A Valanginian turbidite sequence and its palaeogeographical setting (Kuhn Ø, East Greenland)

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After a long period of tectonic quiescence in the main part of the Jurassic, the East Greenland continental margin in Lower Volgian – Upper Ryazanian time underwent strong block-faulting and -tilting. The Valanginian Stage represents a return to quieter conditions. A regional transgression took place over an irregular fault-mosaic exposing mainly Middle Jurassic sandstones and Upper Jurassic mudstones. Coarse Valanginian conglomerates along the western margins of the basin rapidly grade into sandstones, sandy mudstones and finally mudstones with calcareous nodules and layers in the central parts of the basin. Here a turbidite sequence comprising 34 thin graded sandstones in a sequence of mudstones containing large well preserved burrows belonging to the ichnogenus *Zoophycos* occur in what earlier was described as a very shallow water facies. Along the eastern margin of the basin a few erosional remnants of coarse conglomerates again mark the position of the coast-line.

Finn Surlyk and Lars Clemmensen, Mineralogisk Museum, Østervoldgade 5–7, 1350 København K, Denmark. February 2nd, 1975.

In East Greenland Valanginian sediments are known from Jameson Land in the south (Surlyk & Birkelund, 1972; Surlyk et al., 1973) and possibly Milne Land (top of the Hartzfjeld Formation; not proved by fossil evidence) over Traill Ø (Donovan, 1953), Wollaston Forland, Clavering Ø and Kuhn Ø (Maync, 1949; Surlyk & Clemmensen, 1975) to Store Koldewey Ø in the north (Ravn, 1911).

The Valanginian deposits overstep faulted and tilted Jurassic and older rocks with marked angular unconformity. Only in NW Wollaston Forland did a seemingly continuous sedimentation take place from Volgian to late Valanginian time.

A map showing the presumed distribution of the Valanginian sea and the corresponding facies pattern was published by Vischer (1943, fig. 11). He included, however, Volgian as well as Ryazanian rocks in the Valanginian due to limited knowledge of the age relations of the different rock units. Maync (1949, fig. 68) strongly criticized this attempt at a synthesis, and gave his own version of the Valanginian palaeogeography although without facies distribution. Throughout his publications on the East Greenland Mesozoic sediments Maync used a very complicated and inconsistent stratigraphic nomenclature. Practically all units distinguished by him were given formation type names, but with a few exceptions they were actually used as chronostratigraphic units. In contrast Vischer (1943) used an easily understandable and logical lithostratigraphic classification.

New field work in the area by us in the summer of 1974 has shown that, although not very refined stratigraphically, the main outline of Vischer's palaeogeographical setting and facies distribution is correct. The tectonic activity controlling sedimentation started in Lower Volgian and lasted throughout the Ryazanian, with minor phases at least to the Middle Valanginian. The resulting facies types in the marginal parts of the basin were basically of the same type in the Volgian–Ryazanian as in the Valanginian. Vischer's mistake of including marginal Volgian–Ryazanian facies in his map and in the discussion of the Valanginian palaeogeography does not seem to us therefore to be as much a catastrophy as was claimed by Maync (1949, p. 186).

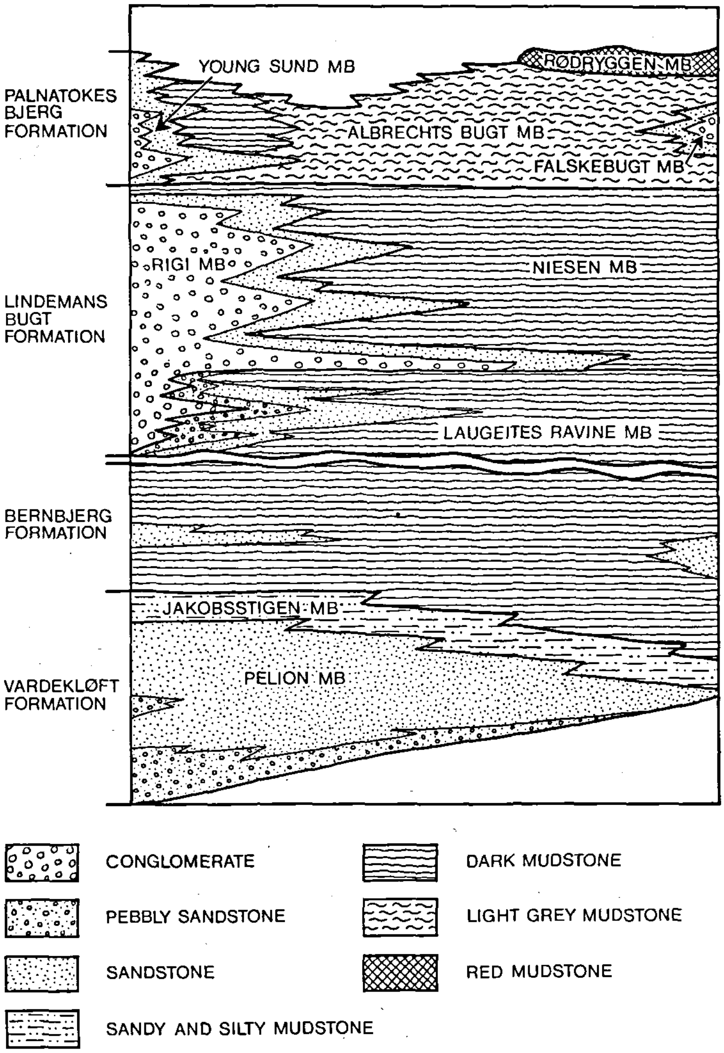

Fig. 1. Generalized scheme showing the spatial distribution of the Bathonian – Valanginian lithostratigraphic units in the Wollaston Forland region. The marked eastwards thinning of the formations and the N-S faulting east of the Dombjerg Fault has not been indicated.

Stratigraphy

Maync (1949) divided the Valanginian of Wollaston Forland, Kuhn Ø and Clavering Ø into four mainly lithostratigraphic units: The Albrechts Bugt Facies, the Young Sound Facies, The Falskebugt Beds and The Rødryggen Beds, and one biostratigraphic unit: The Upper Niesen Beds.

Vischer (1943) included the Rødryggen Beds in the Albrechts Bugt Facies, introduced the term Kuhnpas Facies for a calcareous-clayey transitional facies between the Albrechts Bugt Facies and Maync's Young Sound Facies and finally all the coarse-clastic sediments of Volgian, Ryazanian and Valanginian age comprised the Lindemansbugt Facies (partly on the wrong assumption that they were contemporaneous and of Valanginian age).

In the following we have tried to use a strict lithostratigraphic nomenclature, as far as possible based on the older names of Maync (1949) and Vischer (1943). These units will be formally designated in a stratigraphic revision of the Mesozoic strata in East Greenland between 74½ °N and 75½ °N (Surlyk, in prep.; Surlyk & Clemmensen, in prep.; for a review see Surlyk & Clemmensen, 1975). The stratigraphic scheme as proposed below is therefore to be regarded as prelim-

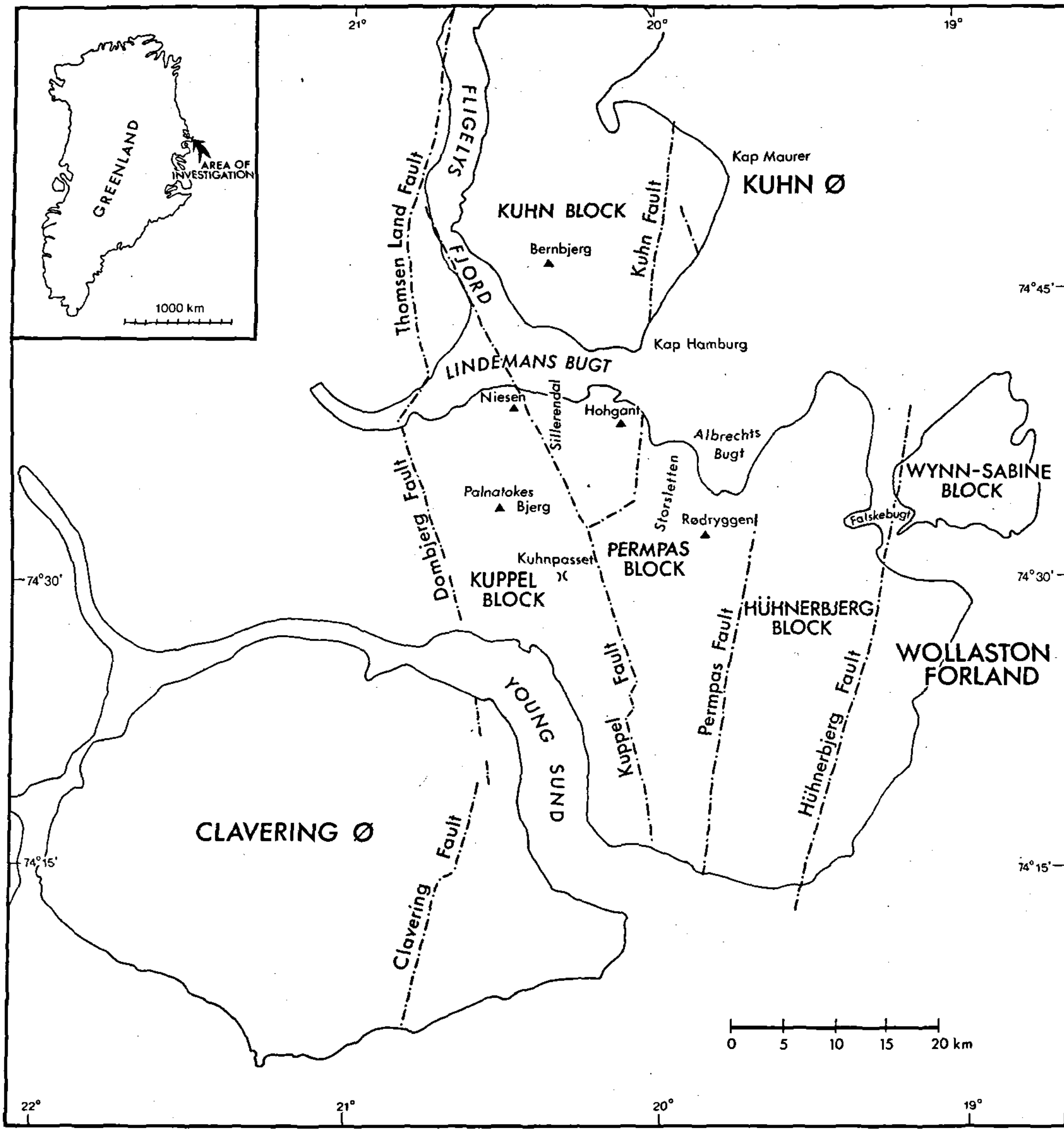

Fig. 2. Map of the investigated area showing topographic names mentioned in the text and the more prominent structural features.

inary and the formal reference to emended or new units will be the above mentioned revisions.

The lithostratigraphic units used by us are as follows (fig. 1).

1. Palnatokes Bjerg Formation. – A maximum 300 m thick clastic wedge of Valanginian sediments grading from thin boulder-beds and conglomerates along the western basin margin into sandstones and further eastwards into dark sandy mudstones and finally into light-grey mudstones with bands of limestone. At a few localities in eastern Wollaston Forland marginal conditions are denoted by a return to sandstones, conglomerates and boulder-beds. The formation overlies conformably or with erosional or angular unconformity the Volgian–Ryazanian Lindemans Bugt Formation (see Surlyk & Clemmensen, 1975) and is overlain by Aptian–Albian mudstones.

a. Young Sund Member. – Boulder-beds, conglomerates and sandstones occurring along the western margins of the depositional basin, that is, east of the Clavering–Dombjerg Fault (fig. 2). The boulder-beds commonly incorporate reworked pieces and calcareous concretions of the Albrechts Bugt Member and large slabs of dark mudstones of Upper Jurassic or Ryazanian age. The sandstones are characterized by a large content of pink feldspar and contain irregular intraformational clasts of the grey mudstones of the Albrechts Bugt Member. The wavy, deformed shape of the clasts shows that the eroded sediment was only slightly lithified when erosion took place. The member shows pronounced intertonguing with the mudstones of the Albrechts Bugt Member and is largely contemporaneous with that member. It is overlain with erosional or angular unconformity by Aptian–Albian mudstones. The member occurs in western Wollaston Forland and on Clavering Ø.

b. Falskebugt Member. – Boulder-beds, conglomerates and sandstones occurring in eastern Wollaston Forland on the western high parts of the tilted and eroded Hühnerbjerg Block. The member corresponds facially completely to the Young Sund Member. Westwards it intertongues with the Albrechts Bugt Member.

c. Albrechts Bugt Member. – Horizontally laminated dark-grey mudstones and fine sandstones eastwards grading into light-grey mudstones with calcareous concretions and bands of limestone. In south-east Kuhn Ø the member at one locality is developed as a turbidite sequence. The thickness of the member decreases rapidly eastwards due to the westwards tilted surface of the fault-blocks. It interfingers with the Young Sund Member to the west, with the Falskebugt Member to the east and is overlain conformably by the Rødryggen Member or with erosional or angular unconformity by dark Aptian–Albian mudstones. The member occurs in south-east Kuhn Ø and Wollaston Forland, where it is especially dominant in the central parts. Sediments comparable to the Albrechts Bugt Member are also known from Traill Ø (Donovan, 1953).

d. Rødryggen Member. – Dark-red and yellowish homogeneous calcareous mudstones and sandy mudstones. Where exposed the member forms the top of the Palnatokes Bjerg Formation and is always overlain by Aptian–Albian dark mudstones. The colour cannot be the result of an in situ "Terra Rossa" weathering of the Albrechts Bugt mudstones as argued by Maync (1949) because the faunal remains of the two members have a totally different character. The member is found in south-east Kuhn Ø and in central Wollaston Forland. A contemporaneous and almost identical facies occurs on Traill Ø but is represented by loose blocks only (Donovan, 1953).

The biostratigraphical age and relations of the rocks of the Palnatokes Bjerg Formation are not well known since no Valanginian fossils have been thoroughly taxonomically described from the region. We have only the ammonites listed by Maync (1949, pp. 226, 238) and a few buchias illustrated by Jeletzky (1965) as guide-lines. The fauna indicates a late Lower, Middle and Upper Valanginian age (Donovan 1953, 1957; Jeletzky, 1965).

A turbidite sequence from the Albrechts Bugt Member of south-east Kuhn Ø

In the low coastal cliff along the south-eastern coast of Kuhn Ø outcrops of black mudstones belonging to the upper part (≈ "Kuhn Beds" of Maync, 1947) of the Upper Jurassic Bernbjerg Formation (Surlyk & Clemmensen, 1975, and in prep.) are overlain with slight angular unconformity by light-grey mudstones belonging to the Albrechts Bugt Member of the Palnatokes Bjerg Formation. About halfway between Kap Hamburg (south point of Kuhn Ø) and Kap Maurer (eastern point of Kuhn Ø) the northern part of this sequence is downfaulted along a NW-SE trending fault and from here and further north the only sediments exposed in the cliff are dark Aptian–Albian mudstones.

Another much more important, NNE-SSW trending fault – the Kuhn Fault of Vischer (1943) – separates the Kuhn Block from the

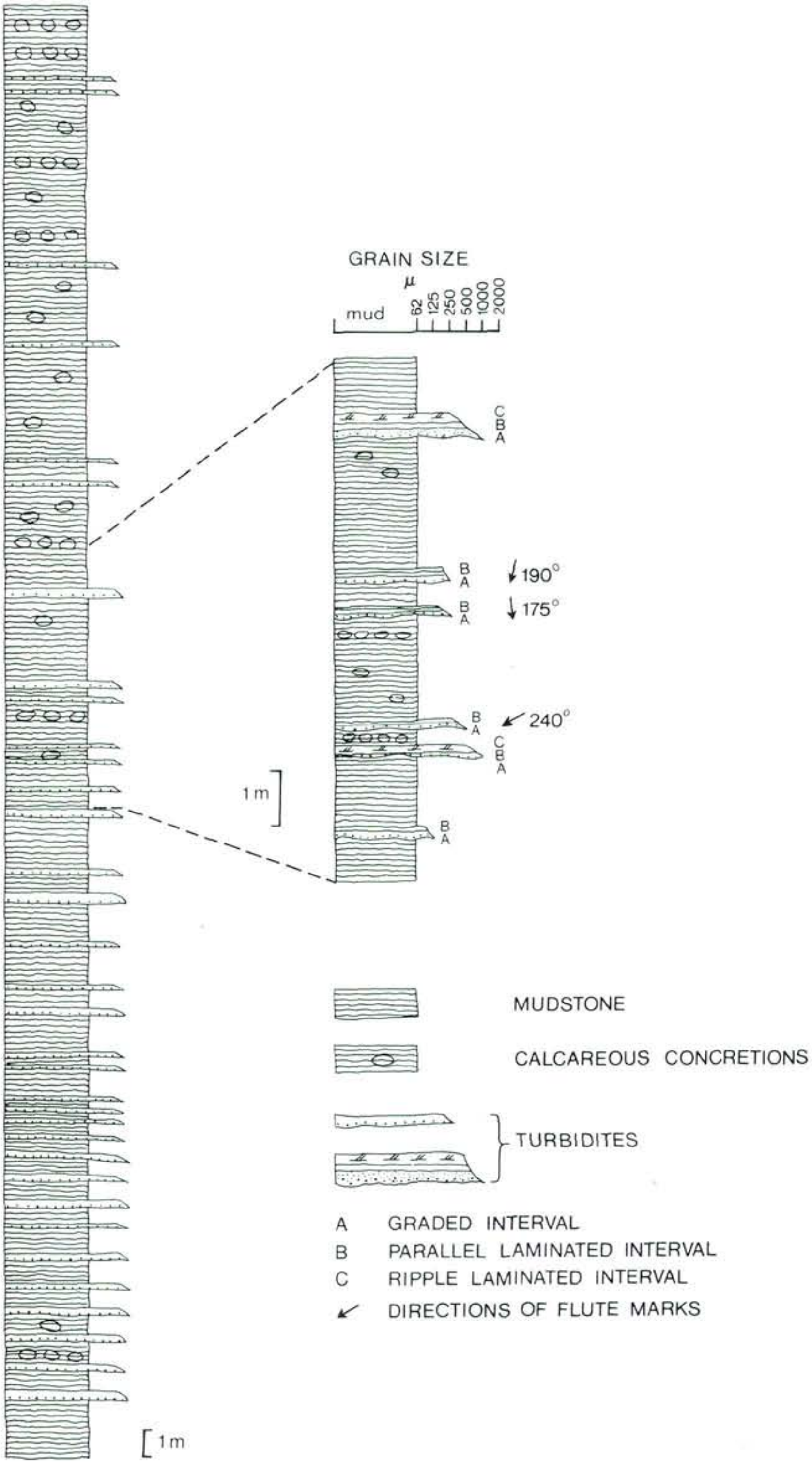

Fig. 3. Section showing mudstone with turbidite sandstones. Albrechts Bugt Member, eastern Kuhn Ø.

Fig. 4. Lower part of the section illustrated in fig. 3. Turbidite sandstones arrowed.

Fig. 5. Upper part of the section shown in fig. 3. Gradual transition from the Albrechts Bugt Member to the Rødryggen Member. Turbidite sandstones almost disappeared.

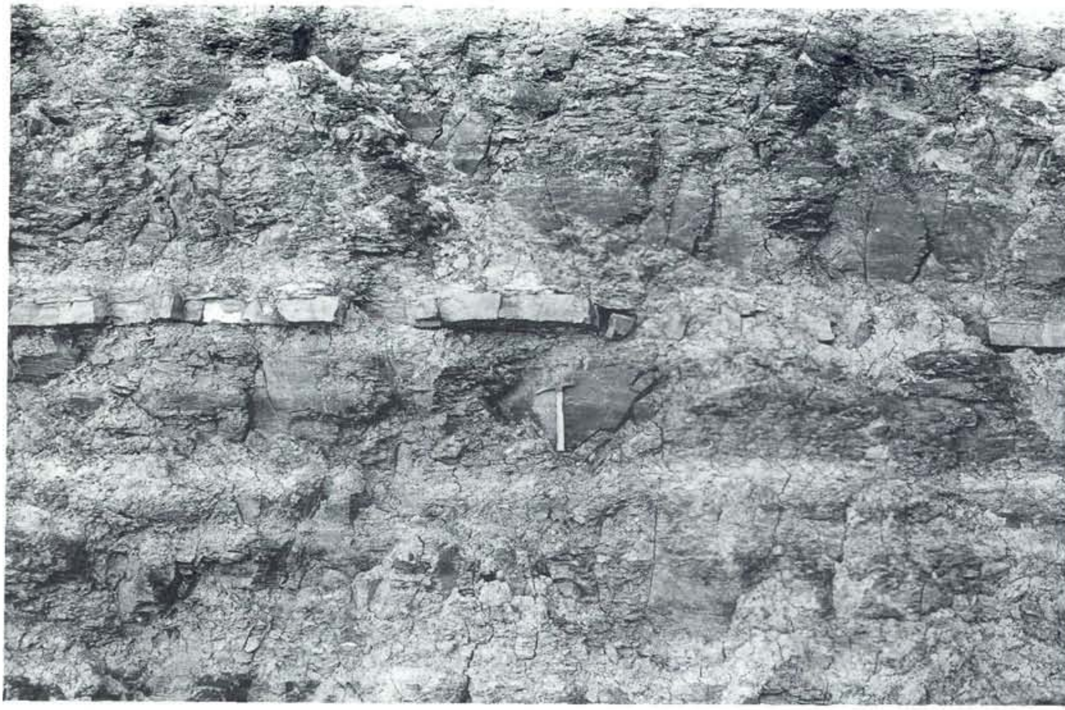

Fig. 6. Turbidite sandstone in grey mudstones. Lower part of section illustrated on fig. 3.

down-faulted Permpas Block of which southeastern Kuhn Ø forms a part (fig. 2). This fault crosses the coast-line 3 km north of Kap Hamburg and dark mudstones of Aptian age crop out immediately east of the fault (not Upper Jurassic as indicated on the maps of Vischer (1943) and Koch & Haller (1971)). Further north these mudstones are underlain by light-grey Valanginian mudstones and a few hundred metres north of the southernmost dolerite dyke cut by the coast-cliff (8 km N of Kap Hamburg) a good Valanginian section is exposed (fig. 3).

The section begins 28 m above sea-level and exposes 53 m of grey often sandy mudstones with irregular calcareous concretionary nodules and layers (fig. 3). Upwards the sediments attain a dark-reddish tinge corresponding to a gradual change from the Albrechts Bugt Member to the Rødryggen Member (figs 4, 5). There are a number of greyish-yellowish sandstone layers varying in thickness from 5–20 cm intercalated with the mudstones (fig. 6). The mudstones are commonly strongly bioturbated and may show a mottled texture; more prominent, however, is the profuse occurrence throughout the section of large and well-preserved burrows belonging to the ichnogenus *Zoophycos* (figs 7–8). The burrows also penetrate the upper part of the sandstone beds.

Body-fossils are represented by scattered belemnites and in some horizons by large numbers of the bivalve *Buchia keyserlingi* (Lahusen) (fig. 9). *Buchia keyserlingi* increases in frequency upwards in the section until, in places, it dominates the sediment in the highest horizons. All size-classes from a length of about 1 mm to the presumed adult length of about 3 cm are represented in large numbers.

Besides trace-fossils and body-fossils the mudstones have a rather large content of pyrite commonly in the form of well-developed centimetre-sized crystals.

The intercalated sandstone beds number 34 and occur almost rhythmically, especially in the lower third of the sequence where the average distance between the sandstone beds is about 1 m. Upwards the density decreases and

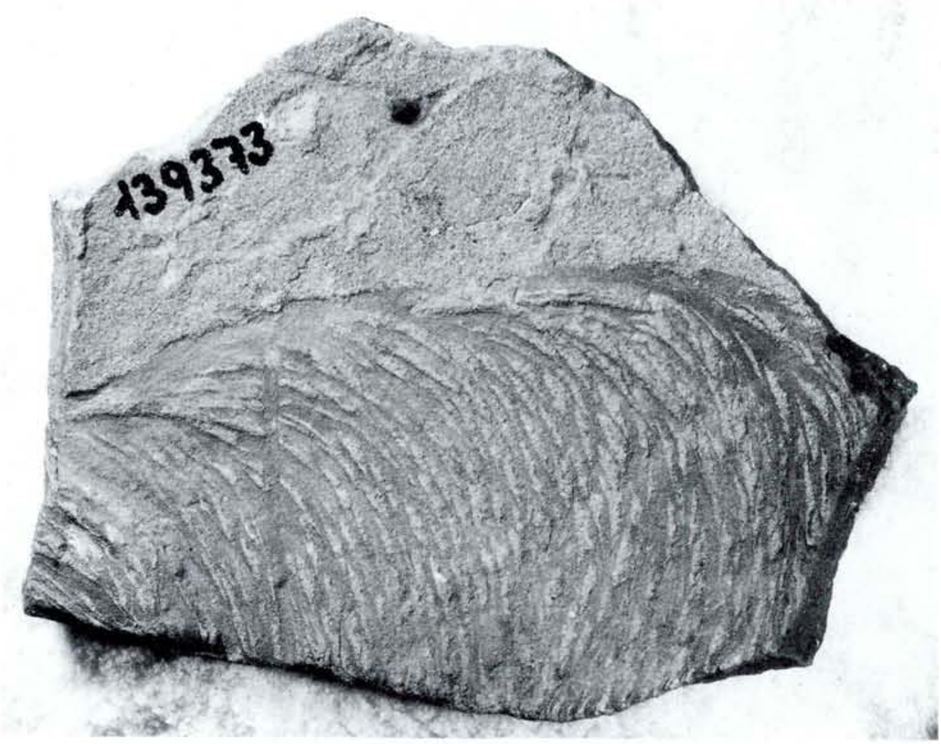

Fig. 7. Zoophycos from upper part of section shown in fig. 3. GGU no. 139373. MMH no. 13358.

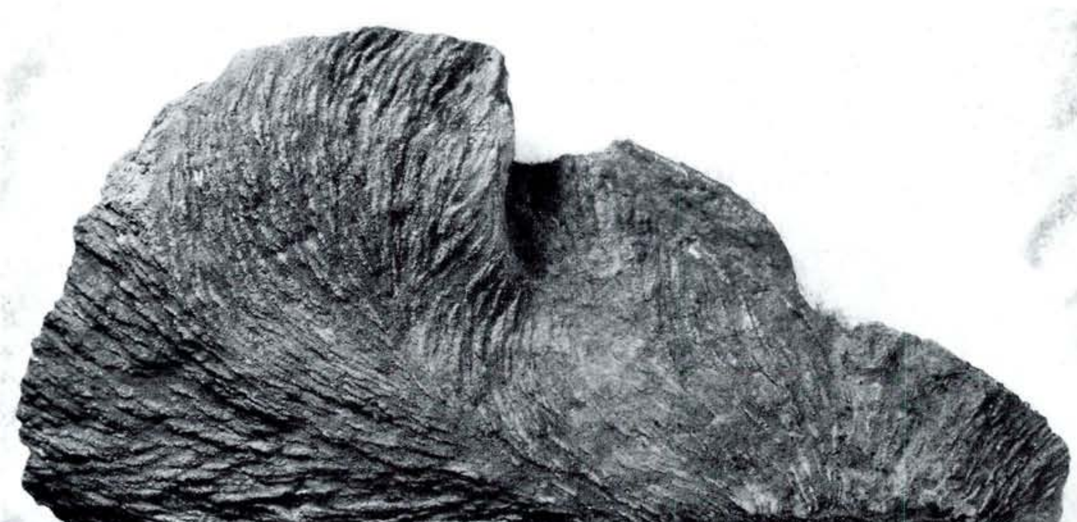

Fig. 8. Zoophycos from upper part of section 13. GGU no. 139373. MMH no. 13359.

Fig. 9. Buchia keyserlingi (Lahusen, 1888). GGU no. 139374. MMH no. 13360–61 (left and right specimen respectively). × 1. Top part of section shown in fig. 3.

there may be up to 7 m between consecutive sandstones.

The sandstone beds consist of medium- to very fine-grained generally well sorted sand. They have sharp, slightly erosional bases and show a marked decrease in grain-size upwards. They are gradationally overlain by mudstones. The sandstone horizons can be traced laterally over the length of the whole outcrop (100 m) and display no change in thickness within this distance.

A study of the sandstone beds revealed that they were, at best, composed of three different units A, B and C, which are described below:

A. This sedimentary unit always occurs as the lowermost interval of the sandstone beds and displays a thickness between approximately a fourth and almost the whole of the respective sandstone layer (5–15 cm). The unit consists of medium-grained sand and very commonly shows grading, but is otherwise structureless.

The lower contact is erosional and shows casts of different types of scour, particularly flute marks. Measurements of the orientations of these markings gave current directions between SE and SW (fig. 3).

B. This unit overlies unit A with a gradual contact and is composed of horizontally laminated medium- to fine-grained sand varying in thickness from a few centimetres to more than 10 cm. The unit is often the dominating sediment type within the sandstone beds.

C. This sediment type appears, when developed, as the uppermost unit and is seldom more than a few centimetres thick. It consists of fine-grained sand and is always the most fine-grained part of the sandstone beds. The unit is characterized by the occurrence of small-scale current ripple lamination or wavering lamination (Leflef, 1973) and is gradually overlain by the mudstone facies.

The regular occurrence, lateral continuity, erosive bases and internal arrangement of the sandstone layers strongly suggest that the sand has been deposited from turbidity currents. The turbidity currents operated in a low-energy environment otherwise characterized by settling of fine-grained material from suspension.

The sharp erosive base of the lowermost unit (unit A) of the sandstone beds represents the initial erosive phase of the turbidite followed by the deposition of the most coarse-grained material available in the density current as a graded, structureless sediment. The described unit corresponds closely to the "graded interval" of the ideal turbidite sequence described by Bouma (1962). According to Walker (1965) the nature of the graded division depends upon the type of currents from which it is formed. In the present case it seems most likely that the sandstones have been deposited from mature currents without traction carpets or autosuspension, the deposits of which should display perfect grading and contain no mud.

The middle unit (unit B) is interpreted as "the lower parallel laminated interval" of the Bouma sequence. The horizontally laminated sediments were most probably deposited during upper flow regime conditions as suggested by Harms & Fahnestock (1965).

The upper unit, or unit C, corresponds to the "interval of current ripple lamination" of Bouma (1962). In contrast to the two lower units this sediment was deposited during lower flow regime conditions characterized by a high amount of suspension load as suggested by the occasional occurrence of wavering lamination (Leflef, 1973).

Palaeogeography

The structural frame (fig. 2) of the area occupied by the Valanginian sea is set by five westwards tilted fault-blocks, from west to east (after Vischer, 1943):

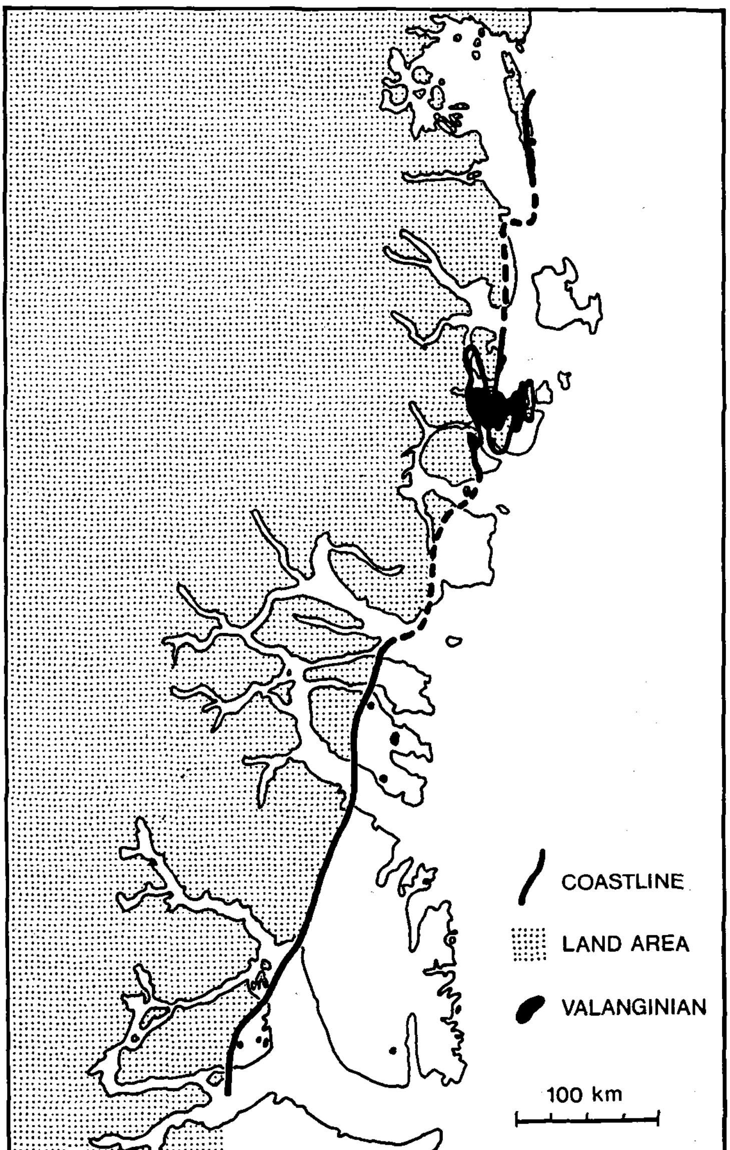

Fig. 10. Palaeogeographical map showing the presumed distribution of land and sea in Valanginian time. The black area indicates the known surface and subsurface occurrences of Valanginian sediments. The stippled coast-lines in the central part of the figure are of a very tentative nature as it is not known whether the Hold with Hope peninsula east of the indicated coastline was submerged or if it formed a landmass. The Valanginian facies types to the south on Traill Ø and to the north on Wollaston Forland are practically identical suggesting a direct marine connection following prominent fault-lines as indicated on the map.

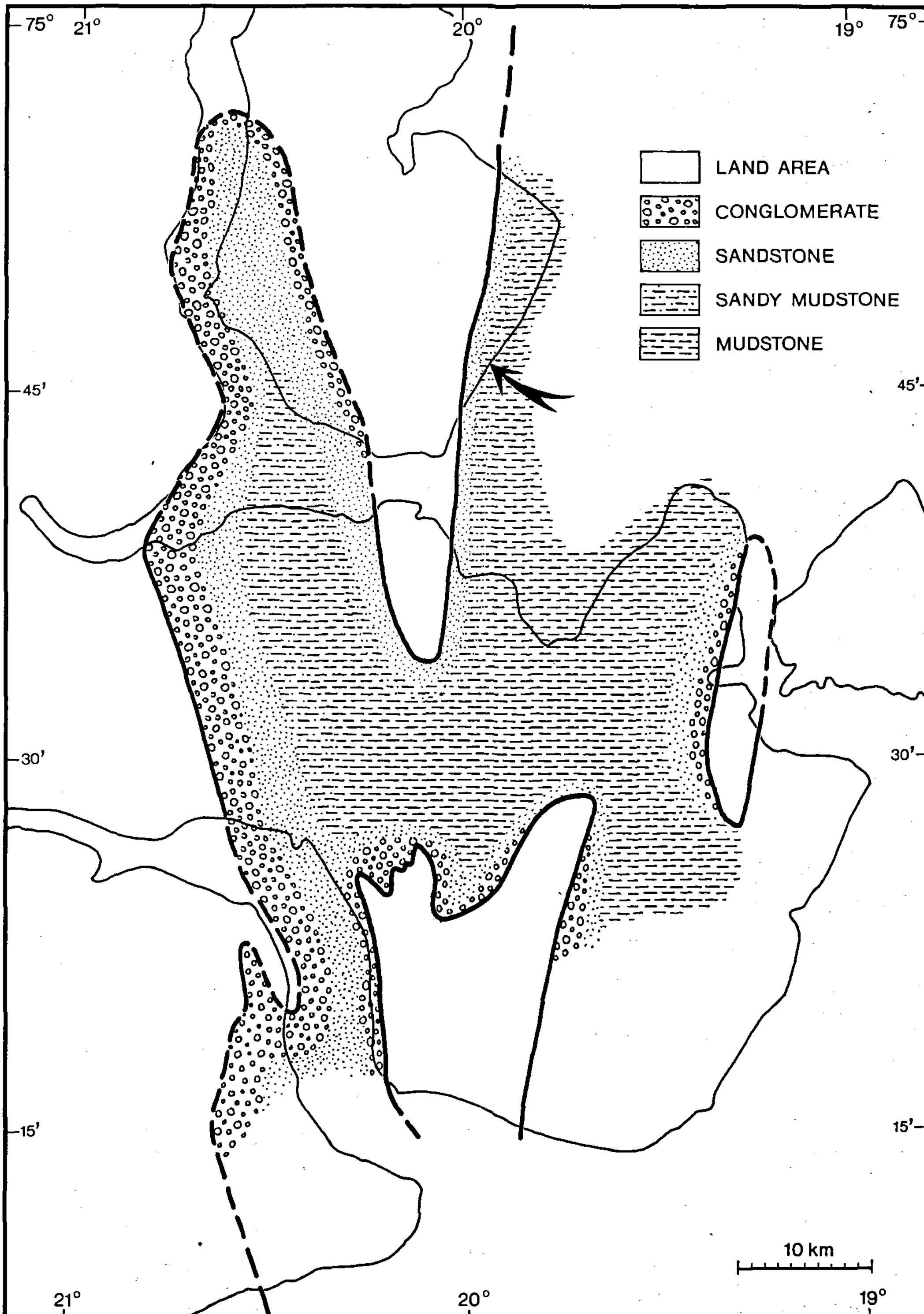

Fig. 11. Palaeogeographical map of the Wollaston Forland region showing the Valanginian facies distribution. The facies types and the position of the coastlines are well known on the main part of Wollaston Forland and eastern Kuhn Ø, whereas they are extrapolated to western Kuhn Ø. Some of the data are taken from Maync (1949) and Vischer (1943). The arrow shows the position of the turbidite sequence.

1. The Kuhn Block separated from the Caledonian area by the Thomsen Land – Dombjerg – Clavering Fault. The western down-tilted part of this block formed the Fligelys – Young Sund Trough.
2. The Permpas Block is separated from the Kuhn Block by the Kuhn Fault. The down-tilted part of the Permpas Block formed the Storslette Trough.
3. The Hühnerbjerg Block is separated from the Permpas Block by the Permpas Fault, and to the east is in turn separated from the
4. Wynn – Sabine Block by the Hühnerbjerg Fault.
5. The Kuppel Block occurs as a southern wedge between the Kuhn and Permpas Blocks.

This faulted and eroded area was transgressed by the Valanginian sea except for parts of the Fligelys Fjord – Young Sund Trough where marine conditions seem to have lasted almost without interruption throughout Volgian, Ryazanian and Valanginian time (figs 1, 10, 11).

Whereas the western shore-line of the Valanginian sea without doubt was formed by the Clavering – Dombjerg – Thomsen Land Fault the role of the other structural elements is not so clear (fig. 11). The cross-sections figured by Vischer (1943) and observations both by Maync (1949) and by us show that the eastern parts of the Kuhn Block were emerged except for the central part of Wollaston Forland which was fully submerged. The sea left exposed only a small part of the present north coast of Wollaston Forland around Hohgant.

Small islands were formed by the southern parts of the Permpas – Kuppel Blocks and by the northern part of the Hühnerbjerg Block.

The distribution of the various Valanginian facies types is shown on fig. 11.

The turbidite sequence described above was deposited about 2.5 km east of the eastern margin of the Kuhn Block formed by the Kuhn Fault (arrow in fig. 11). The actual coast-line was probably situated quite close to this fault. The turbidite sequence was consequently deposited in the deepest parts of the sea covering the western down-tilted side of the Permpas Block. It forms the initial part of the Valanginian sequence and lies with angular unconformity on black Upper Jurassic mudstones. Although the depth of the sea probably never exceeded a few hundred metres and decreased eastwards following the surface of the dip-slope of the fault-blocks, the initial maximum depth was to be found close to the western coast or in other words more or less where the turbidite sequence is exposed today.

In the early phases of Valanginian sedimentation there was a relatively steep slope immediately off the coast. The uplifted and rejuvenated land area supplied large amounts of clastic material which were deposited close to the shore. Off-shore sedimentation was dominated by quiet deposition of fine-grained muds characterized by the trace-fossil *Zoophycos*. This difference in sedimentation led to rapid oversteepening of the slope which, together with earthquakes generated in the latest phases of the tectonically active period, triggered off turbidity currents. These moved down the slope and deposited blankets of sand as the currents waned.

The Storslette Trough, however, was rapidly filled with sediment and the gradient of the slope decreased markedly. This corresponds well with the gradual upwards decrease in number of turbidite sand layers in the sequence. In the highest beds turbidite sedimentation finally came to an end and the deposition of the regressive red mudstones of the Rødryggen Member marks the final stage of a long period of Mesozoic marine sedimentation. The following Hauterivian and Barremian Stages were periods of emergence and erosion (Maync, 1949) and it was not until the Aptian that the East Greenland margin was again transgressed by the sea.

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Dansk sammendrag

Efter en lang periode med tektonisk ro, der varede gennem det meste af Jura perioden blev den østgrønlandske kontinental rand underkastet kraftig blokforkastning og -kipning i Nedre Volgian – Øvre Ryazanian. Valanginian Etagen repræsenterer en tilbagevenden til roligere forhold og havet strakte sig under en regional transgression ind over en uregelmæssig blokmosaik. Grove Valanginian konglomerater aflejredes langs vestranden af bassinet. De går hurtigt over i sandsten, sandede muddersten og endelig muddersten med kalkkonkretioner og knolde i de centrale dele af bassinet. Her aflejredes en turbidit serie på 34 tynde graderede sandsten i en følge af muddersten med store velbevarede *Zoophycos* gravegange, som tidligere tolkedes som en meget lavvandet aflejring. Langs østsiden af bassinet markerer nogle få konglomerater bevaret som erosions rester beliggenheden af den anden kystlinie.

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