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The Jurassic of Milne Land, central East Greenland

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In 1977 field work on the Jurassic of Milne Land (fig. 33) by the authors and C. Heinberg, S. Piasecki and L. Stemmerik was mainly concerned with detailed recording of sections, biostratigraphical and palaeoecological investigations.

Stratigraphy

On the basis of the new detailed work combined with work carried out by J. H. Callomon in 1957–1958 as part of Lauge Koch's expeditions, formal lithological units can now be established for the Jurassic deposits of Milne Land (fig. 34). Since these units will be named and described in detail elsewhere this account is only a brief summary. Established lithological units have been retained where possible, although some have had their boundaries revised.

In what follows, formations and members are described in ascending order. Further

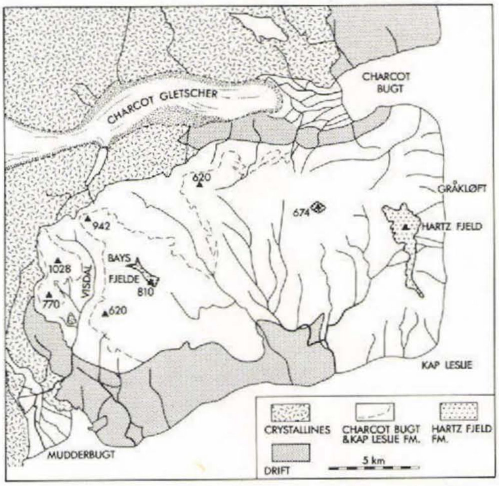

Fig. 33. Map of south-eastern Milne Land showing Jurassic outcrops.

details on the lithology have been given by Aldinger (1935), Håkansson *et al.* (1971) and Sykes & Brand (1976).

1. Charcot Bugt Formation (Aldinger, 1935)

The lithology is dominated by coarse to very coarse arkoses and sandstones with layers of gravelstone. Horizontal bedding and large- and giant-scale cross-bedding are common.

The formation can be subdivided into two new members:

1a. This may be further subdivided roughly into three units which grade into each other.

The lower unit is extremely variable and directly overlies the crystalline basement. In some places this unit commences with conglomerates up to 25 m thick; in other areas conglomerates are subordinate, while intraformational breccias and cross-bedded, deeply channelled sandstones are common. In higher parts bioturbated medium-grained *Curvolithos* sandstones are common. Near hill-tops in the underlying basement very fossiliferous layers (composed mainly of corals and bivalves) may be intercalated in abutting medium- to coarse-grained sandstones and gravelstones.

The middle unit is dominated by horizontally laminated clean sandstone and gravelstone. Coarsening-upwards sequences 10–25 m thick can be recognised, grain-sizes grading from silt to gravel.

The upper unit is dominated by giant-scale cross-bedded sets up to 30 m thick of very coarse sandstone and gravelstone. Large-scale cross-bedding may occur in separate trough cross-bedded units or as low-angle intrasets in the giant-scale units. In certain layers vertical U-shaped burrows and belemnites occur.

The thickness of the member varies between *c.* 100 and 200 m.

1b. This member consists of large-scale trough cross-bedded, coarse to very coarse-grained sandstone and gravelstone. The lower boundary is sharp.

The thickness is up to 6 m and the member is only found in the Mudderbugt area, wedging out northwards.

The Charcot Bugt Formation was previously referred to the Middle Oxfordian on the basis of the few finds of perisphinctid ammonites (Callomon, 1961). However, new finds in 1977 show that the formation ranges from at least the Upper Bathonian to the Middle Oxfordian. Thus, ammonites from the lowermost part can be referred to the Cranocephaloides Zone on the basis of *Arcticoceras* aff. *variabile* Spath and *Kepplerites tychonis* Ravn. Hermatypic corals from the same layers, referred to a new species *Enallocoenia callomoni* by Beauvais (1977), are thus of Upper Bathonian age and not Middle Oxfordian as thought previously.

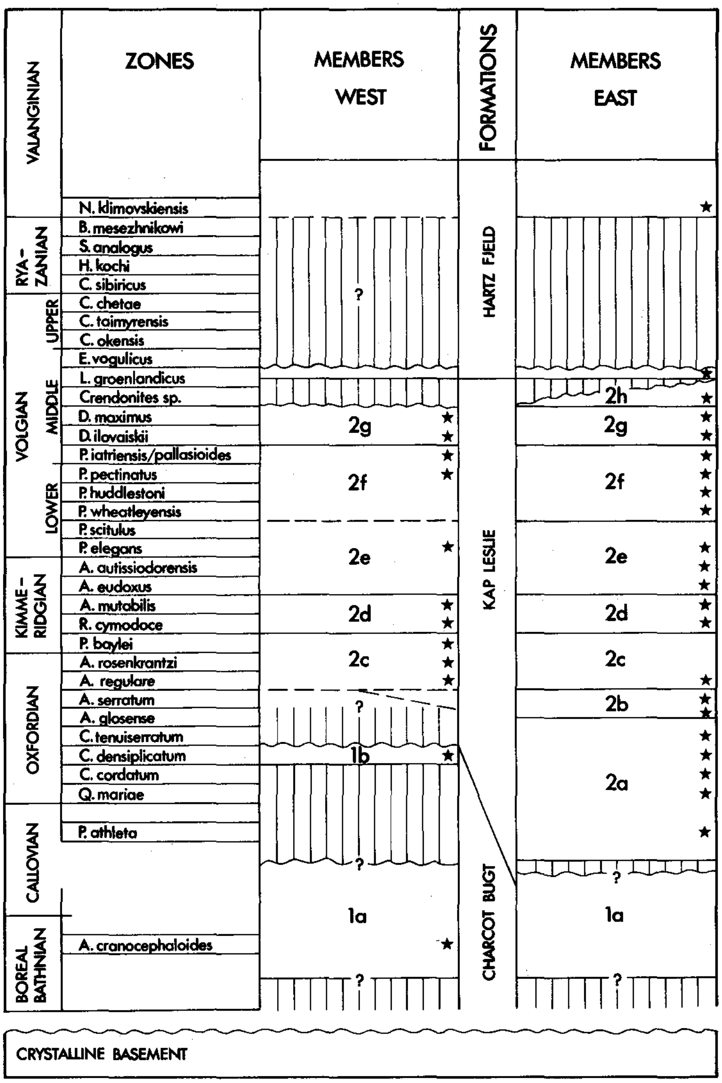

Fig. 34. Age and lithostratigraphical divisions of the Jurassic of Milne Land. Asterisks indicate fossil evidence of zones.

The earlier finds of perisphinctids can now be seen to have been in the upper member (1b), which in addition is characterised by fairly rich occurrences locally of bivalves, belemnites and trace fossils (*Planolites*?). This development of Middle Oxfordian in sandy facies may thus be confined to small erosional remnants in south-western Milne Land.

2. Kap Leslie Formation (Rosenkrantz, 1929, amended)

The name Kap Leslie Sandstone was first used by Bay (1896). The first systematic description was by Rosenkrantz (1929) who placed all the sediments seen by him into two formations: the Kap Leslie Formation, 450 m of shales and sandstones with horizons of marine fossils indicating a Volgian – Portlandian age; and the Hartz Fjeld Formation above, 180 m of sandstone and shales devoid of marine fossils and tentatively ascribed to the Neocomian. Rosenkrantz's units were largely ignored by Aldinger (1935) and Spath (1935, 1936) who introduced alternative informal names for various lesser units within the formations and drew boundaries at different levels, so that e.g. part of Rosenkrantz's Kap Leslie Formation was included in Aldinger's Hartz Fjeld Sandstone. The Kap Leslie Formation is now redefined to include all the micaceous silty shales with subordinate sandstones overlying the arenaceous Charcot Bugt Formation and themselves overlain by the equally arenaceous Hartz Fjeld Formation.

The Kap Leslie Formation can be subdivided into eight members.

2a (= Oxfordmergel of Aldinger (1935) or *Cardioceras* Beds of Spath (1935)). This member is dominated by greyish, silty to fine-sandy shales, locally glauconitic. They are commonly mottled by bioturbation. At the sharp lower boundary they contain coarse sand and gravel, reworked from the Charcot Bugt sandstones. Layers of calcareous, silty to fine-sandy ammonite-bearing concretions or concretionary induration occur throughout. The thickness is up to 170 m in the east, but thins rapidly westwards to 10 m or less. The age is Upper Callovian – Upper Oxfordian. The base is extremely diachronous, ranging from the Athleta Zone (or lower) at Charcot Bugt to the Glosense or Serratum Zone in Visdal (fig. 34). The member has yielded a very extensive ammonite record.

2b (= *Pecten* Sandstone of Aldinger, 1935). This member consists of fine- to medium-grained sandstone showing large-scale cross-bedding and ripple lamination in the lower part, while the upper part is heavily bioturbated. Shell beds dominated by bivalves occur at certain levels. The member grades into the underlying shales, while the top is sharp. The sandstones attain a thickness of up to 70 m to the north-east, but wedge out to the west. The age is Glosense-Serratum Zones.

2c. This member consists of grey or greenish, partly glauconitic, silty shales with intervals of fine-sandy strongly glauconitic horizons in the upper part. It is strongly bioturbated. The lower boundary is well defined in the east but uncertain in the west where the member below is missing or reduced to a thin residue. The upper boundary is defined at the top of a prominent strongly glauconitic fine sand. The member is *c*. 20 m thick in the east and, in contrast to the member below, thins only very little to the west. There it yields ammonites indicating the Rosenkrantzi and Baylei Zones.

2d (= *Amoebites* shales (pars) of Spath, 1935; includes the levels of concretions γ and δ of Aldinger, 1935). This member consists of greyish silty and fine-sandy bioturbated shales with layers of doggers, often giant, very uniformly developed all over the area. The member is always much less glauconitic than the underlying member. The upper boundary is defined by the transition to non-bioturbated, laminated black shales. The member belongs to the Cymodoce and Mutabilis Zones. Three successive faunas of *Rasenia* have been identified: *R. inconstans* Spath (including *R. orbignyi* Spath non Tornquist), *R. cymodoce* (d'Orbigny) and *R. borealis* Spath. The member is up to *c*. 30 m thick.

2e (= Oil shales of Aldinger, 1935 and Spath, 1935; *Amoebites* shales (pars) of Spath, 1935). This member is dominated by black, finely laminated or occasionally lenticularly bedded non-bioturbated carbonaceous silty shales. Subordinate parts may be bioturbated; pyritic and calcareous concretionary beds, most of them rather unfossiliferous, occur at several levels.

The member attains a thickness of 160 m at the east coast and belongs to the Eudoxus-Elegans Zones. Diagnostic fossils are confined to a few thin widely-separated horizons, mostly in the lower part, the rest of the succession yielding little besides plant-remains. Three successive faunas of *Amoeboceras* can be distinguished: *A.* (*Euprionoceras*) *kochi* Spath, common between 15 and 30 m above the base in Gråkløft; *A.* (*Hoplocardioceras*) *decipiens* Spath in a thin indurated bed recognisable over the whole area 55 m above the base and associated with rare *Aulacostephanus eudoxus* (d'Orbigny); and *A.* ('*Amoebites*') *elegans* Spath 3 m above that, 58 m above the base. The Autissiodorensis Zone is indicated by scattered finds of *Aulacostephanus jasonoides* (Pavlow), and the next fauna found, south of Bays Fjelde, consists of *Pectinatites elegans* Cope at levels which cannot be higher than about half-way up the member. The upper half of the member yielded further scattered specimens of *Pectinatites* which show affinities with the forms of the English Kimmeridge Clay rather than those of the Russian/Volgian platform. They may well indicate the presence also of the Scitulus Zone.

2f (incorporates the level of concretions β of Aldinger, 1935). The member consists of greyish, very fine-grained micaceous shaly sandstones, completely bioturbated at all except a few levels. The sharp boundary between the hard black shales below and the softer and more porous beds above is marked in the field by a prominent spring-line. Layers of concretions ranging from small phosphoritic ones to large sandy doggers occur at a number of levels, and the upper part of the member may contain some glauconitic horizons. The total thickness approaches 150 m.

The earliest fauna came from concretions 10 m above the base and consists of *Sphinctoceras* sp., a genus which in England occurs mainly in the Wheatleyensis Zone. This is followed by other English species of *Pectinatites* into the Pectinatus Zone. Thereafter the faunas become mixtures, those of English affinities being steadily displaced by forms more characteristic of northern Russia and Siberia. The top of the member corresponds roughly to the Pallasioides and Iatriensis Zones.

2g (= lower part of Glauconitic Series of Aldinger, 1935 and Spath, 1935). This member consists of fine- to medium-grained glauconitic sandstone and sandy siltstone with ironstone and layers of concretions. Locally shell beds packed with fossils occur. The lower boundary is defined at the base of the first prominent medium-grained glauconitic sandstone, and not merely by the content of glauconite. It belongs to the Rotunda-Albani Zones of the British Middle Volgian, equivalent roughly to the Ilovaiskii-Maximus Zones of the northern Urals. The full thickness of the member is up to 125 m.

2h (= upper part of Glauconitic Series with concretions α of Aldinger, 1935). This member consists of whitish, fine-grained sands and highly micaceous silts with indurated lenticles or concretions. It is up to 30 m thick. The boundary with the underlying member is sharp. It is only typically developed on the eastern slopes of Hartz Fjeld and is cut out north-westwards by the unconformably overlying Hartz Fjeld Formation. The age is ?Albani – lower Gorei Zones of the British succession, (*Crendonites* sp.) – Groenlandicus Zone of the northern Urals.

3. Hartz Fjeld Formation (*sensu* Aldinger, 1935)

The thickness of the Hartz Fjeld Formation is about 300 m. Sykes & Brand (1976) follow Aldinger (1935) and informally recognise lower and upper sandy units separated by a shale unit. They interpret the clastic lithologies as fluvial sand bars (at the base) and fan-delta deposits with the shale unit as lagoonal or enclosed bay.

We prefer a more marine regime at least for the lower unit. This is based on (1) the recognition of vertical U-shaped trace-fossils at the tops of the upward-coarsening sequences as marine burrows (and not root-horizons as interpreted by Sykes & Brand, 1976); (2) the occurrence of undoubted marine burrows and macrofossils throughout the greater part of the lower section; (3) the large lateral extent of the sedimentary cycles; and (4) the total absence of channel morphologies.

The age of the lower unit is Middle Volgian (Gorei Zone of the British succession, Groenlandicus Zone of the northern Urals) – Upper Ryazanian/?Lower Valanginian (Tolli Zone of Siberia) with a large non-sequence in between, above the *Lingula* horizon. The age of the shaly middle unit and the upper unit is unknown.

Palaeoecological investigations

The Upper Jurassic strata of Milne Land contain a profuse fauna of benthic invertebrates, especially bivalves, brachiopods and gastropods. This fauna is particularly abundant at some levels.

Between Middle Oxfordian and Middle Volgian more than 100 statistical samples have been taken, each containing between 100 and 250 specimens, in order to study the distribution and composition of a typical Boreal benthic fauna. In addition the associated sediments, sedimentary structures and trace fossils have been studied in detail.

To demonstrate the mode of occurrence of the fauna and its potential in palaeoecological analysis, two of the most fossiliferous horizons are briefly discussed below.

The benthic fauna of Member 2b

The well-sorted, fine- to medium-grained sandstones of this member are intensely bioturbated or exhibit many sedimentary structures such as large-scale cross-bedding or ripple lamination. Several benthic associations occur at various levels. The most conspicuous ones are dominated either by the bivalves *Camptonectes giganteus* or by *Eocallista* and *Cucullaea.* The serpulid *Cycloserpula* occasionally forms an important part of the associations. These bivalve-dominated benthic associations occur in a wide range of preservation. Occasionally the fauna has been preserved in life-position (e.g. clusters of semi-infaunal *Modiolus*), but usually it forms shell beds or shell pavements exhibiting current orientation, sorting, and imbrication. Between these two extreme modes of preservation all transitional stages are found, and the fauna of these sandstones provides an excellent example to demonstrate the breaking up of benthic communities into transported and sorted assemblages among which the latter dominates by far.

The predominance of suspension-feeding bivalves, partly epibyssate or free-living, partly infaunal, indicates an environment in which most nutrients were kept in suspension. The widespread shell beds point to periodic reworking of the sea floor, but the excellent preservation and high percentage of bivalved specimens not uncommon in many of the shell beds indicate that reworking was often only a short interlude. These features, combined with evidence from sedimentary structures, favour a relatively shallow-water environment like that of a large offshore sand bar whose top layers were occasionally reworked by storms. In contrast, during quieter periods a relatively low rate of deposition led to extensive bioturbation of the sediments.

The benthic fauna of Member 2g

Most of the benthic invertebrate fauna of this member is concentrated either in sandstone or concretionary layers, whilst the uncemented shales are largely unfossiliferous. This fauna does not occur in a random fashion, but in several characteristic associations which were found repeatedly both in vertical and lateral extent. The most conspicuous association is found in the so-called *Pinna* Bed, a moderately glauconitic, fine- to medium-grained sandstone whose highly diverse fauna is dominated by *Pleuromya, Pinna, Entolium* and *Camptonectes.* Already Aldinger (1935) noticed that a large part of the infauna and semi-infauna (e.g. *Pleuromya, Homomya, Pinna*) occurs in position of life and that this shell bed was formed *in situ*, thus representing an autochthonous relic of a former community. This kind of preservation is typical of most beds in the member: abundant bivalved faunal elements; fauna commonly preserved in life position (e.g. nests of terebratulids); lack of sorting, shell abrasion, or other signs of transport – indicate that throughout the succession disturbance of the fauna, except through bioturbation, was kept to a minimum and that most shell beds contain the relics of former communities.

Another association is dominated by *Entolium nummulare,* another by *Pleuromya tellina*; terebratulids and *Parallelodon keyserlingii* dominate a third, whilst in others *Necrassina*, or *Parallelodon schourovskii* and *Thracia* are the prominent species. The good preservation of most faunal elements indicates a fairly rapid sedimentation, which however, cannot be continuous. Thus, the depositional units preserved represent only a very small fraction of time in the depositional history of the member, most of which consist of lacunae.