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Ammonite and dinoflagellate cyst succession of an Upper Oxfordian – Kimmeridgian black shale core from the Nordkapp Basin, southern Barents Sea

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with 6 figures

Abstract. The drilling core 7227/8–U–3 located at 72°19'05.655"N 27°33'37.635"E in the southern Barents Sea (Figs. 1 and 2) has revealed a fairly complete succession of species of the ammonite genus *Amoeboceras* which enables the identification of the standard Boreal ammonite zones, and some informal ammonite horizons of the Upper Oxfordian and Kimmeridgian, well established in East Greenland. The dinoflagellate cyst assemblages in the same core are dominated by seven long-ranging species. Less common are *Scriniodinium crystallinum* and *Scriniodinium galeritum* which occur relatively consistently up into the *A. regulare* Zone, where they seem to disappear. The last representatives of *Rhynchodiniopsis cladophora* have been found in the *A. decipiens* and *A. elegans* horizon corresponding to the *A. eudoxus* Zone, from where this taxon via transitional forms may evolve into the *Cribroperidinium sarjeantii* group.

Zusammenfassung. Kern 7227/8–U–3 (72°19'05.655"N, 27°33'37.635"E) aus der südlichen Barentssee (Abb. 1 und 2) enthält eine ziemlich komplette Artenfolge des Ammoniten-Genus *Amoeboceras*. Dies ermöglicht die Identifizierung der üblichen borealen Ammonitenzonen und einiger informeller Ammonitenhorizonte des Oberen Oxfordiums und Kimmeridgiums, die in Ostgrönland gut etabliert sind. In den Dinoflagellatenzysten-Vergesellschaftungen dieses Kerns herrschen sieben Arten vor, deren geologisches Auftreten sich über längere Zeiträume erstreckte. Weniger häufig sind *Scriniodinium crystallinum* und *Scriniodinium galeritum*, welche relativ zusammenhängend bis hinauf in die *A. regulare*-Zone vorkommen, dort jedoch anscheinend verschwinden. Die letzten Vertreter von *Rhynchodiniopsis cladophora* wurden in dem Horizont *A. decipiens* und *A. elegans* gefunden, die der *A. eudoxus*-Zone entsprechen. Von dort aus hat sich dieses Taxon möglicherweise über intermediäre Formen zur *Cribroperidinium sarjeantii*-Gruppe weiterentwickelt.

Introduction

The only ammonite faunas of the Upper Oxfordian and Kimmeridgian known so far in the Barents Sea area are those from Spitsbergen and neighbouring islands (see e.g. FREBOLD 1930, SOKOLOV & BODYLEVSKY 1931; see also YERSHOVA 1983 and earlier papers cited therein, WIERZBOWSKI 1988), and from Franz Josef Land (SHULGINA 1960, MESEZHNIKOV & SHULGINA 1982), but their succession, especially in some parts, has not been recognized in detail. The evidence from the borehole may thus be of general interest.

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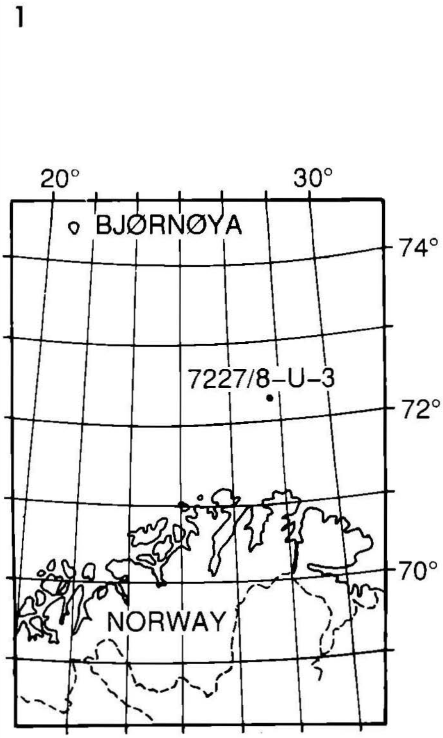

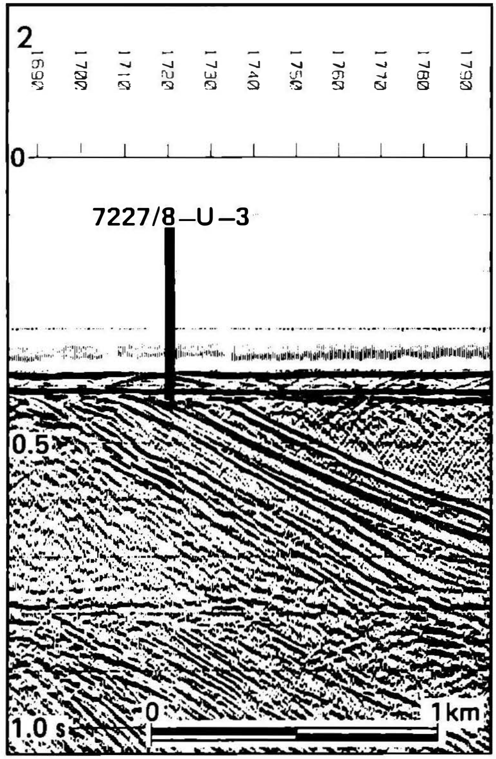

Fig. 1. Sketch map showing the location of the examined core 7227/8–U–3.

Fig. 2. Section of NW-SE running digital seismic line C86–10 with location of hole indicated.

The abundant ammonites found in the core belong almost exclusively to the family Cardioceratidae, more precisely to the genus *Amoeboceras,* whereas perisphinctids are very uncommon. Although always flattened, and sometimes fragmentary, many of the specimens are identifiable to specific level. The figured specimens are housed in Paleontologisk Museum, Oslo (PMO).

Core description

The core consists of 21.5 m of very dark grey micaceous shale from between 53.05 (TD) and 31.55 m below sea floor (Figure 3). Two thin carbonate beds/concretions are present around 49.0 and 45.85 m in the Upper Oxfordian *A. serratum* and *A. regulare* Zones. Between 39.0 and 35.75 m in the Kimmeridgian numerous up to 2 mm thick graded siltstone to very fine-grained calcite cemented sandstone laminae occur. In this interval also some up to 5 mm thick laminae rich in belemnite hooks are observed.

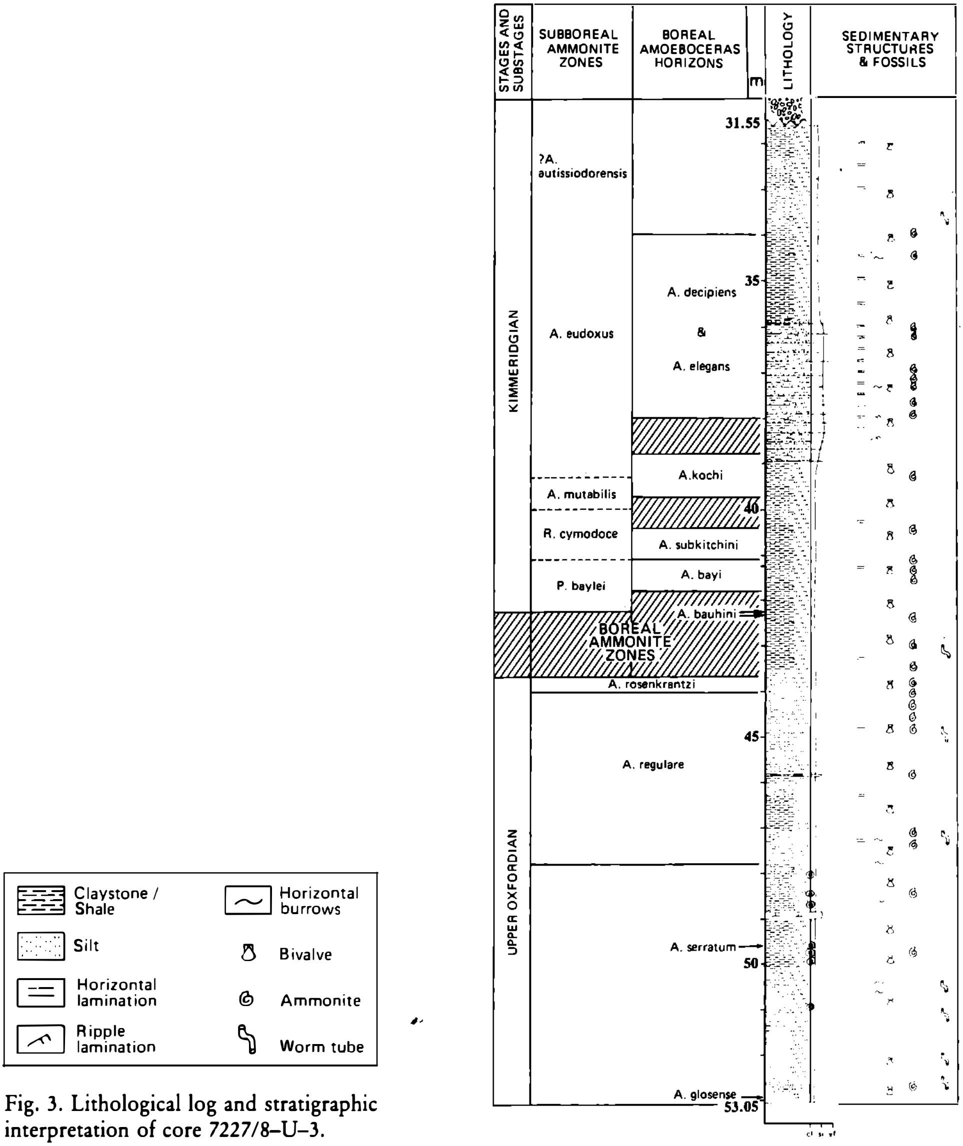

Fig. 3. Lithological log and stratigraphic interpretation of core 7227/8–U–3.

Some bioturbation and the presence of a benthic fauna (bivalves, worm tubes) suggest at least some episodes with oxygenated bottom water during deposition, but the penetrated section is very rich in organic matter (up to 19% TOC), especially in the uppermost Oxfordian to lowermost Kimmeridgian interval between 49 and 40 m.

The palynologically examined samples are generally richer in unstructured organic material than in woody material except at 51.86 and 36.85 m. At 49.90, 48.80, 43.77 and 37.65 m the amounts are about equal. Blade-shaped opaque wood fragments are particularly common at 50.90 m, i.e. about 1 m below the level where the marked increase in the TOC content starts.

The γ-radiation is markedly higher in the upper part of the Upper Oxfordian and in the Kimmeridgian than in the lower part of the Oxfordian. Exceptionally high radiation comes from two Kimmeridgian samples (39.4 and particularly 35.8 m). Above 39 m the TOC curve does not correlate with the γ-activity to the same extent as below.

Ammonites (see Figs. 4, 5 and 6)

The lowermost ammonite in the core occurs at 52.95 m. It is a poorly preserved, nevertheless typical *Amoeboceras* showing strongly forward projected secondary ribs. This feature indicates its close relation to the *Amoeboceras glosense* fauna being indicative of the *A. glosense* Zone, and corresponding to the lowermost part of the Boreal Upper Oxfordian (SYKES & CALLOMON 1979).

The next ammonite fauna is also poorly represented. The only fragmentary ammonite from 49.63 m is tentatively referred to the species *Amoeboceras serratum* (SOWERBY), having a strong, rectiradiate ribbing on the inner whorl, and a marked fading of ribbing on the outer whorl except the periumbilical part, where the rib swellings are developed (Fig. 5 A). This determination possibly indicates the presence of the *A. serratum* Zone.

The presence of the *A. regulare* Zone is much more firm. The fauna is composed of two specimens of *Amoeboceras regulare* SPATH from 47.20 m and 44.25 m (Figs. 5 B, D), and one specimen of *Amoeboceras* cf. *freboldi* SPATH from 47.80 m (Fig. 5 C), to the virtual absence of the species *A. serratum*. The thickness of the *A. regulare* Zone is at least 3.55 m.

The two small ammonites from 44.05 m and 43.80 with strongly rursiradiate secondary ribs are possibly microconchs which could be ascribed to the species *Amoeboceras rosenkrantzi* SPATH and/or *Amoeboceras marstonense* SPATH (Figs. 5 E, F). Also poorly preserved fragments of big whorls from 44.05 m and 43.95 m seem to be similar to an outer whorl of *A. rosenkrantzi* macroconch (see SYKES & CALLOMON 1979, pl. 120, fig. 6). Thus, the ammonite fauna found between 44.05 m and 43.80 m may be treated as indicative of the *A. rosenkrantzi* Zone, which is the highest ammonite zone of the Boreal Oxfordian. It is also noteworthy that the discussed small specimens attributed to the Boreal species *A. rosenkrantzi* and/or *A. marstonense* are very similar to the representatives of the microconch species *Amoeboceras ovale* (QUENSTEDT) known from the lower part of the *E. bimammatum* Zone of the Submediterranean Europe, which confirms the recently presented stratigraphical correlations of MATYJA & WIERZBOWSKI (1988).

The ammonites from 42.30 m and 42.25 m (Fig. 5 G) are poorly preserved, but probably related to the species *Amoeboceras bauhini* (OPPEL). This species is known to occur in the Boreal/Subboreal areas in the lowermost Kimmeridgian, and the *A. bauhini* Subzone distinguished there by SYKES & CALLOMON (1979) is entirely Kimmeridgian in age, corresponding to a lower part of the *P. baylei* Zone in the Subboreal zonal subdivision (Fig. 4: see BIRKELUND & CALLOMON 1985; BIRKELUND in ÅRHUS et al. 1989). It should be remembered that the findings of this species are useful not only for the recognition of the base of the Kimmeridgian in the Boreal/Subboreal Provinces, but they also enable the correlation between the Boreal/Subboreal and the Submediterranean zonal schemes (BIRKELUND & CALLOMON 1985;

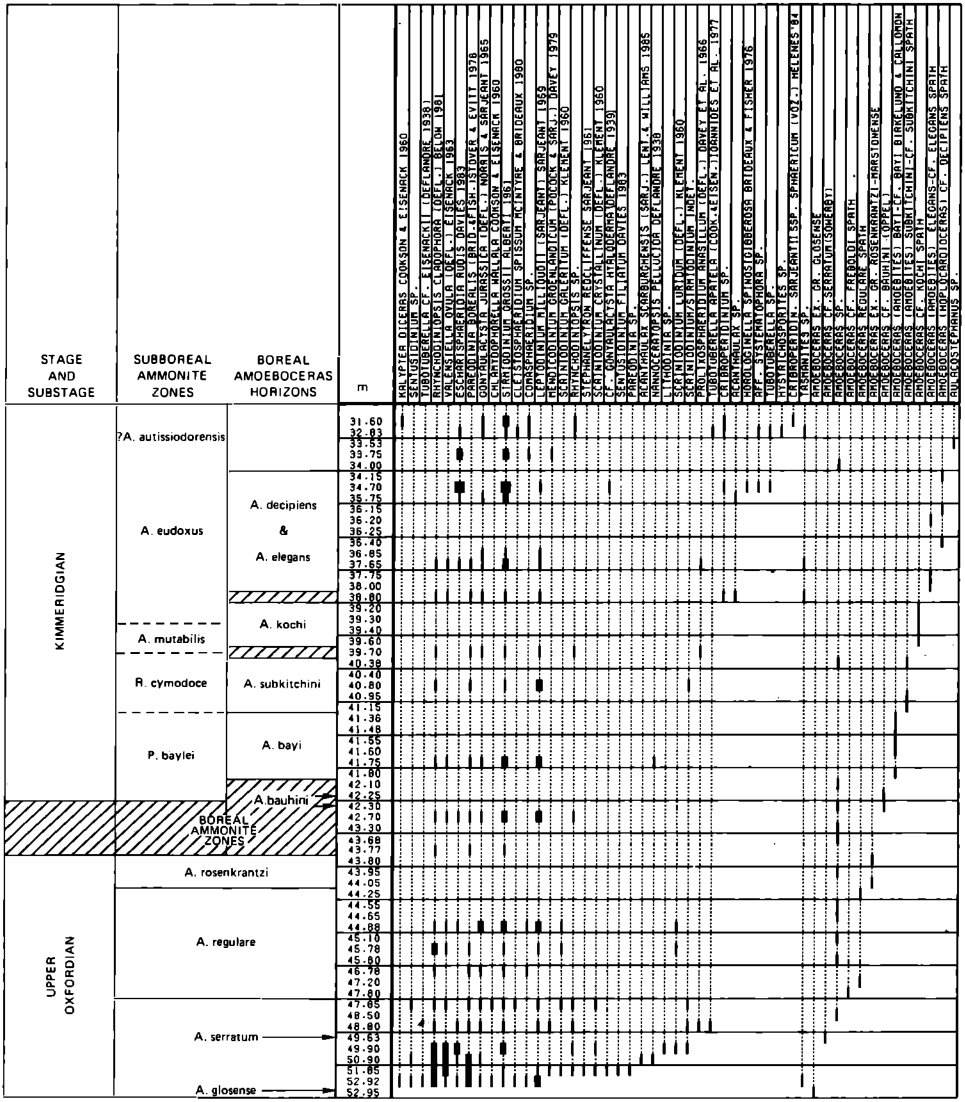

Fig. 4. Distribution of ammonites and palynomorphs in the core and their stratigraphic interpretation.

MATYJA & WIERZBOWSKI 1988). The presence of *A. bauhini* in the core studied indicates that the base of the Kimmeridgian runs possibly somewhat below 42.30 m. This also indicates that the thickness of the Upper Oxfordian is about 10 m.

The younger ammonite faunas of the Kimmeridgian stated in the core can be assigned to several successive *Amoeboceras* horizons and compared with those distinguished recently in East Greenland (BIRKELUND & CALLOMON 1985). It is a step towards the working out of the

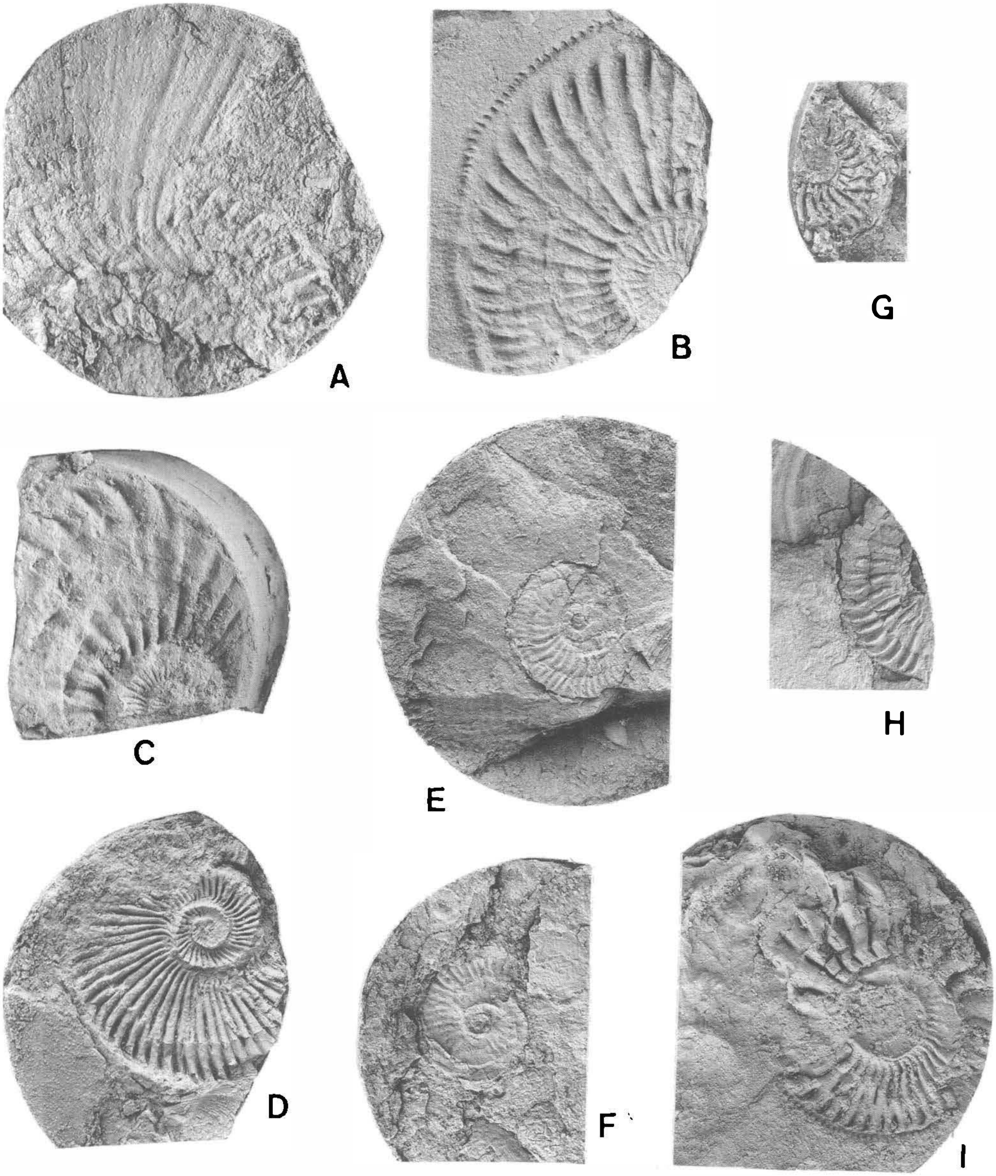

Fig. 5. Oxfordian and Kimmeridgian ammonites from the core;
A. *Amoeboceras* cf. *serratum* (Sowerby), 49.63 m. PMO 116.532
B. *Amoeboceras regulare* Spath, 47.20 m. PMO 116.533
C. *Amoeboceras* cf. *freboldi* Spath, 47.80 m. PMO 116.534.
D. *Amoeboceras regulare* Spath, 44.25 m. PMO 116.535
E–F. *Amoeboceras* ex gr. *rosenkrantzi* Spath-*marstonense* Spath, 43.80 m (PMO 116.536) and 44.05 m (PMO 116.537)
G. *Amoeboceras* cf. *bauhini* (Oppel), 42.30 m. PMO 116.538
H. *Amoeboceeras* cf. *bayi* Birkelund & Callomon, 41.55 m. PMO 116.539
I. *Amoeboceras bayi* Birkelund & Callomon, 41.48 m. PMO 116.540
All photos of natural size.

ammonite zonal scheme for the Kimmeridgian of the Boreal Province, but at present the ammonite horizons have to be placed, more or less precisely, within the framework of the perisphinctid Subboreal zonation (BIRKELUND & CALLOMON 1985; Fig. 4).

The ammonites found at 41.80 m and 41.48 m, as well as possibly that at 41.60 m, are very similar to the macroconchs of *Amoeboceras (Amoebites) bayi* BIRKELUND & CALLOMON (Figs. 5 I, 6 A), whereas two small and incomplete specimens showing a moderate dense, single and biplicate ribbing from 41.55 m and 41.36 m, may possibly be compared with microconchs of the same species (Figs. 5 H, 6 B; cf. also BIRKELUND & CALLOMON 1985, pl. 4, figs. 4, 5). The species *A. bayi* occupies morphologically an intermediate position between the older species *A. bauhini* (OPPEL) and the younger *A. subkitchini* SPATH. It is also treated as indicative of the *Amoeboceras bayi – Pictonia* aff. *normandiana* horizon from East Greenland, being an equivalent to an upper part of the *P. baylei* Zone from the Subboreal zonal scheme (BIRKELUND & CALLOMON 1985; see also Fig. 4). All these data indicate that the *A. bayi* horizon can be distinguished in the core studied, representing at least the interval 41.80 to 41.36 m.

The younger beds have yielded three fragmentary ammonites (at 41.15 m, 40.95 m and 40.38 m) which due to their bigger sizes, and the development of ventrolateral nodes may be attributed to *Amoeboceras (Amoebites) subkitchini* SPATH (Figs. 6 C, D). This ammonite fauna is possibly of a wide stratigraphical value. Of the two horizons with *A. subkitchini* which have been distinguished recently in East Greenland, the older one (*Rasenia inconstans-Amoeboceras subkitchini* horizon) corresponds to the lowermost part of the Subboreal *R. cymodoce* Zone, whereas the younger one (*Rasenia cymodoce-Amoeboceras* aff. *subkitchini* horizon) corresponds to the middle part of the same Zone (BIRKELUND & CALLOMON 1985, fig. 5). In Spitsbergen the stratigraphical ranges of the species *A. subkitchini* and *R. cymodoce* slightly overlap, but generally *A. subkitchini* occurs below *R. cymodoce,* representing the oldest Kimmeridgian ammonite fauna known so far from this area (WIERZBOWSKI 1988). Hence, taking into account the presence in the core studied of the *A. bayi* horizon below, it may be assumed that the *A. subkitchini* horizon, as recognized here, can correspond to some lower and/or middle parts of the *R. cymodoce* Zone (Fig. 4).

A still younger ammonite fauna in the core studied has been discovered between 39.60 m and 39.20 m. The ammonites are 30–40 mm in diameter, and at least some of them appear to be microconchs. The ribbing is composed of single and biplicate ribs, which are straight in the dorsolateral part of whorls, and strongly bent forward in the ventrolateral parts; the point of rib division is situated somewhat above the mid-height of whorl (Figs. 6 E, F). These ammonites resemble strongly the alleged microconchs of *Amoeboceras (Euprionoceras) kochi* SPATH (see BIRKELUND & CALLOMON 1985, pl. 8, figs. 5–7; cf. also SPATH 1935, pl. 3 figure 1), and are here tentatively referred to this species. Their occurrence indicates eventually the presence of the *A. kochi* horizon. This horizon has so far been distinguished only in East Greenland between the faunas indicative of the *A. mutabilis* and the *A. eudoxus* Zones of the Subboreal zonal scheme (BIRKELUND & CALLOMON 1985).

The ammonite fauna found in the core between 38.00 m and 34.15 m includes *Amoeboceras (Amoebites) elegans* SPATH – *A.* cf. *elegans* SPATH (Figs. 6 G, H) which occurs rather in the lower part of the interval (at 38.00 m, 37.7[illegible] and also 36.20 m), and *Amoeboceras (Hoplocardioceras)* cf. *decipiens* SPATH (Fig. 6 I) – occurring in the upper part of the interval (at 36.40 m and 34.15 m). The two recognized species occur together only in a narrow zone in the core studied (Fig. 4). It is noteworthy that at least some overlapping of the stratigraphical ranges of these two species has been stated in Franz Josef Land (Shulgina 1960, cf. Birkelund & Callomon 1985, p. 24–26) and recently also in Spitsbergen (Wierzbowski 1988). On the other hand the stratigraphical ranges of the species in question are clearly distinct in East Greenland, where the two ammonite faunas and corresponding ammonite horizons were distinguished – the lower with *Amoeboceras decipiens* Spath and *Aulacostephanus eudoxus* (d'Orbigny), and the upper with *Amoeboceras elegans* Spath (Birkelund & Callomon 1985). All these differences in stratigraphical ranges of the two species may be only of local significance, and at this stage it may be best to distinguish only one ammonite fauna and corresponding ammonite horizon, viz. the *A. decipiens* and *A. elegans* horizon.

Ammonites of the genus *Amoeboceras* were discovered in the core at 34.00 m. They are small, about 15 mm in diameter, somewhat *Nannocardioceras*-like, but poorly preserved and do not allow closer identification.

The last ammonite found at 33.53 m is a poorly preserved, nevertheless typical representative of the genus *Aulacostephanus* sensu stricto, with strong, non fasciculate secondaries (2.5 per primary at 50 mm diameter), what indicates the *A. eudoxus* Zone, or even more likely the *A. autissiodorensis* Zone of the Upper Kimmeridgian (Birkelund et al. 1983, Birkelund & Callomon 1985). The thickness of the Kimmeridgian in the core studied is at least about 11 metres.

Bivalves

Crushed flat and fragmentary bivalves occur throughout the core, but are most numerous in the upper part. A few *Inoceramus* fragments are present at 49 m, but most of the material belongs to the genus *Buchia*. Only the representatives at 44.06 and 43.40 m (and possibly 44.68 m) are determinable and can be assigned to *Buchia tenuistriata* (Lahusen 1888) according to Kelly (pers. comm. 1987). This species is widely distributed in the Kimmeridgian in the Boreal Realm (Zakharov 1981). In the Lower Kimmeridgian it is subordinate to *Buchia concentrica* whereas it is the dominant species in the Upper Kimmeridgian. Its occurrence in 7227/8–U–3 together with *Amoeboceras* ex gr. *rosenkrantzi – marstonense* is reason to extend the range of *B. tenuistriata* down into the uppermost Oxfordian *A. rosenkrantzi* Zone.

Dinoflagellate cysts (see Fig. 4)

Most of the recorded dinocyst species range throughout the interval and are not very age significant. *Rhynchodiniopsis cladophora, Valensiella ovula* and *Pareodinia borealis* are the most common taxa in the lower part (Fig. 4). *Kalyptea diceras* which is found only in the lowermost sample at 52.92 m points to an age no younger than somewhere in the upper part of the Oxfordian. Piasecki (1980) did not record it above the basal part of *A. glosense* Zone in East Greenland.

Stephanelytron redcliffense at 51.86 m according to Sarjeant (1979) ranges into the lowermost Kimmeridgian *P. baylei* Zone. Woollam & Riding (1983) indicated rare or uncertain occurrences of the genus as high as in the *A. mutabilis* Zone. This and its presence at 51.86 m conflicts the range given by Raynaud (1978) who did not record representatives of the genus

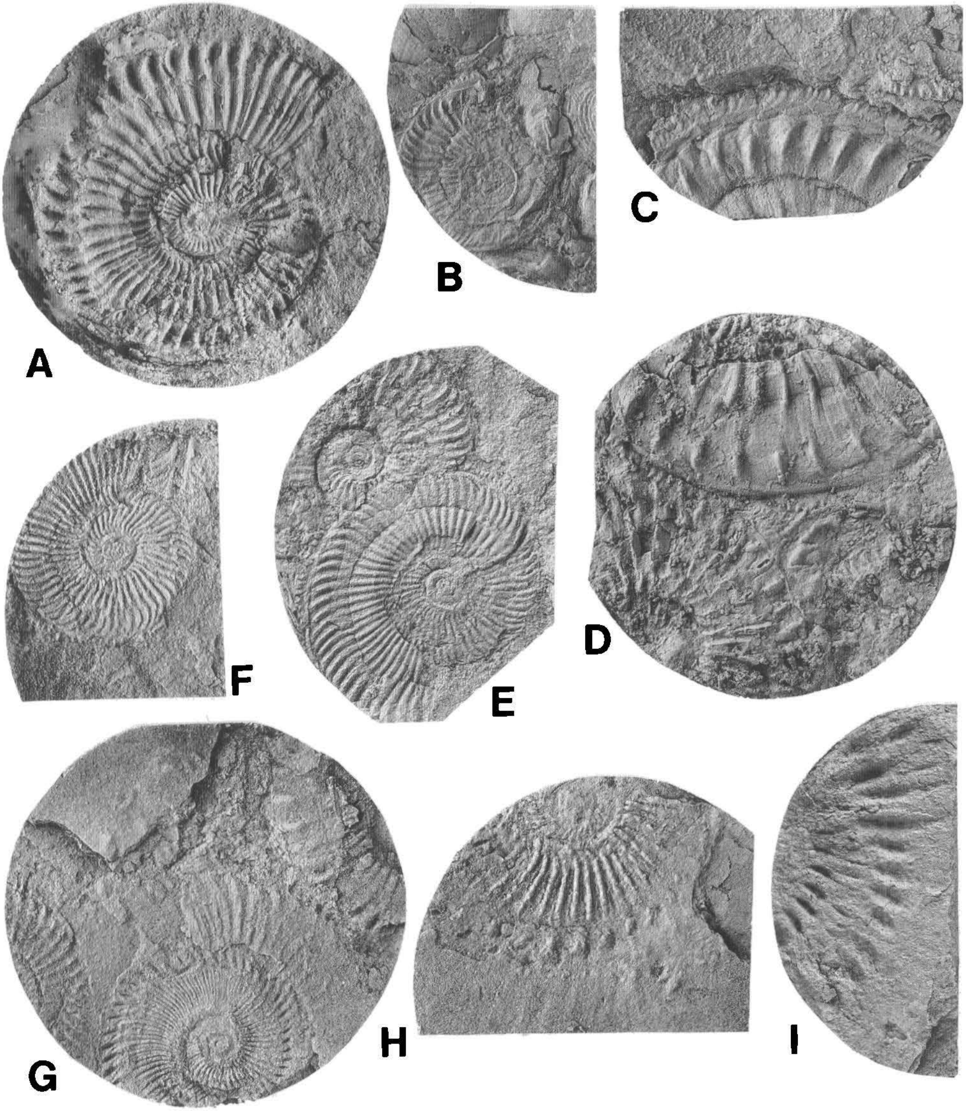

Fig. 6. Kimmeridgian ammonites from the core;
A. *Amoeboceras bayi* Birkelund & Callomon, 41.80 m. PMO 116.541
B. *Amoeboceras* cf. *bayi* Birkelund & Callomon, 41.36 m.PMO 116.542
C. *Amoeboceras* cf. *subkitchini* Spath, 40.38 m. PMO 116.543
D. *Amoeboceras subkitchini* Spath, 41.15 m. PMO 116.544
E–F. *Amoeboceras* cf. *kochi* Spath, 39.30 m (PMO 116.545) and 39.20 m (PMO 116.546)
G–H. *Amoeboceras elegans* Spath, 38.00 m (PMO 116.547) and 36.20 m (PMO 116.546)
I. *Amoeboceras* cf. *decipiens* Spath, 34.15 m. PMO 116.549
All photos of natural size.

above the Lower Oxfordian in the North Sea. These conflicting ranges probably reflect that *Stephanelytron* is uncommon in the upper part of its range. A single specimen of *Acanthaulax scarburghensis* at 50.90 m is somewhat problematic. RAYNAUD (1978) recorded this species no higher than the Lower Oxfordian whereas PIASECKI (1980) reported it slightly higher from the lowermost part of the Middle Oxfordian *C. densiplicatum* Zone, in good agreement with WOOLLAM & RIDING (1983). The occurrence at 50.90 m may most easily be explained by reworking.

Scriniodinium crystallinum is found consistently in samples between 51.86 m and 45.78 m and *Scriniodinium galeritum* between 51.86 and 44.88 m, i.e. they range up into the *A. regulare* Zone. WOOLLAM & RIDING (1983) and others reported both species to range into the lowermost Kimmeridgian *P. baylei* Zone (*S. galeritum* possibly into the *A. eudoxus* Zone).

Rhynchodiniopsis cladophora occurs in high numbers in the four samples from the interval 52.92 – 49.90 m and also at 45.78 m which is the youngest examined sample with common representatives of this species.

The presence of *Chlamydophorella wallala* in three samples between 52.92 and 47.85 m may be of some stratigraphic value, but its range is not well known.

Gonyaulacysta jurassica is recorded in high numbers at 44.88 m in the upper part of the *A. regulare* Zone. Most of the specimens are short, fat forms with large antapical openings. The species is far more common in this sample than in any other examined sample from the core. In the sample below and above, *G. jurassica* is not recorded at all and the sample above is very poor also in other dinocysts. These differences in abundance and recovery are probably due to environmental changes.

The presence of *Nannoceratopsis pellucida* at 41.75 m indicates an age no younger than the earliest Kimmeridgian *P. baylei* Zone, in good agreement with the ammonite data. Also higher in the interval the assemblages have most taxa in common with the Upper Oxfordian unit below. *Rhynchodiniopsis cladophora* is recorded consistently up to 37.65 m, where it seems to disappear. This probable extinction somewhere in the lower part of the *A. eudoxus* Zone is two ammonite zones lower than claimed by WOOLLAM & RIDING (1983) who also reported rare or uncertain occurrences of *R. cladophora* in the Volgian equivalent *P. scitulus – V. fittoni* Zones. NØHR-HANSEN (1986) found scattered specimens of *R. cladophora* in the *R. cymodoce* and nearly to the top of the *A. mutabilis* Zones in Westbury, England with no records in the *A. eudoxus* Zone. The taxon recorded as *Acanthaulax* sp. at 38.80 and 35.75 m, i.e. in the beds approximately corresponding to the *A. eudoxus* Zone also seems to have its first occurrence in the *A. eudoxus* Zone in Spitsbergen (own unpublished observation). This species may as well be referred to the genus *Trichodinium*, and PIASECKI (1980) reported it as *Trichodinium* aff. *ciliatum* from the Early Volgian *P. scitulus* and *P. wheatleyensis* Zones in East Greenland.

One sample at 34.70 m from the upper part of the *A. decipiens* and *A. elegans* horizon corresponding to the *A. eudoxus* Zone contains abundant *Escharisphaeridia rudis* and *Sirmiodinium grossii.* Rare poorly preserved hystrichospheres, possibly a species of *Systematophora* are present at 34.70 m and 32.83 m. The latter sample interestingly also contains Lower to Middle Devonian *Hystrichosporites* sp.

Remarks on Late Oxfordian – Kimmeridgian palaeobiogeography and biostratigraphy in the Boreal Realm

The low diversity *Pareodinia borealis* dinoflagellate cyst assemblage described from Canada by Brideaux & Fisher (1976) has also been recovered from middle Oxfordian to Berriasian strata in North Greenland (Håkansson et al. 1981) and Svalbard (Bjærke 1980). Assemblages from East Greenland (Piasecki 1980) are intermediate between those found in the restricted Boreal areas and those of Subboreal sections in Britain and northern France studied by e.g. Gitmez (1970), Gitmez & Sarjeant (1972), Nøhr-Hansen (1986), Thomas & Cox (1988), and Riding & Thomas (1988).

Due to low diversity and partly also bad preservation, a detailed dinoflagellate cyst stratigraphy is not established in the Boreal Province. Most of the recorded taxa are long-ranging species known also from Subboreal areas. The few endemic Boreal elements (e.g. *Pareodinia borealis, Pareodinia capillosa, Horologinella spinosigibberosa*) may be more useful, but *P. borealis* is also long-ranging and *H. spinosigibberosa* is scarce in many areas. Davies & Poulton (1986) reported *P. capillosa* to range from Late Oxfordian to Late Tithonian (Oppel-Zones H-K of Davies 1983), but it is confined to the youngest part of Late Kimmeridgian sensu gallico in East Greenland (Piasecki 1980). *H. spinosigibberosa* was only recovered from the Upper Kimmeridgian and the Upper Kimmeridgian – Upper Tithonian Oppel-zones J and K of Davies (1983) by Davies (1986) in British Columbia and has also not been found below the upper part of the Upper Kimmeridgian sensu gallico in core 7227/8–U–3 and in the Janusfjellet section, Spitsbergen.

One of the most striking differences between Boreal and Subboreal dinoflagellate cyst assemblages are the much rarer skolochorate forms in Boreal areas. Skolochorate forms such as representatives of the *Cleistosphaeridium polytrichum* and the *Systematophora areolata* groups were e.g. reported by Riding (1987) to be common in the *A. regulare* and *A. rosenkrantzi* Zones of an English borehole and several such forms were also reported by Nøhr-Hansen (1986) from southern England. *Systematophora orbifera* is common in Oxfordian/Kimmeridgian boundary beds on Isle of Skye, Scotland, whereas *Perisseiasphaeridium pannosum* and *Oligosphaeridium pulcherrimum* are skolochorate elements in the uppermost part of the Kimmeridgian in East Greenland and offshore mid Norway.

The Late Oxfordian floral privincialism corresponds to provincialism observed very clearly in Middle and Late Oxfordian ammonite faunas. Three separate ammonite zonal schemes have been worked out for the European Middle and Upper Oxfordian, and the faunas from 7227/8–U–3 belong to a restricted Boreal Province as evidenced by an overall dominance of Cardioceratidae (genus *Amoeboceras*).

Also in the Kimmeridgian (sensu gallico) the ammonite faunas of the Barents Sea area seem to be strongly dominated by Cardioceratidae (genus *Amoeboceras*) up to the evolutionary decline of this family. In this aspect the studied area differs somewhat from East Greenland where representatives of the family Aulacostephanidae are found together with Cardioceratidae, but is very similar to Spitsbergen and possibly (poorly documented) to North Greenland.

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