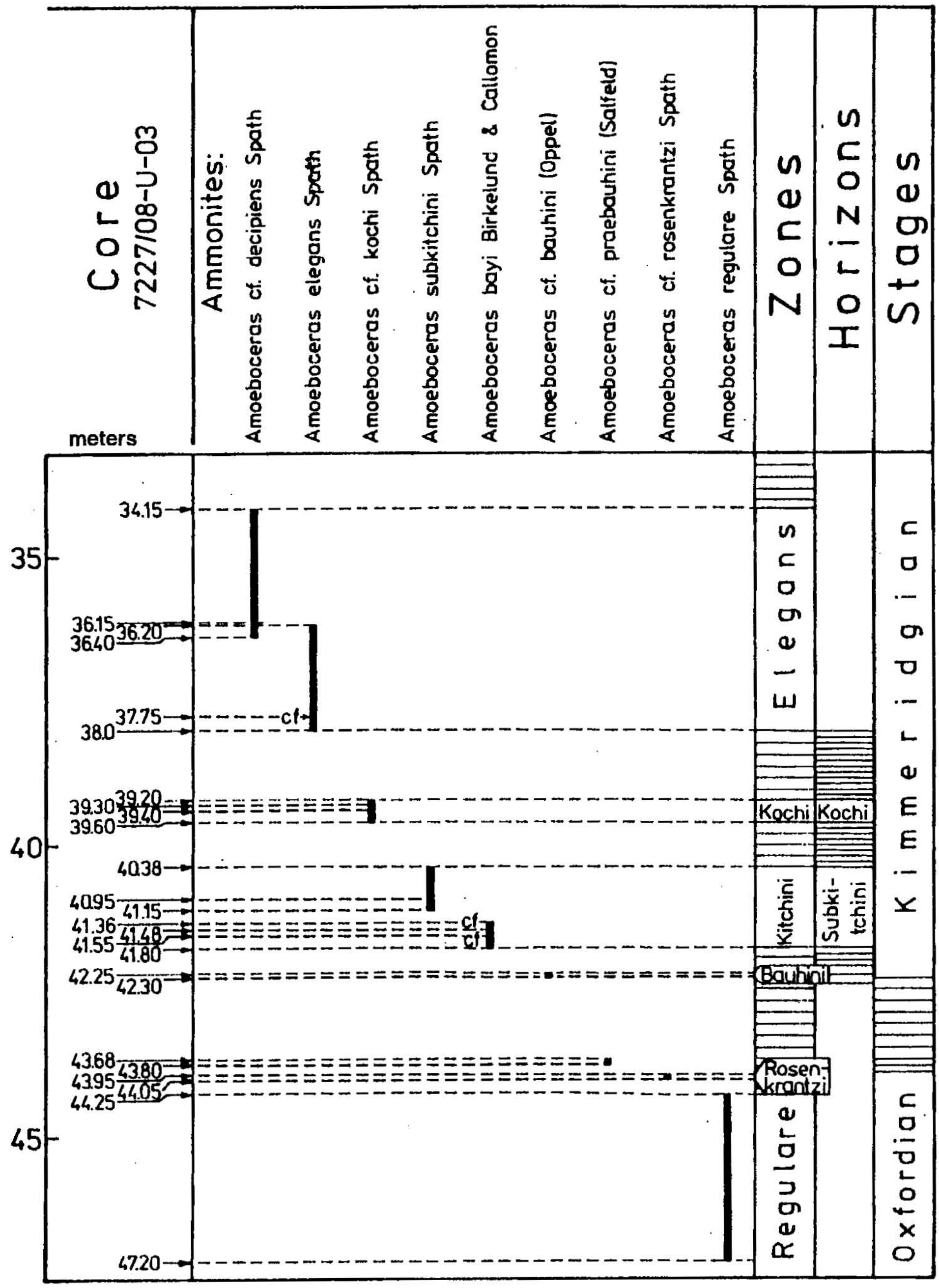


Fig. 3. Distribution of ammonites of the genus *Amoeboceras* in the uppermost Oxfordian and Kimmeridgian in core *7227/08-U-03*, and their stratigraphic interpretation

bauhini (OPPEL) — *A.* cf. *bauhini* (OPPEL). These specimens show a more or less well developed smooth band on the upper part of the whorl side separating the primary and secondary ribs (Pl. 1, Figs 7–11). The ribbing is wiry; the primaries are rather sparsely placed and show characteristic backward bent in the mid-height of the whorl, whereas the secondaries are sweeping markedly forward at the ventral part of the whorl; then, the secondaries are continuing with some weakening into the crenulae on the keel. This species is common in core *7231/01-U-01* where several specimens have been found between 89.87 m and 88.31 m. On the other hand, only a few poorly preserved specimens have been discovered in cores *7230/05-U-02* (at 39.28 m), and *7227/08-U-03* (at 42.25 m and 42.30 m: WIERZBOWSKI & ÅRHUS 1990, Fig. 5G).

In the same stratigraphic interval as *A. bauhini,* a few larger specimens have been found in core *7231/01-U-01.* Of these the most complete specimen from 89.84 m (Pl. 1, Fig. 6) attains a diameter of about 50 mm. All of them show strong, sparsely placed, flexuous primaries which are bent backwards in the mid-height of whorls, and well separated from short, curved secondaries continuing with some weakening up to the crenulated keel. The specimens are very similar to *A. bauhini,* but at least twice as large in their diameters. They are very close to representatives of the type series of *Amoeboceras schulginae* MESEZHNIKOV (*cf.* MESEZHNIKOV 1967, Pl. 1, Fig. 4; Pl. 3, Fig. 1; Pl. 4, Fig. 1) coming from the Boyarka river section in northern Siberia, and thus they may be safely attributed to that species. The specimens referred to as *Amoeboceras* cf. *schulginae* by SYKES & CALLOMON (1979, Pl. 118, Fig. 5) as well as those as *Amoeboceras (Amoebites)* sp. aff. *schulginae* by BIRKELUND & CALLOMON (1985, Pl. 4, Figs 1–3) differ markedly from the studied specimens, and they cannot be included in the species *A. schulginae* (*cf. also* MESEZHNIKOV & *al.* 1989).

The co-occurrence of *A. schulginae* and *A. bauhini,* as well as their similarity, indicate that these two species represent the corresponding macro- and microconchs. This clarifies the problem of the macroconch partner for *A. bauhini* whose nature for a long time has become problematical (*cf.* SYKES & CALLOMON 1979). It should be indicated, however, that more recently *A. bauhini* was regarded as a macroconch with a very small form *A.* aff. *cricki* or *A.* cf. *schlosseri* as its presumed microconch (BIRKELUND & CALLOMON 1985, Pl. 9, Fig. 13a-c; *cf.* WRIGHT 1989). Such variations of the final diameter within one biospecies is consistent with the concept of developmental polymorphism presented by MATYJA (1986).

The subgeneric position of the studied ammonites needs some discussion. These ammonites have hitherto been treated mostly as representing the subgenus *Amoeboceras* (or *Prionodoceras,* if macroconchs), but a closer relation with the subgenus *Amoebites* has been postulated for *Amoeboceras bauhini* (*see* BIRKELUND & CALLOMON 1985), and suggested for *Amoeboceras schulginae* (*see* MESEZHNIKOV 1967), *i.e.* for the youngest members of a part of the lineage. This taxonomic interpretation corresponds well to successive evolutionary changes:

the presence of mid-lateral tuberculation of the primary ribs typical of the Upper Oxfordian *Amoeboceras—Prionodoceras*, and appearing instead strongly accentuated secondary ribs typical of the Lower Kimmeridgian *Amoebites* (*cf.* Birkelund & Callomon 1985).

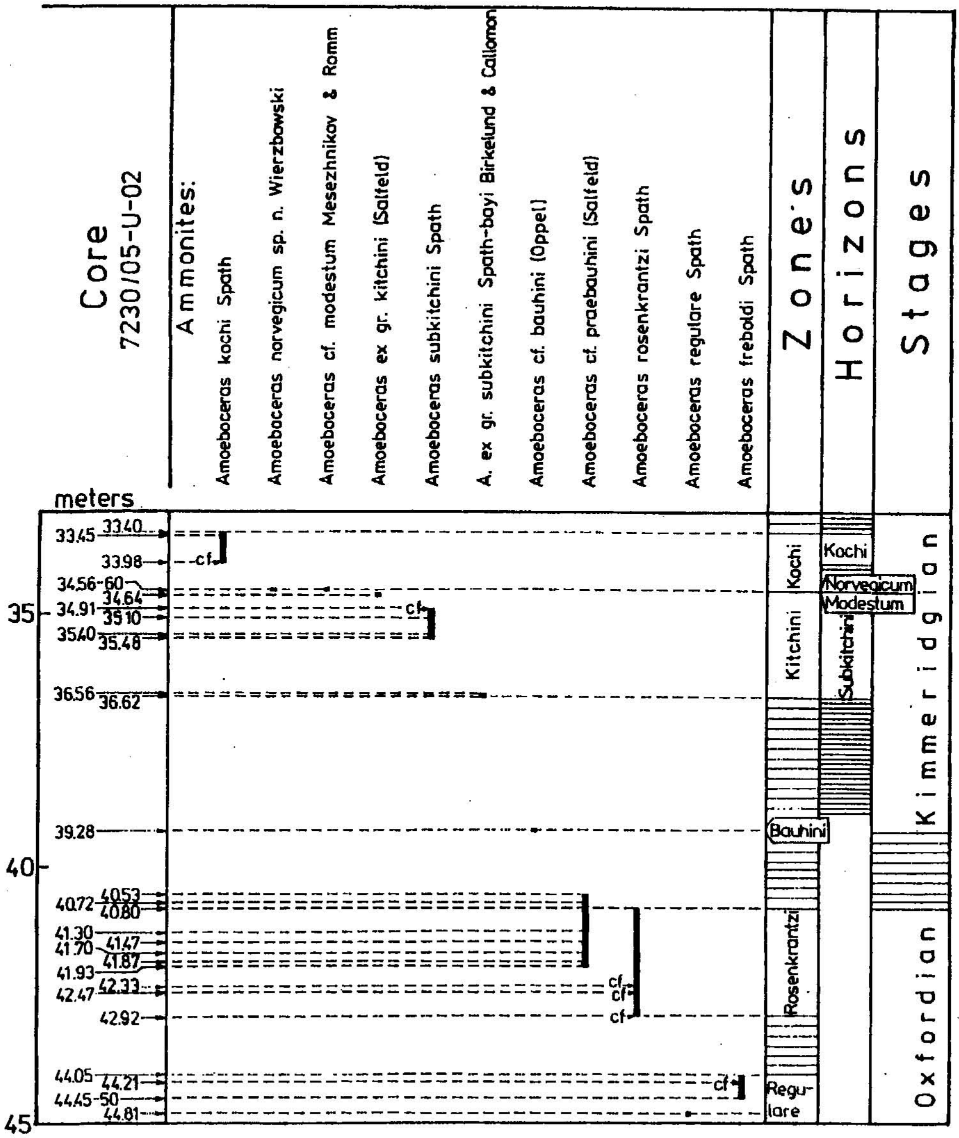


Fig. 4. Distribution of ammonites of the genus *Amoeboceras* in the uppermost Oxfordian and Kimmeridgian in core *7230/05-U-02*, and their stratigraphic interpretation

Some of the species discussed, such as *A. regulare*, *A. rosenkrantzi* and *A. schulginae* have recently been attributed to the newly established subgenus

Paramoeboceras GERASSIMOV (*in* MESEZHNIKOV & *al.* 1989). The relation between this group of species from one side, and the type species of the subgenus, *Amoeboceras ilovaiskii* (M. SOKOLOV) from the other, appears in fact to be rather distant as these ammonites differ in the character of ribbing and in stratigraphic distribution. Such a wide treatening of the subgenus *Paramoeboceras* seems thus to be unjustified, and it is better to retain this subgenus for early forms of the genus *Amoeboceras* only, *i.e.* for the *A. glosense* group.

The three succeeding faunas in the studied cores are composed of ammonites of the subgenus *Amoebites* BUCKMAN, 1925. The oldest fauna contains specimens of *Amoeboceras (Amoebites) bayi* BIRKELUND & CALLOMON — *A. (A).* cf. *bayi* BIRKELUND & CALLOMON. This fauna was described from core *7227/08-U-03* between 41.80 m and 41.36 m, by WIERZBOWSKI & ÅRHUS (1990, Figs 5H-I and 6A-B) well above the fauna with *A.* cf. *bauhini* (see Text-fig. 3). The fauna has not been confirmed unequivocally in core *7230/05-U-02*, but possibly a few poorly preserved ammonites from the interval 36.62 m to 36.56 m may be assigned either to *A. bayi* or to *A. subkitchini* SPATH (Pl. 1, Fig. 12). This fauna was not recognized in core *7231/01-U-01* where the corresponding beds are possibly enclosed in a very narrow interval between 88.31 m and 88.06 m, *i.e.* between the last occurrence of *A.* cf. *bauhini* and the first occurrence of *A. subkitchini.*

A still younger fauna, represented by *Amoeboceras (Amoebites) subkitchini* SPATH — *A. (A.)* cf. *subkitchini* SPATH is well recognized in the studied cores. In core *7227/08-U-03,* between 41.15 m and 40.38 m (WIERZBOWSKI & ÅRHUS 1990, Fig. 6C-D) there occur some fragmentary ammonites of larger size showing the development of ventrolateral nodes what is typical of the macroconchs of this species (*cf.* BIRKELUND & CALLOMON 1985). The ammonites *A. subkitchini* — *A.* cf. *subkitchini* have also been found in core *7230/05-U-02* between 35.48 m and 34.91 m (Text-fig. 4 and Pl. 1, Figs 15-16), and in core *7231/01-U-01* between 88.06 m and 87.77 m (Text-fig. 5 and Pl. 1, Figs 13-14). In these two cores the macroconchs were most common, but there also occurred a few small, not very well preserved microconchs (at 34.91 m core *7230/05-U-02,* and at 87.78-87.77 m core *7231/01-U-01*; *see* Pl. 1, Fig. 17). These are closely comparable with those illustrated by BIRKELUND & CALLOMON (1985, Pl. 3, Figs 4, 7-9, 11), and WIERZBOWSKI (1989, Pl. 16, Figs 2-3).

The youngest fauna with *Amoebites* is poorly known as it consists only of a few fragmentary and/or badly preserved specimens. Core *7231/01-U-01* yielded two ammonites from 85.33 m. Of these, the smaller one is a fragment of about 15 mm in diameter showing a high value of the secondary/primary ribs ratio (about 1.6). The larger specimen is better preserved: it is about 35 mm in diameter (Pl. 2, Fig. 1), involute (the whorl height in percentage of shell diameter is 42.5, whereas the umbilical diameter in percentage of shell diameter is 30.5), rather densely ribbed (about 45 primaries per whorl at 33 mm diameter), and showing a middle value of the secondary/primary ribs ratio

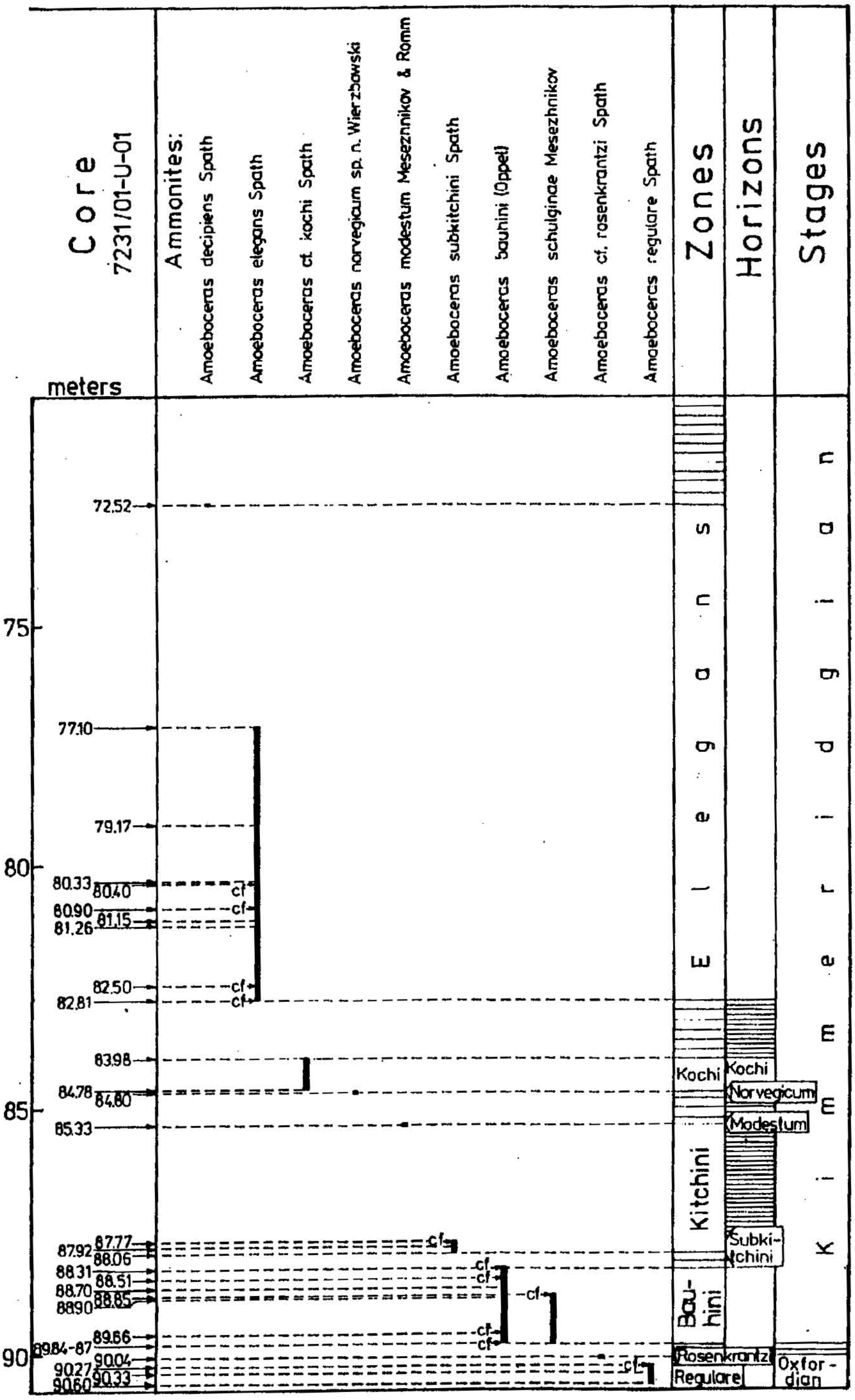


Fig. 5. Distribution of ammonites of the genus *Amoeboceras* in the uppermost Oxfordian and Kimmeridgian in core *7231/01-U-01*, and their stratigraphic interpretation

(somewhat above 1.0). Both specimens are similar to *Amoeboceras (Amoebites) modestum* MESEZHNIKOV & ROMM (*see* MESEZHNIKOV & ROMM 1973, Pl. 3, Figs 1-3) as well as to a very closely related form referred to as *Amoeboceras (Amoebites)* cf./aff. *beaugrandi* (SAUVAGE) by BIRKELUND & CALLOMON (1985, Pl. 4, Figs 6-8; *see also* SPATH 1935, Pl. 4, Fig. 8 and Pl. 5, Fig. 4).

From core *7230/05-U-02* three specimens representing the youngest fauna with *Amoebites* are recorded. At 34.64 m a fragment of a large whorl with coarse ribs and strong ventrolateral nodes has been found (*see* Pl. 2, Fig. 3). This may represent *Amoeboceras (Amoebites) kitchini* (SALFELD). On the same bedding surface there occurs a small, densely ribbed specimen showing the numerous secondary ribs. This specimen seems to be similar to the inner whorls of the lectotype of *Amoeboceras (Amoebites) kitchini* (*see* BIRKELUND & CALLOMON 1985, Fig. 6); but it is also similar to *Amoeboceras (Amoebites)* cf./aff. *beaugrandi* of BIRKELUND & CALLOMON (1985). The two ammonites discussed are referred to as *Amoeboceras (Amoebites)* ex gr. *kitchini* (*see* Text-fig. 4). An even younger ammonite from the same core is found at 34.60-34.56 m (Pl. 2, Fig. 2). This is a fragment of a moderately involute shell, rather densely ribbed with weak ventrolateral nodes; it shows a middle value of the secondary/primary ribs ratio (about 1.1 to 1.2 at 20 mm whorl height). This specimen is referred to as *Amoeboceras (Amoebites)* cf. *modestum* MESEZHNIKOV & ROMM.

Above the discussed faunas with *Amoebites*, and also possibly along with their youngest representatives, there appears a quite different new fauna. It is represented by the new species, *Amoeboceras (Euprionoceras) norvegicum* WIERZBOWSKI sp. n., which is formally described hereafter.

The ammonites of the species *A. norvegicum* WIERZBOWSKI, sp.n. have been found in core *7230/05-U-02* at 34.60 — 34.56 m (Pl. 2, Fig. 4), and in core *7231/01-U-01* at 84.80 m (Pl. 2, Fig. 5), as well as in other cores still unpublished. All these specimens show the inner whorls with vestigial striations, and the outer whorl with stronger single and biplicate ribs, and weak ventrolateral tubercles. In the studied cores the fauna with *A. norvegicum* generally precedes the appearance of the fauna with *Amoeboceras (Euprionoceras) kochi* SPATH.

The fauna with *Amoeboceras kochi* SPATH is represented in all the cores studied. The small specimens interpreted as microconchs of *A. kochi*, and tentatively referred to that very species (WIERZBOWSKI & ÅRHUS 1990, Fig. 6E-F), were found between 39.60 m and 39.20 m in core *7227/08-U-03*. Similar small specimens have also been discovered between 84.78 m and 83.98 m in core *7231/01-U-01* (Pl. 2, Fig. 8), but the small specimens along with the larger ones, about 50 mm in their diameters, occurred between 33.98 m and 33.40 m in core *7230/05-U-02* (*see* Pl. 2, Figs 6-7). The specimens show the innermost whorls very finely ribbed, and then the single and biplicate ribs appear. The ribs are nearly rectiradiate in the dorsolateral part of the whorl, and strongly bent forwardly in its ventrolateral part. At bigger diameters, weak elongated tubercles are developed on the ribs at the ventrolateral part of whorl. All these features are typical of *Amoeboceras kochi* as recently emended by BIRKELUND & CALLOMON (1985). Thus, when the new material from the cores has been accessible, it becomes evident, that all the specimens discussed can be attributed to the species *A. kochi.*

The youngest *Amoeboceras* fauna is characterized by the very finely ribbed innermost whorls, and appearing thereafter a strong ornamentation with well developed nodes and clavi at the ventrolateral part of the whorl, resembling that of earlier *Amoebites,* or with more or less strongly developed three rows of tubercles occurring from the umblical edge up to the ventrolateral shoulders. The fauna includes *Amoeboceras elegans* SPATH — *A.* cf. *elegans* SPATH, and *Amoeboceras decipiens* SPATH — *A.* cf. *decipiens* SPATH. It was described previously from core *7227/08-U-03* between 38.0 m and 36.20 m, as well as between 36.40 m and 34.15 m (*A. elegans* and *A. decipiens,* respectively; *see* WIERZBOWSKI & ÅRHUS 1990, Fig. 6G-I; Text-fig. 3 herein). Such a fauna has also been discovered in core *7231/01-U-01* between 82.81 m and 77.10 m (*A. elegans*), and at 72.52 m (*A. decipiens,* see Text-fig. 5 and Pl. 2, Figs 9-13), but it is absent in core *7230/05-U-02* where the corresponding beds are missing. Although the two ammonite species have been described in details by SPATH (1935), BIRKELUND & CALLOMON (1985), and WIERZBOWSKI (1989), their phyletic relations remained obscure. The species *A. elegans* was traditionally placed in the subgenus *Amoebites,* whereas the species *A. decipiens* was distinguished as the type of the subgenus *Hoplocardioceras* SPATH, 1935. However, as shown recently (BIRKENMAJER & WIERZBOWSKI 1991), these two species are closely related, and thus should be placed into a single subgenus. The name *Hoplocardioceras* seems here the most appropriate. The problem of the stratigraphic distribution of *A. elegans* and *A. decipiens* will be discussed below.

No younger *Amoeboceras* fauna has been found in the studied cores. The only ammonites discovered in younger beds belong to the genus *Aulacostephanus* (*see* WIERZBOWSKI & ÅRHUS 1990). These are, however, rare, poorly preserved, and cannot be determined at species level.

THE *AMOEBOCERAS* ZONES OF THE BOREAL KIMMERIDGIAN

The *Amoeboceras* zonation in the western part of the Boreal Province has so far been established for the Upper Oxfordian only (SYKES & SURLYK 1976, SYKES & CALLOMON 1979). The detailed succession of the *Amoeboceras* species in the Boreal Kimmeridgian was for a long time poorly known, thus preventing any attempt to distinguish the ammonite zones and subzones. The first approach towards the elaborating of the *Amoeboceras* zonal scheme for the Kimmeridgian has been the recognition in East Greenland of several unconnected ammonite horizons, each of them based on "horizontally" interpreted ammonite fauna, and composed of the single ammonite biospecies (BIERKELUND & CALLOMON 1985). As the monophyletic character of the cardioceratid evolution was shown (CALLOMON 1985), and as the succession of ammonite horizons has become more fully recognized also in other areas, *ie.* in Spitsbergen (WIERZBOWSKI 1989, BIRKENMAJER & WIERZBOWSKI 1991) and southern Barents Sea (WIERZBOWSKI & ÅRHUS 1990), new premises for establishing the *Amoeboceras* zonation in the Boreal Kimmeridgian appeared. The firm basis for the new zonation has recently been obtained from the study of the new cores from the south-western Barents Sea, which are especially rich in ammonites of the genus *Amoeboceras* (*see* Text-figs 3-5).

The subdivision of the Boreal Upper Oxfordian in Siberia, based on ammonites of the genus *Amoeboceras*, as well as the position of the Oxfordian-Kimmeridgian boundary (MESEZHNIKOV 1967, 1988; *cf.* MESEZHNIKOV & *al.* 1989), differs from this accepted in the present paper. The only *Amoeboceras* zone distinguished so far in the Kimmeridgian was the Amoeboceras kitchini Zone of Siberia (MESEZHNIKOV 1968).

The four *Amoeboceras* zones are herein proposed in the Boreal Kimmeridgian. Their correlation with the *Amoeboceras* horizons of East Greenland and Spitsbergen is discussed (*see* Text-fig. 6). The new zones are defined by their character of ammonite faunas, and usually not by the type sections. The latter, except of the type section of the Bauhini Zone, cannot at the moment be precisely designated in the exposures on the land.

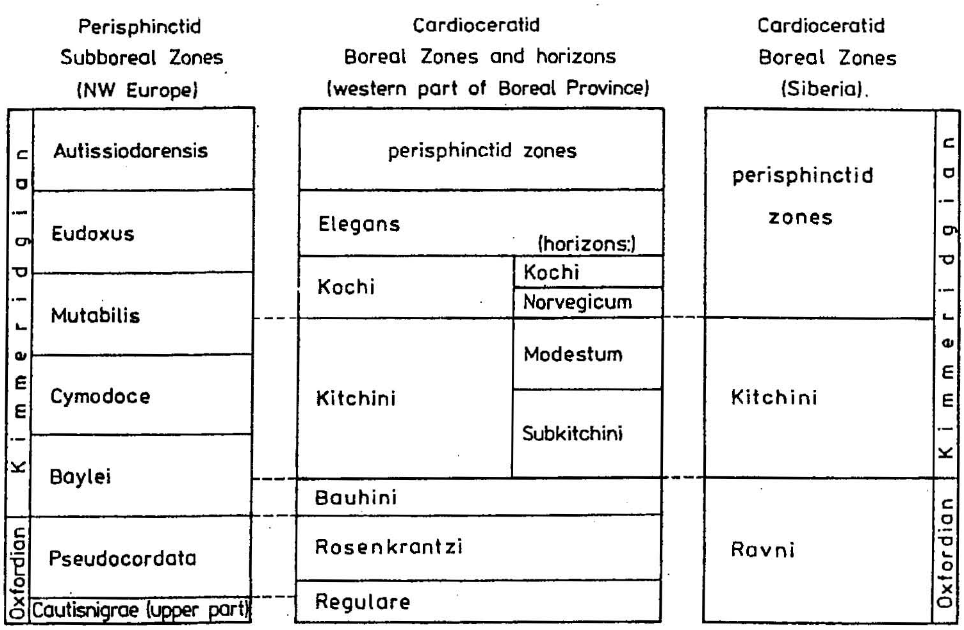


Fig. 6. Ammonite zonal schemes of the uppermost Oxfordian and Kimmeridgian in the Subboreal and Boreal Provinces

The Bauhini Zone

INDEX: *Amoeboceras bauhini* (OPPEL). The species has been discussed more recently by SYKES & CALLOMON (1979) who refigured the holotype (SYKES & CALLOMON 1979, Pl. 121, Fig. 1a-c), as well as by BIRKELUND & CALLOMON (1985).

DEFINITION and CHARACTERISTIC FAUNA: The Zone is characterized by the incoming of small microconch species *Amoeboceras bauhini*, and its macroconch counterpart, *Amoeboceras schulginae* MESEZHNIKOV. The characteristic feature of these species is a differentiation of coarse ribbing by a smooth spiral band into simple primaries, and short secondaries, what is a first step in the development of the subgenus *Amoebites*.

NOMENCLATURE and CORRELATION: The ammonites typical of the Zone occur in the cores studied (*see* Text-figs 3-5) above *Amoeboceras rosenkrantzi* SPATH and *Amoeboceras* cf. *praebauhini* (SALFELD) which may represent corresponding macro and microconchs. Thus, the Bauhini Subzone distinguished in the upper part of the Rosenkrantzi Zone of the uppermost Oxfordian, and defined originally by SYKES & CALLOMON (1979, pp. 856-857) as "*characterized by incoming of diminutive species of the group of bauhini, including A. praebauhini* (SALFELD)...", as well as by persisting of *A. rosenkrantzi*, should theoretically, but partly correspond to the new zone. However, when classification of the beds at the Oxfordian/Kimmeridgian boundary in the type section of the Bauhini Subzone at Staffin in Skye, Scotland, has been modified (BIRKELUND & CALLOMON 1985, pp. 16-17), it becomes evident that the corresponding bed *37* of the section (bed *36* is barren) is entirely of Early Kimmeridgian age, and it does not contain any ammonites of the Rosenkrantzi Zone. Hence, the Bauhini Subzone, in its type section corresponds to the bed *37*, as well as *38* (*cf.* WRIGHT 1989), and it is equivalent to the Bauhini Zone as defined in the present paper. The type section of the Bauhini Zone must thus be at Staffin, *ie.* beds *37-38* of the Flodigarry Shale Member (*cf.* SYKES & CALLOMON 1979, WRIGHT 1989).

In the Bauhini Zone (=Bauhini Subzone of SYKES & CALLOMON 1979) in Scottish (Staffin, Skye) and English sections (South Ferriby, eastern England) the representatives of *Pictonia*, close to *P. densicostata* (SALFELD) (*see* BIRKELUND & CALLOMON 1985, WRIGHT 1989) occur along with the zonal index form. As *P. densicostata* is typical of the lower part of the Baylei Zone of the lowermost Kimmeridgian in the Subboreal zonal scheme (BIRKELUND & CALLOMON 1985), this part of the zone may be treated as an equivalent to the Bauhini Zone.

In Siberian sections, the Bauhini Zone cannot be precisely recognized. The Ravni Zone distinguished in the Upper Oxfordian (MESEZHNIKOV 1967, 1988) is marked by the occurrence of *Amoeboceras regulare, A. leucum, A. freboldi, A. marstonense, A. schulginae*. The Ravni Zone presumably corresponds jointly to the Regulare Zone, the Rosenkrantzi Zone, and the newly emended Bauhini Zone of the western part of the Boreal Province (*cf.* MESEZHNIKOV 1989, MESEZHNIKOV & *al.* 1989).

DISTRIBUTION in the cores: The Bauhini Zone is recognized in core *7227/08-U-03* between 42.30 m and 42.25 m, in core *7230/05-U-02* at 39.28 m, and core *7231/01-U-01* between 89.87 m and 88.31 m (*see* Text-figs 3-5).

The Kitchini Zone

INDEX; *Amoeboceras (Amoebites) kitchini* (SALFELD) as emended by BIRKELUND & CALLOMON (1985, pp. 20-22; lectotype designated and refigured therein in Text-fig 6).

DEFINITION and CHARACTERISTIC FAUNAS: The Zone is characterized by the succession of typical *Amoebites* species, from Amoeboceras (Amoebites) bayi BIRKELUND & CALLOMON, through *A. (Amoebites) subkitchini* SPATH, up to the assemblage of the closely allied species composed of *A. (Amoebites) mesezhnikovi* SYKES & SURLYK, *A. (Amoebites) pingueforme* MESEZHNIKOV, *A. (Amoebites) modestum* MESEZHNIKOV & ROMM, and *A. (Amoebites) kitchini* (SALFELD), as well as such related the microconch species as *Amoeboceras (Amoebites) rasenense* SPATH, and the forms referred to as *Amoeboceras (Amoebites)* cf./aff. *beaugrandi* (SAUVAGE) by BIRKELUND & CALLOMON 1985 (*see* WIERZBOWSKI 1989).

The Zone may informally be subdivided into two parts. The lower one is designated as the Subkitchini horizon, after *Amoeboceras subkitchini* (SPATH), which is marked by the occurrence of *A. bayi* near the base, and by *A. subkitchini* at higher levels (*cf.* BIRKELUND & CALLOMON 1985). The ammonites of this horizon show fairly dense, nearly straight, mostly simple ribs on inner whorls, while their outer whorls display the elongated ventrolateral tubercles and/or nodes separated from the primary ribs by a smooth spiral band. At larger diameter, which is observed in *A. subkitchini,* the ventrolateral nodes are spaced independently of the ribs, and sometimes transformed into clavi.

The upper part of the Kitchini Zone is designated as the Modestum horizon (after *Amoeboceras modestum* MESEZHNIKOV & ROMM), which is marked by the occurrence of *A. modestum, A. pingueforme, A. kitchini* and some other related forms. These ammonites show the common presence of biplicate ribs on the inner whorls, as well as often on the outer whorl. The ventrolateral nodes are generally weakly developed, apart from some more rare forms, as *A. kitchini,* where heavy nodes can also appear on the outer whorl (*cf.* WIERZBOWSKI 1989).

The boundary between these two horizons cannot be defined very precisely due to the poor knowledge of ammonites of the Modestum horizon, and the occurrence of some specimens with more common biplicate ribs already in the Subkitchini horizon (*cf.* WIERZBOWSKI 1989). When better understood the two horizons should possibly be transferred into the subzones.

NOMENCLATURE and CORRELATION: The Kitchini Zone was distinguished by MESEZHNIKOV (1968) for the assemblage of ammonites of the subgenus *Amoebites*. Later (MESEZHNIKOV 1984), the type area of this Zone was indicated in eastern Taimyr. The Kitchini Zone has however never been defined precisely: its lower boundary was placed at the transition of the subgenera *Amoeboceras* and *Prionodoceras* into the subgenus *Amoebites,* and the upper boundary generally defined below the beds with *Amoeboceras (Euprionoceras)* (*cf.* MESEZHNIKOV 1984, 1988).

The Kitchini Zone, as emended herein, includes several ammonite horizons distinguished previously in Eastern Greenland by BIRKELUND & CALLOMON (1985): from horizon no. *14* (with *A. bayi*) through the horizons no. *15* and no. *17* with *A. subkitchini,* up to the horizon no. *18* with *A.* cf. *rasenense,* and no. *19* with *A.* cf. *beaugrandi.* Whereas the horizons *14* to *17* correspond generally to the lower part of the Kitchini Zone, *i.e.* to the Subkitchini horizon, the horizons *18* and *19* correspond to the upper part of the Kitchini Zone, *i.e.* to the Modestum horizon.

In Spitsbergen (WIERZBOWSKI 1989), the following horizons belong to the Kitchini Zone: no. *1a-1b* with *A. subkitchini*, no *2* with *A. mesezhnikovi*, and no. *3* with *A. pingueforme*. The boundary between the lower and upper part of the Kitchini Zone (between the Subkitchini and the Modestum horizons) possibly lies at the base of horizon no. *3* with *A. pingueforme*.

The correlation of the discussed ammonite horizons from East Greenland and Spitsbergen with the standard ammonite zones of the Subboreal subdivision (BIRKELUND & CALLOMON 1985, Fig. 5; WIERZBOWSKI 1989, Fig. 7) indicates that the Kitchini Zone corresponds jointly to the upper part of the Baylei Zone, to the Cymodoce Zone, and partly to the Mutabilis Zone. The boundary between the Subkitchini horizon and the Modestum horizon runs in the middle part of the Cymodoce Zone (*see* Text-fig. 6).

DISTRIBUTION in the cores: The Kitchini Zone is recognized in core *7227/08-U-03* between 41.80 m and 40.38 m (the Subkitchini horizon only), in core *7230/05-U-02* between 36.62 m and 34.60-34.56 m (including the Subkitchini horizon between 36.62 m and 34.91 m, and the Modesum horizon between 34.64 m and 34.60-34.56 m), and in core *7231/01-U-01* between 88.06 m and 5.53 m (including the Subkitchini horizon between 88.06 m and 87.77 m, and the Modestum .orizon at 85.53 m) (*see* Text-figs 3-5).

PLATE 1

1 — *Amoeboceras regulare* SPATH; Regulare Zone, core *7231/01-U-01* (90.33 m), PMO 138.945

2 — *Amoeboceras rosenkrantzi* SPATH; Rosenkrantzi Zone, core *7230/05-U-02* (40.80 m), PMO 138.946

3-5 — *Amoeboceras* cf. *praebauhini* (SALFELD); Rosenkrantzi Zone, core *7230/05-U-02* (41.93 m, 41.30 m and 40.72 m), PMO 138.947, PMO 138.948, and PMO 138.949; note a coarsely ribbed variant similar to *A. bauhini* in upper part of Fig. 3 (*cf.* MATYJA & WIERZBOWSKI 1988, Pl. 2)

6 — *Amoeboceras schulginae* MESEZHNIKOV; Bauhini Zone, core *7231/01-U-01* (89.84 m), PMO 138.950

7-9 — *Amoeboceras bauhini* (OPPEL); Bauhini Zone, core *7231/01-U-01* (88.70 m, 88.85 m and 88.90 m), PMO 138.951, PMO 138.952, and PMO 138.953

10-11 — *Amoeboceras* cf. *bauhini* (OPPEL); Bauhini Zone, core *7231/01-U-01* (89.66 m, and 88.31 m), PMO 138.954, and PMO 138.955

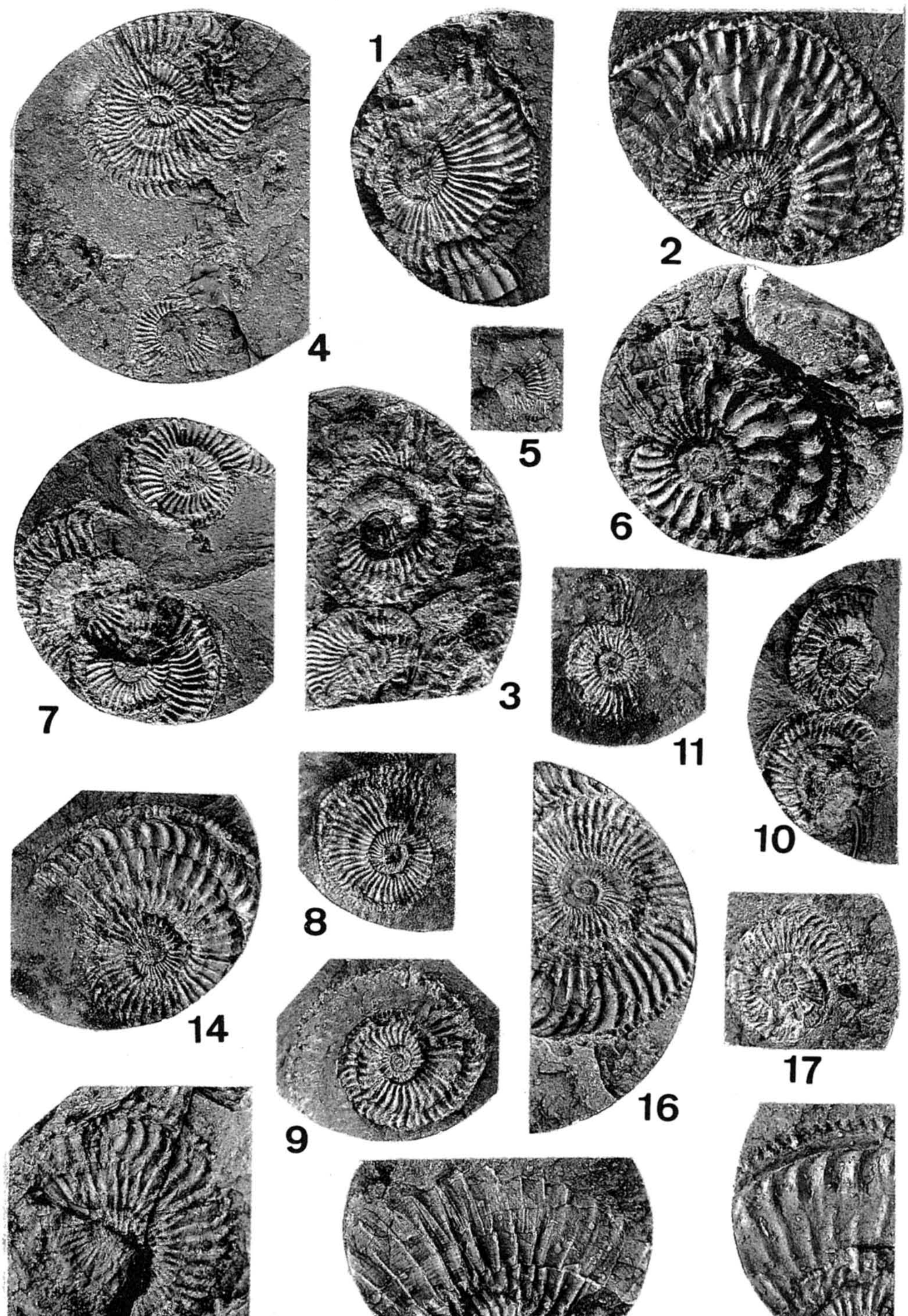
12 — *Amoeboceras* ex gr. *subkitchini* SPATH — *bayi* BIRKELUND & CALLOMON; Kitchini Zone, Subkitchini horizon, core *7230/05-U-02* (36.56 m), PMO 138.956

13-14 — *Amoeboceras subkitchini* SPATH; Kitchini Zone, Subkitchini horizon, core *7231/01-U-01* (88.06 m, and 87.92 m), PMO 138.957, and PMO 138.958

15-16 — *Amoeboceras subkitchini* SPATH; Kitchini Zone, Subkitchini horizon, core *7230/05-U-02* (35.40 m), PMO 138.959, and PMO 138.960

17 — *Amoeboceras* cf. *subkitchini* SPATH; Kitchini Zone, Subkitchini horizon, core *7231/01-U-01* (87.77 m), PMO 138.961

All specimens in natural size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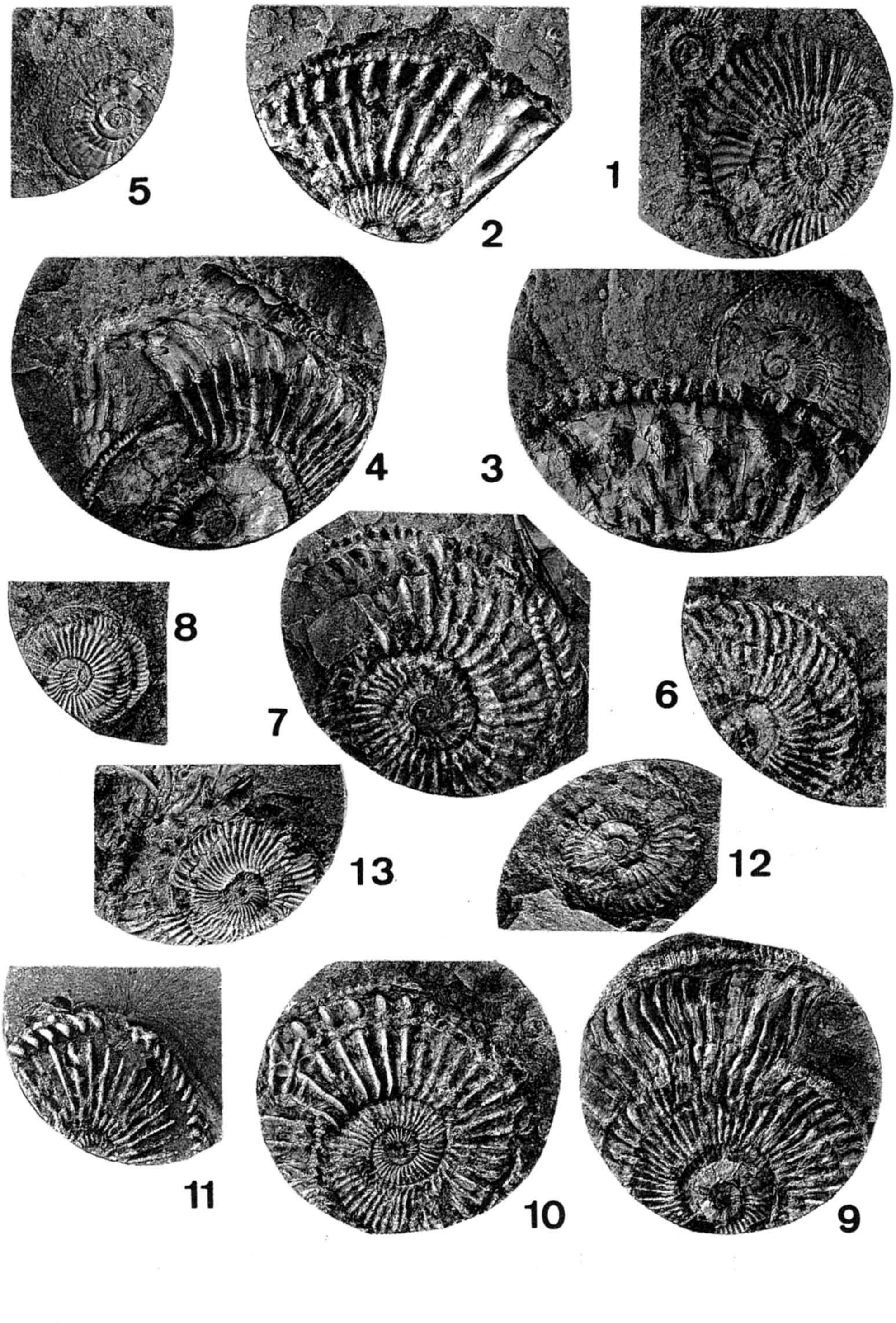
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The Kochi Zone

INDEX: *Amoeboceras (Euprionoceras) kochi* SPATH. The holotype is figured by SPATH (1935, Pl. 5, Fig. 2a), and the species has been discussed by BIRKELUND & CALLOMON (1985, pp. 26-28).

DEFINITION and CHARACTERISTIC FAUNAS: The new Zone is characterized by the occurrence of representatives of the subgenus *Euprionoceras* showing single and biplicate ribs and poorly developed tubercles in the ventrolateral part of whorls. The base of the Zone is marked by the appearance of *Amoeboceras norvegicum* WIERZBOWSKI, sp. n., whereas the upper part of the Zone is characterized by the occurrence of *A. kochi.*

The Zone can be subdivided into two informal horizons which, if better recognized, possibly should be transferred into the subzones. The lower horizon is designated as the Norvegicum horizon, which is marked by the occurrence of *A. norvegicum* appearing rather abruptly, together, or slightly above the last representatives of the subgenus *Amoebites* (Text-figs 4-5). This distinctive index species has the inner whorls very weakly ornamented up to a much later stage than it occurs in other species. The upper horizon is designated as the Kochi horizon, and it is marked by the occurrence of *A. kochi,* having only the innermost whorls nearly smooth.

CORRELATION: The Kochi Zone has not been distinguished so far. It includes the horizon no. *20* with *A. kochi* from East Greenland distinguished by BIRKELUND & CALLOMON (1985), as well as possibly the horizon with *Amoeboceras sokolovi* (BODYLEVSKY) from Spitsbergen (*cf.* BIRKELUND & CALLOMON 1985, WIERZBOWSKI 1989).

PLATE 2

1 — *Amoeboceras modestum* MESEZHNIKOV & ROMM; Kitchini Zone, Modestum horizon, core *7231/01-U-01* (85.33 m), PMO 138.962

2 — *Amoeboceras* cf. *modestum* MESEZHNIKOV & ROMM; Kitchini Zone, Modestum horizon, core *7230/05-U-02* (34.56-34.60 m), PMO 138.963

3 — *Amoeboceras* ex gr. *kitchini* (SALFELD); Kitchini Zone, Modestum horizon, core *7230/05-U-02* (34.64 m), PMO 138.964

4 — *Amoeboceras norvegicum* WIERZBOWSKI, sp. n.; Kochi Zone, Norvegicum horizon, core *7230/05-U-02* (34.56-34.60 m), **holotype**, PMO 138.965

5 — *Amoeboceras norvegicum* WIERZBOWSKI, sp. n.; Kochi Zone, Norvegicum horizon, core *7231/01-U-01* (84.80 m), **paratype**, PMO 138.966

6-7 — *Amoeboceras kochi* SPATH; Kochi Zone, Kochi horizon, core *7230/05-U-02* (33.45 m, and 33.40 m), PMO 138.967, and PMO 138.968

8 — *Amoeboceras* cf. *kochi* SPATH; Kochi Zone, Kochi horizon, core *7231/01-U-01* (84.78 m), PMO 138.969

9-11 — *Amoeboceras elegans* SPATH; Elegans Zone, core *7231/01-U-01* (81.26 m, 81.15 m, and 77.10 m), PMO 138.970, PMO 138.971, and PMO 138.972

12-13 — *Amoeboceras* cf. *elegans* SPATH; Elegans Zone, core *7231/01-U-01* (82.81 m, and 82.50 m), PMO 138.973, and PMO 138.974

All specimens in natural size

The Kochi Zone corresponds possibly to the upper part of the Mutabilis Zone and/or a lower part of the Eudoxus Zone of the Subboreal ammonite subdivision (*cf.* BIRKELUND & CALLOMON 1985, WIERZBOWSKI 1989).

DISTRIBUTION in the cores: The Kochi Zone is recognized in core *7227/08-U-03* between 39.60 m and 39.20 m (the Kochi horizon only), in core 7230/05-U-02 between 34.60-34.56 m and 33.40 m (the Norvegicum horizon at 34.60-34.56 m, and the Kochi horizon between 33.98 and 33.40 m), and in core *7231/01-U-01* between 84.80 m, and 83.98 m (the Norvegicum horizon at 84.80 m, and the Kochi horizon between 84.78 m and 83.98 m) (*see* Text-figs 3-5). Moreover, the succession of *A. norvegicum* to *A. kochi* has been recognized in other, still unpublished cores from other parts of the western Barents Shelf.

The Elegans Zone

INDEX: *Amoeboceras (Hoplocardioceras) elegans* SPATH. The holotype was figured by SPATH (1935, Pl. 4, Fig. 2), and the species has recently been discussed by BIRKELUND & CALLOMON (1985, pp. 24-26) and WIERZBOWSKI (1989, pp. 363-365).

DEFINITION and CHARACTERISTIC FAUNA: The new Zone is characterized by the occurrence of moderately to heavily ornamented *Amoeboceras elegans* SPATH and heavily ornamented *Amoeboceras decipiens* SPATH. The base of the Zone is marked by the appearance of a single ammonite assemblage of wide, but continuous, range of variability with end forms strongly resembling *A. elegans* and *A. decipiens*, but with the most common intermediate *Amoeboceras uralense* MESEZHNIKOV (*see* BIRKENMAJER & WIERZBOWSKI 1991).

The ammonites characteristic of the Zone show the innermost whorls nearly smooth with very early appearing either three rows of nodes as in *A. decipiens*, or with ventrolateral nodes and clavi, but sometimes also with middle nodes accentuated, as in *A. elegans* (*cf.* BIRKELUND & CALLOMON 1985; WIERZBOWSKI 1989).

The two species discussed show at least a marked overlapping, if not total covering, of their stratigraphic ranges (WIERZBOWSKI 1989, WIERZBOWSKI & ÅRHUS 1990), which precludes the differentiation of smaller biostratigraphic units of wider importance within the Elegans Zone. However, when the detailed stratigraphic ranges of these two species are recognized in a particular section, it may be shown that they markedly differ each other. It could be related, partly at least with the local environmental factors such as character of the bottom. This may be inferred from the occurrence of a monospecific assemblage of *A. decipiens* in a close proximity of the lumachelle bed (*cf.* FÜRSICH 1984, pp. 31-33), as well as of that of *A elegans* (but with a few *A. decipiens*) in the dark micaceous shales (*see* Text-figs 3 and 5).

CORRELATION: The Elegans Zone has not been distinguished so far. It includes the horizons no. *21* with *A decipiens* and no. *22* with *A. elegans* from East Greenland distinguished by BIRKELUND & CALLOMON (1985). The Zone includes also the horizon no. *4* with *A. elegans* and *A. decipiens* from Spitsbergen (WIERZBOWSKI 1989).

The Elegans Zone corresponds, partly at least, to the Eudoxus Zone of the Subboreal ammonite subdivision (*cf.* BIRKELUND & CALLOMON 1985, WIERZBOWSKI 1989).

DISTRIBUTION in the cores: The Elegans Zone is recognized in core *7227/08-U-03* between 38.00 m and 34.15 m, and in core *7231/01-U-01* between 82.81 m and 72.52 m (*see* Text-figs 3 and 5).

SYSTEMATIC ACCOUNT
(written by A. WIERZBOWSKI)

Amoeboceras (Euprionoceras) norvegicum WIERZBOWSKI, sp. n.
(Pl. 2, Figs 4-5)

TYPE MATERIAL: Holotype figured in Pl. 2, Fig. 4, and one paratype in Pl. 2, Fig. 5.

TYPE AREA AND LOCALITY: Southern Barents Sea, Nordkapp Basin; holotype (core *7230/05-U-02* at 34.60-34.56 m), and paratype (core *7231/01-U-01* at 84.80 m).

TYPE HORIZON: Kimmeridgian, Kochi Zone (lower part), Norvegicum horizon.

ETYMOLOGY: Named after the country of first reported occurrence.

DIMENSIONS: Holotype: D (diameter) max. about 55 m; at D-48 mm, Wh (whorl height in mm and in percentage of D) is 20 mm and 42%, Ud (umbilical diameter in mm and in percentage of D) is 16 mm and 33%.

DIAGNOSIS: Inner whorls with vestigial striations, on outer whorl appear stronger, single and biplicate ribs, and weak ventrolateral tubercles.

DESCRIPTION: The ammonites are small to medium-sized but, as the sutures are not preserved and the specimens are incomplete, it is difficult to state whether they are fully grown. The holotype shows, however, a fragment of the aperture with rostrum which suggests that it is fully grown.

The inner whorls are covered with flexuous vestigial striations up to diameter of 15 mm (paratype), and 30 mm (holotype). Then the ribs become stronger and much more distant, single and biplicate with point of division lying somewhat above the middle of the whorl height. The ribs are curved at the umbilicus, weakly prorsiradiate on the whorl side, except the ventrolateral part where they strongly bend forward. In the holotype, on the last part of the outer whorl there occur weak elongated tubercles developed either on the ribs or between them in the ventrolateral area. The keel is crenulated, and the ratio of crenulae to primary ribs on the last whorl of the holotype is about 3:1.

DISCUSSION: The specimens are the most similar to *Amoeboceras (Euprionoceras) kochi* SPATH (*see* SPATH 1935, and BIRKELUND & CALLOMON 1985), but differ in their very weakly ornamented inner whorls. These two species are closely related and thus belonging to the same subgenus *Euprionoceras* SPATH, 1935.

Acknowledgements

The cores discussed were obtained during shallow drilling projects performed by IKU in the Barents Sea in 1987. Geir ELVEBAKK provided the sedimentological descriptions of the core logs (*see* Text-fig. 2) which have been prepared by Ingrid BRANDSLET, IKU. The photographic work was performed by S. KOLANOWSKI, University of Warsaw.

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