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The geology of Sarqaqdalen, West Greenland, with special reference to the Cretaceous boundary fault system

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October 1989

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Abstract

Sarqaqdalen is a wide valley which runs northwards from the coast of Vaigat into the Nûgssuaq peninsula. The valley lies along a major geological boundary - that between the Cretaceous-Tertiary sedimentary basin to the west and the Precambrian basement to the east. This boundary is a fault. Fluvial, coal-bearing Cretaceous sediments on the west side of the fault are largely the deposits of a braided river system, passing north into a swampy plain. The Cretaceous beds dip at 10^{o}-16^{o} towards the fault, but Tertiary strata, which overlie the Cretaceous with angular unconformity, are virtually horizontal. This implies that the main movement on the fault was pre-middle Danian (the age of the earliest Tertiary sediments). The actual fault contact between Cretaceous and Precambrian is only exposed at one locality to the east of outer end of Sarqaqdalen, where there is a relay fault striking ca. 110^{o}. Neither here nor anywhere else is there evidence in the Cretaceous strata of sediments having been fed in from the east or north-east or of the proximity during sedimentation of a steep fault scarp on this side of the valley. On the contrary, palaeocurrent directions are almost all towards the north and north-west, parallel to the boundary fault system.

It is suggested that either 1) the north-south Cretaceous river valley in the Sarqaqdalen area was localised by subsidence along the boundary fault system, but sedimentation kept pace with the fault movements so that no marked relief developed along the line of the fault, or 2) the valley developed in a sag which in this area did not develop into a fault-bounded basin until the end of the Cretaceous. (To the north, however, on the islands Upernivik Ø and Qeqertarssuaq, there is evidence of syn-sedimentary faulting having begun as early as during the Albian-Cenomanian).

A striking feature of inner Sarqaqdalen is the major dolerite sheet which coats the steep gneiss slopes on the eastern side of the inner part of the valley. The gneiss in contact with this sheet is bleached and brecciated, and there is no doubt that, as previous workers have suggested, this sheet was intruded along the fault plane between the Precambrian and Cretaceous. The contact between the sheet and the Cretaceous sediments to the west is not however exposed.

CONTENTS

INTRODUCTION

Renewed interest in the style and timing of the major fault system that marks the easterly limit of the outcrop of Cretaceous sediments in central West Greenland is a consequence of the new programme of reinterpretation of offshore seismic lines from the 1970s that has recently been initiated in GGU (Chalmers, 1988, 1989). In offshore areas with little or no borehole control, dating of seismic sequences is greatly influenced by what can be learnt from the nearest onshore outcrops, for example proven unconformities in onshore sequences, and demonstrable relationships between sedimentation and fault movements.

In central West Greenland Cretaceous sediments are separated from the Precambrian basement to the east by a system of faults running from near Sarqaq in southern Nûgssuaq to Svartenhuk Halvø in the north (Plate 1). Everywhere apart from Svartenhuk Halvø, the Cretaceous strata near the fault system have been tilted and dip towards the faults, while Tertiary (Paleocene) strata are virtually horizontal and, in the eastern part of the basin, overlie the Cretaceous with angular unconformity.

Observations pertaining directly to the boundary fault system have been made on Svartenhuk Halvø (Rosenkrantz & Pulvertaft, 1969; Larsen, 1981; J. Grocott, pers. comm.), Qeqertarssuaq and Upernivik Ø (Rosenkrantz & Pulvertaft, 1969), and on the north side of Nûgssuaq near Kûk (Pulvertaft, 1979). However, nothing has been published about the Sarqaqdalen segment of the fault system since the work of Munck (1945), whose observations date from the first of A. Rosenkrantz's Nûgssuaq expeditions in 1938. The principal aim of the writer's field work in this valley was therefore to supplement Munck's observations with new data on the geometry and timing of the faulting in this segment of the fault system, in particular to find out if the Cretaceous sediments contain any evidence of syn-sedimentary fault movements, as they do in the northern segments of the system.

In the event only limited additions could be made to our knowledge about these matters. This is because exposures in the Sarqaqdalen valley are very poor, and most of what can be said about the faults in Sarqaqdalen has already been written by Munck (1945). However, Munck worked with a very poor topographic map and had no aerial photographs, so at least as regards the geological map of the area a considerable improvement has been made. Furthermore, the observations made by the writer concerning faulting in the Akínaq area, north-east of Sarqaq, are completely new.

As regards the Cretaceous sediments in Sarqaqdalen, there was previously little published information other than that contained in the final report of the special investigation of the coal resources in the Cretaceous of West Greenland financed by the then Ministry of Commerce (Shekhar et al., 1982). Most of this information is in the form of graphic logs of the many profiles excavated by Shekhar's group, in particular in inner Sarqaqdalen. The present writer did not carry our similar digging operations, but has made more detailed logs of some of the better natural exposures, including some exposures not recorded at all by Shekhar et al. Thus the present study complements that of Shekhar et al.

Palynological dating of the Cretaceous sediments has been carried out on samples from a profile near Atanikerdluk to the west of the outer end of Sarqaqdalen (Croxton, 1978a) and from a profile just north of E13 (fig. 1) measured by Ehman et al. (1976). The palynomorphs (pollen) indicate a Cenomanian age for both sections, although Croxton suggests that the lowermost part of her section might be Lower Cretaceous.

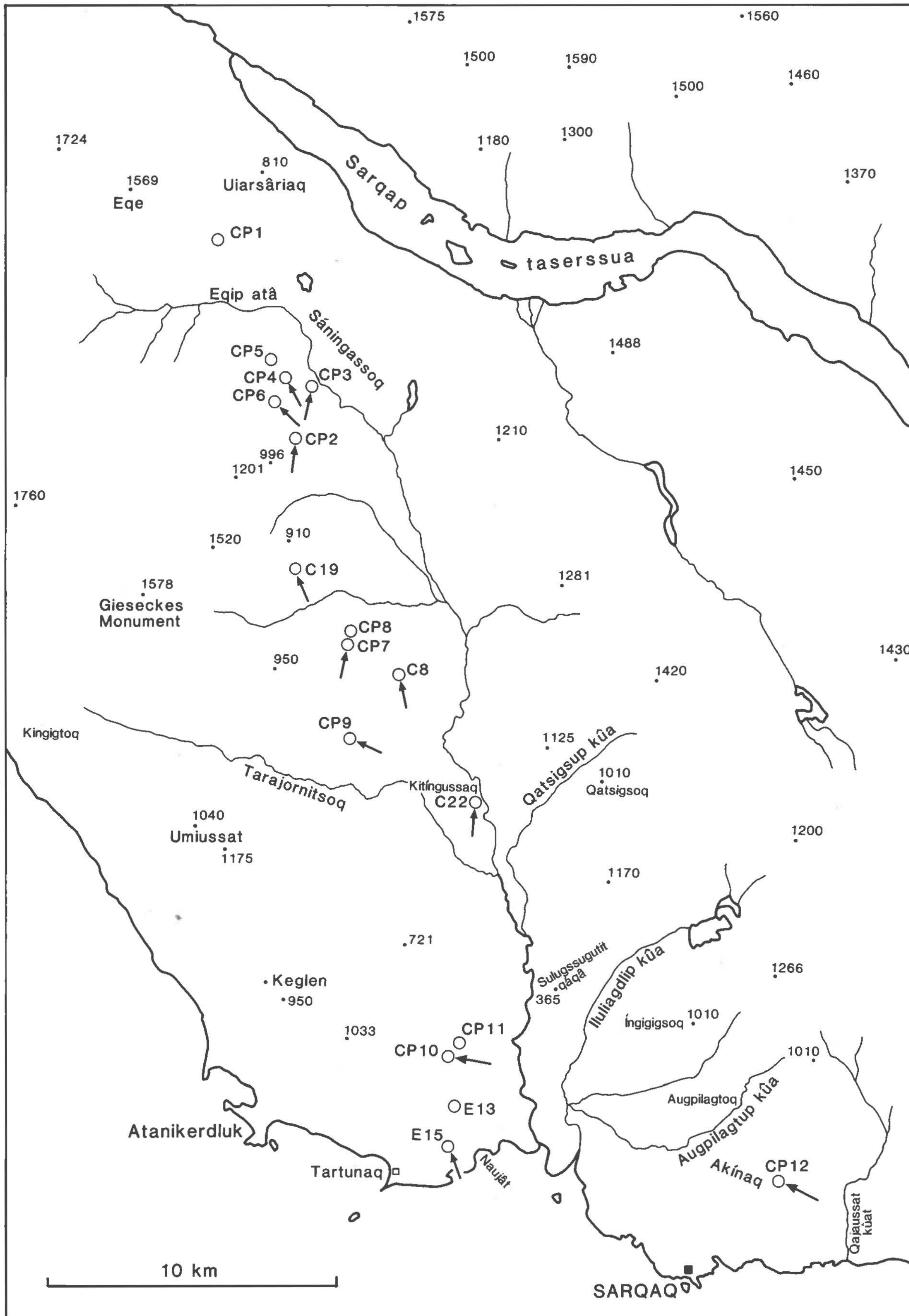
The writer's investigations in Sarqaqdalen were carried out in the period 5 July - 26 August 1988. Camp moves were carried out by helicopter based at Atâ on Arveprinsens Ejland, the base for GGU's operations in the Disko Bugt region in 1988. The weather during the field season was mainly good, apart from an unstable period at the beginning of August and some periods with fog.

PRECAMBRIAN

Outcrops of Precambrian rocks were only visited on the hills Uiarsâriaq and Sáningassoq, and in the area around Akínaq.

Uiarsâriaq and Sáningassoq are built up of thinly banded, striped or streaky biotite gneiss with thin leucocratic layers ("pegmatite-layering" - Myers, 1978). Locally the gneiss is hornblendic, hornblende being easiest to see in, or near the margins of, the leucocratic layers. Dips in this area are low, less than 30°, in directions between SW and SE. A crude lineation is often developed in the gneiss, generally in the form of rodding or ribbing plunging at a low angle to either east or west/west-northwest.

Observations made with binoculars indicate that similar low-dipping gneiss occurs in the cliffs on the north-east side of Sarqap taserssua and on the east side of inner Sarqaqdalen. Farther south, there is a major amphibolite in the gneiss south-east of Qatsigsup kûa, and on the north side of the inner end of Iluliagdlip kûa a thick unit of varied supracrustal rocks occurs.


1575
1560
1500
1590
1460
1500
1724
1180
1300
810
Sarqap
1370
1569
Uiarsâriaq
Eqe
CP1
taserssua
Eqip atâ
Sâningassoq
1488
CP5
CP4
CP3
CP6
CP2
1210
996
1201
1450
1760
910
1520
C19
1281
1578
Gieseckes Monument
CP8
CP7
1430
950
C8
1420
CP9
Kingigtoq
1125
Qatsigsup kûa
1010
Qatsigsoq
Tarajornitsoq
Kitíngussaq
C22
1040
Umiussat
1175
1200
1170
721
Sulugssugutit qáqâ
365
Iluliagdlip kûa
1266
Keglen
950
Íngigigsoq
1010
1033
CP11
CP10
1010
Augpilagtoq
Augpilagtup kûa
E13
Atanikerdluk
E15
Naujât
Akínaq
CP12
Tartunaq
Qajaussat kûat
10 km
SARQAQ

In the outermost part of Sarqaqdalen and the area south of Akínaq the gneiss outcrops are of homogeneous biotite augen gneiss, with pinkish augen up to 1 x 3 cm in size. Biotite-rich layers occur but are rare. Locally the foliation becomes so intense that the rock approaches being a mylonite. There are occasional pink quartz-K feldspar veins, some of which are deformed while others cross-cut the foliation. The strike and dip of the foliation are fairly constant (120-147/34-50 SW). This constant orientation seems to be the cause of the prominent WNW-ESE trending features seen in aerial photographs of the Sarqaq area. These features were mistakenly shown on the 1:500 000 map sheet Søndre Strømfjord - Nûgssuaq as fractures associated with Cretaceous faulting.

South of Akínaq the augen gneiss often shows a lineation due to preferred orientation of minerals or mineral aggregates. The lineation generally plunges at 27^{o}-32^{o} towards 280-300.

North of the Cretaceous outcrops at Akínaq the gneiss is homogeneous medium-fine-grained biotite gneiss; the foliation is oriented in ca. 110-120/48-54 S.

On the east side of Sáningassoq an isolated small pod of 'metabasite' occurs in the gneiss. This is a dark medium-fine-grained rock consisting of plagioclase $An_{ca.55}$, clinopyroxene, hornblende, garnet, biotite, opaque phases and a little epidote. Hornblende occurs both as rims to clinopyroxene grains and in aggregates of small grains.

CRETACEOUS

Outcrops; structure

Cretaceous sediments are presumed to underly the whole of the western side of Sarqaqdalen all the way in to the slopes south-west of Uiarsâriaq, but they outcrop only on the higher slopes and in stream-cut gullies. Due to their generally unconsolidated nature the sediments are very prone to weathering and erosion, so most 'outcrops' turn out on closer inspection to be loose sand.

Fig. 1 (opposite). Map showing position of localities mentioned in the text, and of selected spot heights.
Source: Geodetic Institute 1:50 000 maps 70 V.2, J, K, N and O.
The arrows denote palaeocurrent directions in fluviatile Cretaceous sediments (see later).

Only in steep ravines are the outcrops suitable for proper sedimentological examination. There are very few good, accessible lateral profiles.

In the following description, locality numbers used in the report by Shekhar et al. (1982) are retained where relevant (fig. 1). Localities not described by Shekhar et al. are numbered CP1, CP2 etc. In the 1988 season most attention was given to outcrops lying closest to the gneiss basement, as these were most likely to give information as to whether there were syn-sedimentary fault scarps along the Precambrian-Cretaceous boundary and whether syn-sedimentary faulting had any influence on sedimentation.

In spite of the poor quality of outcrop it is often possible to get a good impression of the attitude of the Cretaceous strata from hillsides where the loose material has only slipped a little, and the overall layering is recognisable from the alternation of light (sand) and dark (mudstones and coal) bands. As a general rule the Cretaceous strata in Sarqaqdalen dip towards the east and north-east, i.e. towards the Precambrian basement, at angles between 10° and 16°, although dips up to 27° to NE have been recorded. At one locality (C22 at Kitíngussaq) the orientation of the Cretaceous is 10/46 W, which is completely anomalous. Since the outcrops here are isolated from the remainder of the Cretaceous, this orientation cannot be readily accounted for.

At Akínaq strike directions between 72 and 98 have been measured; dips range from 12° to 24° towards north.

Facies

Two facies dominate the Cretaceous sediments in Sarqaqdalen: cross-bedded coarse-grained sandstone, and mudstone. The other facies represented are conglomerate, cross-bedded medium-grained sandstone, laminated fine-grained sandstone, coal, and cross-bedded fine-grained sandstone. Note that a three-fold (0.06-0.2, 0.2-0.6, 0.6-2.0 mm) division of sand is used rather than the five-fold Wentworth division, on account of the poor sorting of most of the sandstone.

A) Conglomerate

Conglomerate composed of granules occurs in a number of sections in the Cretaceous in Sarqaqdalen. Coarser conglomerate is rare and has only been recorded at C22, CP10, and in two sections in the Akínaq area. Clasts reach 9 cm in length at CP10, but otherwise never exceed pebbles. Quartz is by far the dominant clast type, but there are also clasts of weathered gneiss and schist, particularly in the pebble conglomerates in the Akínaq area. The clasts are usually well rounded.

Cross-bedding is characteristic of the conglomerate beds, although the normally graded pebble conglomerate beds near the top of the section at C22 show no obvious internal structure. Both tabular and trough cross-bedding occur in cross-bedded conglomerate, the former being the most common.

At CP12 at Akínaq the cross-strata in the main pebble conglomerate cross-set is parallel to the base of the channel structure in which the conglomerate occurs. There is a tendency for the pebbly cross-strata to become wider spaced upwards; at the same time the amount of finer material increases. This channel-fill conglomerate constitutes a subfacies of facies A, as it was seemingly not deposited from the same type of bedform as the conglomerate layers elsewhere.

B) Cross-bedded coarse-grained sandstone

White, pale buff or yellowish, very poorly consolidated cross-bedded sandstone is the main component of the Cretaceous sediments in the outer (southern) part of Sarqaqdalen, but is slightly subordinate to mudstone in the inner part of the valley (Shekhar et al., 1982). The sandstone is generally poorly sorted, with grain-sizes ranging from medium-grained sand to granules in single samples. The granules occur both scattered in the sand and concentrated in toesets or along the base of the cross-bedded sets. Grain roundness varies from rounded-subrounded for the largest grains (granules) to subangular-angular for smaller grains.

The composition of the sandstone was estimated in the field to vary from subarkosic to quartz arenitic. The feldspar clasts are weathered; dispersed kaolinite in the sand can be either the product of post-depositional alteration of feldspar clasts or material trapped in the sand during sedimentation.

From the texture and composition of the sandstone it is reasonable to suppose that the sediment is first-cycle material derived by weathering of the Precambrian basement rocks.

In addition to the principal components quartz and feldspar the sandstone often contains a little organic material (coalified wood fragments and comminuted plant material) which is seen especially draping the lower parts of foresets or toesets. Organic-rich mudstone chips or larger, up to 20 x 5 cm, mudstone flakes also occur enclosed in the sandstone.

As already stated, the coarse sandstone is characteristically very poorly consolidated. However, cementation by carbonate (presumably dolomite) has taken place locally, either along selected horizons or, more often, in lenses giving rise to 'doggers'. The cemented sandstone weathers to a characteristic buff-orange colour.

Cross-bedding is seen in all fresh, wind-swept outcrops of the coarse-grained sandstone. Sets seldom exceed 1.2 m in thickness; the thickest set observed is 1.85 m thick. Although it is seldom possible to get a good three-dimensional view of the cross-bedding, the impression gained was that tabular and wedge cross-bedding are the dominant structures in this facies, while trough cross-bedding is subordinate. Commonly the cross-laminae are tangential (Reineck & Singh, 1980, p. 29), i.e. the foresets pass fairly abruptly into short toesets, and long sweeping bottomsets are absent. In thick and coarser-grained sets the foresets are sometimes distinctly graded; the grading is normal (granule to sand) in almost every case recorded, reverse graded foresets only having been observed in the main coarse sand horizon at CP1. There is also a tendency for granules to be concentrated towards the lower parts of the foresets and in toesets, so that the set as a whole appears normally graded. As already mentioned, organic material tends also to be concentrated in toesets and continue up-dip as a draping on the lower parts of foresets.

At three localities - C22, CP4 and CP12 - distinct backflow ripple cross-lamination occurs in the lowest parts of some sets; this backflow structure can be seen because of draping of organic meterial on the ripple foresets. At all three localities the cross-bedding which hosts the backflow structures appears to be tabular.

Water-escape structures are common in the cross-bedded coarse-grained sandstone facies. These usually take the form of antiforms with sharp crests or more complex convolutions. At one locality - CP5 - convolutions 1-2 m high dominate the whole outcrop. The sediments here are coarse sand to pebbly gravel with subrounded quartz pebbles up to a centimetre in size, i.e. the facies here is coarser than usual. Where not totally disturbed by convolutions the cross-bedding is tabular or wedge type.

C) Cross-bedded medium-grained sandstone

This facies resembles facies B in most respects, but the grain-size is finer, the cross-bedded sets are thinner, and neither backflow ripple structures nor grading effects have been observed in the medium sandstone. Lunate ripples were seen in one cemented horizon at CP2.

D) Laminated fine-grained sandstone

The fine sandstone can be completely unconsolidated and better referred to as sand, or well enough consolidated to fully justify the designation sandstone. In colour it varies from white, yellowish, brown, or different shades of grey. A varying content of organic material is the main cause of the colour. Sometimes this material is concentrated in very thin laminae or flasers; muscovite may accompany the organic material. Rarely mudstone is a constituent of the facies which thereby becomes heterolithic.

Structures in the fine-grained sandstone vary from planar lamination through slightly undulating lamination to low-angle trough and tabular cross-lamination and finally small-scale ripple-drift cross-lamination. Since the spread of structures can occur in a single bed, without any specific trend, all the fine-grained sandstone is included in a single facies. Where the fine sandstone is heterolithic, flaser bedding can be developed.

At a few localities, e.g. 7 m above the base of the section at E15, wave ripple lamination is clearly developed in the fine sandstone.

E) Mudstone

This heading covers sediments varying from clay to silt, from black to grey in colour, and from homogeneous and structureless to laminated and fissile. Usually the mudstone is dark in colour and silty, and it often contains scattered grains of fine to medium sand size. Where sand has collected into thin laminae, streaks and lenses, the mudstone becomes a heterolith. Organic material is always present; as the amount of such material increases the mudstone passes into impure coal. Plant fossils of varying quality are to be found in most outcrops.

Where the mudstone in 'pure' (i.e. totally lacks sand) the only structure that can be seen is planar lamination, and even this is not everywhere distinct. As soon as the mudstone becomes heterolithic, with fine sand in distinct structures, lenticular, wavy or planar lamination can be developed.

F) Coal

As documented by Shekhar et al. (1982), the coal layers in the Cretaceous in Sarqaqdalen vary greatly in character, quality and thickness. The following types occur: laminated silty coal, layers composed of coal (coalified wood) fragments, interlaminated mudstone and glossy vitrain, vitrain lenses in mudstone, pure vitrain layers. While the coal in layers consisting of coal fragments is probably allochthonous coal, thin rootlets in the sediment underlying other coal layers indicate that the coal in these layers is autochthonous.

G) Cross-bedded fine-grained sandstone

This facies occurs only at one locality - locality CP8. This is the only locality where intense bioturbation has been observed; the burrowed horizon is about 2 m above the top of the cross-bedded fine-grained sand, and is described later.

The fine-grained sand is very pale in colour and it is well sorted. The cross-bedding is of tabular (-wedge) type, and shows low-dipping foresets sweeping through toesets into bottomsets. Sets are up to 65 cm thick. In some sets there is a little organic material draping toesets and along the base of the set.

The tabular cross-bedded fine sand passes up into trough cross-bedded fine-grained sand in which set thicknesses are 3-10 cm.

Trace fossils

Burrows are seen occasionally in the Cretaceous sediments in Sarqaqdalen. At one locality, CP8, there is a conspicuous intensely burrowed horizon which will be described separately. Minor burrowing has been observed at C8, C19, C22 and E15.

At C8 burrows have been observed at two levels in the coarse sand. The burrows are 3-4 mm in diameter, steep, and slightly irregular. They do not appear to have any wall structure or back-fill. The centre is paler than the host sand, while the wall is darker buff-brown. The burrows are related to levels where there is a slight accumulation of purplish fine sandstone on the toesets of the cross-bedded sand, or rip-up clasts of fine muddy sandstone. The burrows start from this fine sandstone and penetrate the overlying coarse sand almost at right-angles to the foresets (fig. 2). These burrows are interpreted as escape burrows created by organisms that settled in the fine sand during a lull in sedimentation. With renewed strong current and migration of bedforms the organisms made their way towards the new sediment surface as rapidly as possible.

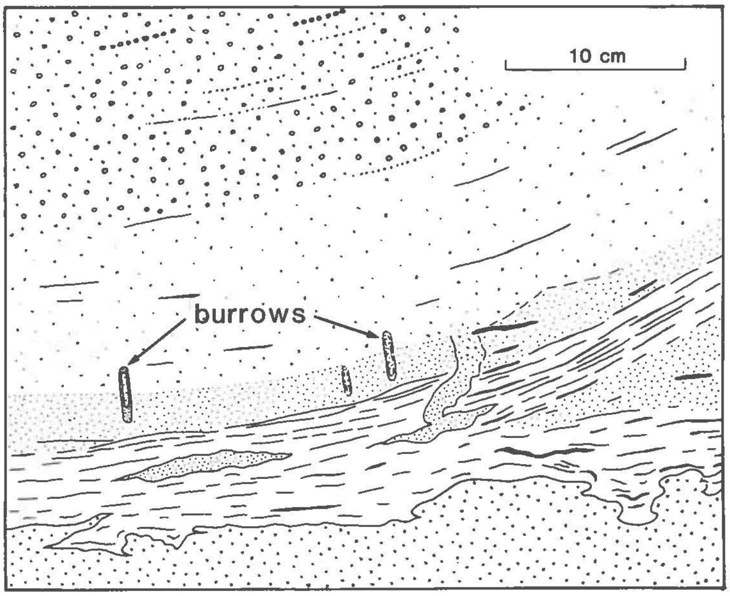


Fig. 2. Sketch of small burrows at a high angle to cross-strata at locality C8, Sarqaqdalen.

The burrows at C19 occur as networks of burrows 4-5 mm wide in fine-grained sand or siltstone.

At C22 steep, slightly irregular burrows 2-3 mm in diameter occur at one level. The host sediment is heterolithic dark siltstone and fine-grained sandstone with wavy and lenticular bedding. Similar burrows occur at E15 in plane-laminated coarse sand and the overlying wave-rippled fine sand near the base of the measured section; some of these burrows branch upwards. At 120 m in the same section small funnel-shaped structures and steep burrows occur at the top of a coarse sandstone layer, immediately below lenticular-bedded mudstone.

The most intense bioturbation in the area is seen at CP8. The section here (fig. 3) shows many other features that have not been observed at any other locality in Sarqaqdalen.

The lowest 7.3 m of the measured section is made up of facies G: cross-bedded fine-grained sand. Foreset dip directions in facies G are towards ESE. This is completely anomalous compared to all the other palaeocurrent indicators measured in the Cretaceous in Sarqaqdalen (fig. 1).

Below the intensely bioturbation horizon the coarse gravelly sand shows what appears to be herring-bone cross-bedding, although the outcrop did not provide a good three-dimensional view of the structure.

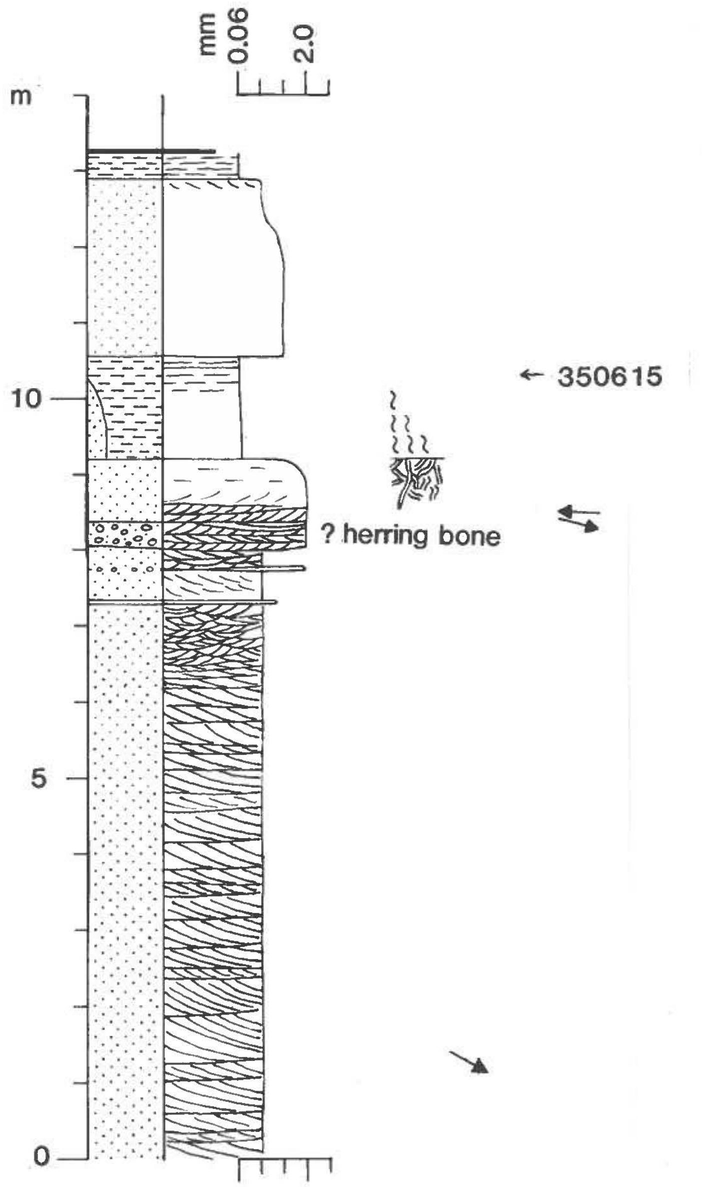


Fig. 3. Graphic log of section with trace fossils at locality CP8, Sarqaqdalen. For legend see Plate 2.

The most intense bioturbation occurs towards the base of a 1.35 m thick dark mudstone layer. The burrows are filled with yellowish fine sand, so that the sediment is a heterolith where the burrowing was strongest.

Burrows extend down from the intensely bioturbated horizon into the coarse sand below. Here the burrows are discrete and can be studied more easily. There are two types:

1) Steep, somewhat irregular tubular burrows 2-3 mm in diameter, marked by dark walls.

2) Irregular burrows 8-9 mm in diameter, with a maximum recorded length of 60 cm. Just below the intensely burrowed mudstone the burrows are in all directions, but as one goes deeper and the burrows become fewer, they also

become generally fairly steep. There is no wall structure, but the burrows stand out clearly because of their dark linings and also because of differential weathering. The dark colour is due to very fine organic material. There is no convincing back-fill structure. The sand filling the burrows may be a little finer-grained than that outside.

The situation described resembles what the writer has observed in the Østerborg Member of the Robbedal Formation of Bornholm (Skaarup & Pulvertaft, 1984). Here an intensely bioturbated horizon of organic-rich very fine sand overlies fine sand with numerous burrows of *Ophiomorpha nodosa*. The *Ophiomorpha* burrows become both steeper and scarser as one proceeds down from the base of the dark bioturbated very fine sand.

The burrows below the intensly burrowed mudstone at CP8 resemble *Ophiomorpha* but lack the knobbly wall structure of the ichnospecies *O. nodosa*. In the intensely bioturbated horizon no ichnogenera could be identified.

Interpretation of facies

Facies A and *B* are high-energy facies. Both facies were deposited mainly from fairly large bedforms, to judge from the thickness of the cross-bedded sets. Where cross-bedding is of tabular type the bedforms must have been transverse bars or megaripples, while the less common trough cross-bedded sets arose from lunate megaripples. Facies B is very similar to facies 1 of Johannessen & Nielsen (1982, p. 15), the dominant facies in the lower part of the Cretaceous section at Pingo, east Disko.

A conglomerate occurring as channel fill (locality CP12 at Akínaq) could not however be related to deposition from any specific bedform.

The following characteristics of the cross-strata enable a more detailed interpretation to be made: cross-laminae are often tangential; concentrations of comminuted coalified plant material commonly drape the toesets; normal grading of cross-strata is quite common, reverse grading rare; there is a concentration of coarser grains towards the toes of the cross-strata; backflow cross-lamination sometimes occurs on toesets and the lowest parts of foresets. Together these features indicate that the cross-strata are sand-flow cross-strata formed by avalanching on lee-side slip faces; reworking by lee-side eddies has moulded the toesets and in places given rise to backflow ripples. The bulk of the sediment was bedload transported by fairly powerful currents in moderate depths of water. It might be avered that avalanching should give rise to reverse grading in foresets as a result of movement of larger particles upwards into zones of lower shear. However, the predominance of normal grading in the foresets does not negate the origin of the cross-strata as sand flows. In a paper on subaqueous sand-flow cross-strata Hunter (1985, p. 887) writes: "In the lower part of a set, grading across the cross-stratum is less regular than in higher parts, and normal size grading is fairly common". In the same paper Hunter states that "... the concentration of coarser grains at the toes of cross strata can be regarded as sufficient evidence of a sand-flow origin" (*op. cit.* p. 888).

The occurrence of numerous water escape structures in some units of facies B indicates that the sand in these units was originally poorly compacted. This in turn suggests rapid deposition.

Facies C was deposited in lower energy conditions and from smaller bedforms than facies A and B, but otherwise does not call for comment.

Facies D is a low-energy deposit. It was deposited entirely from small bedforms varying from undulatory to linguoid in plan form and from rather flat to normal ripples in profile. These variations in bedform were the result of variations in current velocity, water depth and sediment supply during deposition.

The isolated few tens of centimetres of facies D that show wave ripple lamination were obviously deposited under the influence of wave action.

Facies E is a low-energy deposit. However, its silty character and the common presence of sand grains and thin laminae or lenses of very fine sand as components of the facies indicate that deposition took place under the influence of intermittent tranction currents. Only the weakly laminated, sand-free parts are likely to be entirely deposited from suspension.

Facies F - coal is the deposit of the lowest energy conditions that existed in Sarqaqdalen during the Cretaceous. Regardless of whether the coal layers are autochthonous or allochthonous, energy conditions must have been extremely low, as only material that formed on the spot or could float accumulated during deposition of these layers. Increasing content of clay and silt indicate incoming sediment-laden water.

Facies G is a high-energy facies. It is not clear from what bedform the facies was deposited. The cross-strata have too low a dip and too well developed toe- and bottomsets for them to be sand-flow cross-strata (contrast with cross-bedding in facies B).

Facies G will not be discussed further as this point, as the interpretation must take into account the anomalous foreset dip direction in the facies and the position of the facies in a sequence which includes the most intensely bioturbated sediments seen anywhere in the Cretaceous of Sarqaqdalen.

Palaeocurrent directions

Information on palaeocurrent directions was provided mainly by foreset dip directions; supplementary information was provided by pebble imbrication (locality C22) and ripple axes and asymmetry (locally CP2). Fig. 1 summarises the information collected by the writer in 1988.

Accurate readings of foreset dip directions were difficult to obtain because most outcrops only provide a two-dimentional exposure of the cross-strata. If one attempts to expose a cross-strata surface by digging one usually makes it impossible to recognise the structure at all. Thus the total number of readings on current-generated structures obtained in Sarqaqdalen is rather small, and the palaeocurrent arrows on fig. 1 are means of only 3-11 readings from each locality.

Even though reservations must be made on account of the very limited data available, fig. 1 does give a clear impression that palaeocurrents and sediment transport in the Cretaceous of Sarqaqdalen were dominantly towards north and north-west, parallel to the basin axis and to the boundary fault system. This impression is in accord with the preliminary synthesis of the Cretaceous basin presented by Schiener (1975). Only at one outcrop (CP5) does it seem that sediment input was from the nearby gneiss terrain. This is a locality where the sediments are coarser than usual and large-scale water escape structures are the dominant feature.

The outcrops at CP10 are also exceptional. Here the Tertiary Naujat Member is underlain by a few tens of metres of hardened cross-bedded coarse-grained sandstone and pebble, locally cobble, comglomerate. Foreset dip directions show a very wide spread, from 218 to 52, mean 280. As regards both lithology and palaeocurrent data the outcrops recall the Tertiary Quikavsak Member which underlies the Naujat Member elsewhere (Koch, 1959), but set boundaries have much the same strike and dip as the Cretaceous strata in this part of Sarqaqdalen; for this reason the outcrops are assigned to the Cretaceous. They are believed to represent an incursion of the transverse fluvial system that existed in the Akínaq area into the main north- or north-west-flowing longitudinal system in Sarqaqdalen.

In the Akínaq area all foreset dip directions that could be recorded are towards WNW, which is roughly parallel to the fault separating the Cretaceous outcrops in this area from the gneiss terrain to the north (see later).

At locality CP8 the foreset dip directions in facies G are towards ESE, i.e. towards the gneiss hinterland. This is but one of the ways in which this locality is unique in Sarqaqdalen - the others being, as previously mentioned, the occurrence of intense bioturbation and of herringbone cross-bedding (not included in the palaeocurrent measurements).

Facies sequences

In the graphic logs (see figs 4 and 5; plates 2 and 3) the reader can see that rhythmic patterns are not particularly clear in most of the sections logged. Shekhar et al. (1982) recognised only 7 convincing fining-upwards and 3 coarsening-upwards sequences in a total thickness of 1265 metres of measured section from 22 localities in Sarqaqdalen. However quickly Shekhar's group had to work, they would not have failed to record more such sequences had these been distinct.

In the graphic logs presented in this report distinct fining-upwards sequences can be seen at C8, from 9 to 30 m at CP1 and from 70 to 81 m at C22. Less distinct fining-upwards sequences can be seen from 0 to 10 and from 43.5 to 67 m at E15, and from 10.5 to 13.3 m at CP8. The facies sequences are as follows:

C8: A-B-D (-E-F-E; dark mudstone and coal occur in the upper, poorly accessible part of the section)

CP1: A-B-C-D-E-F

C22: A-B-D-E

E15: 0-10 m: B-D (with wave ripples)-E-C-E
43.5-67 m: B-C-D-E

CP8: C-D-E-F

Coarsening-upwards sequences are seen from 47 to 63 m at C22 and from 140 to 150.5 m at E15. At C19 there is an incomplete coarsening-upwards sequence from 28 to 38.5 m in the measured section. The facies sequences are as follows:

C22: E(-B)-E-D-E-C-B

E15: E-D-E-D-E-D-C-B

C19: E-D-?C

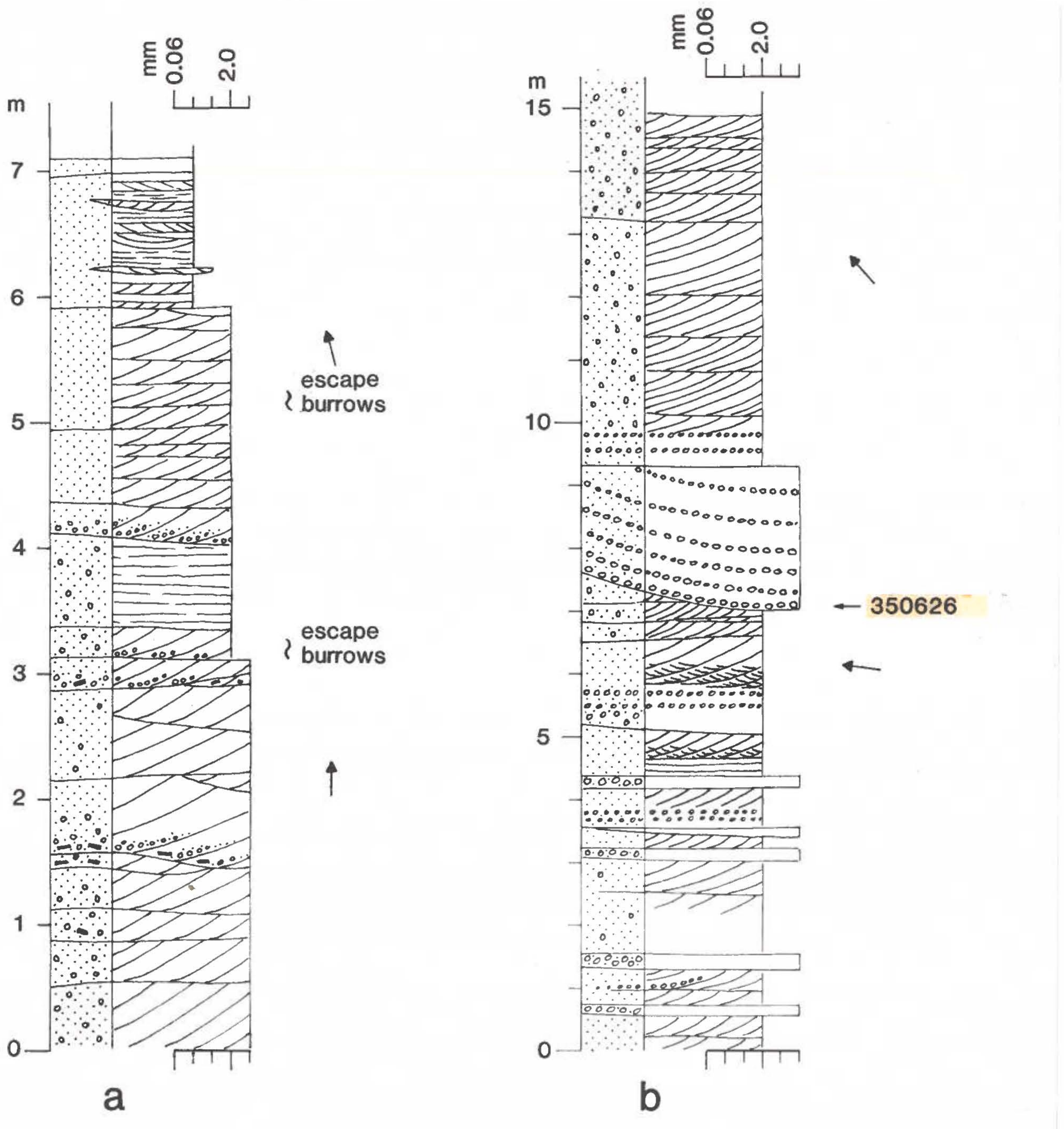


Fig. 4. Graphic logs of sections at localities C8(a) and CP12(b), Sarqaqdalen. For legend see Plate 2.

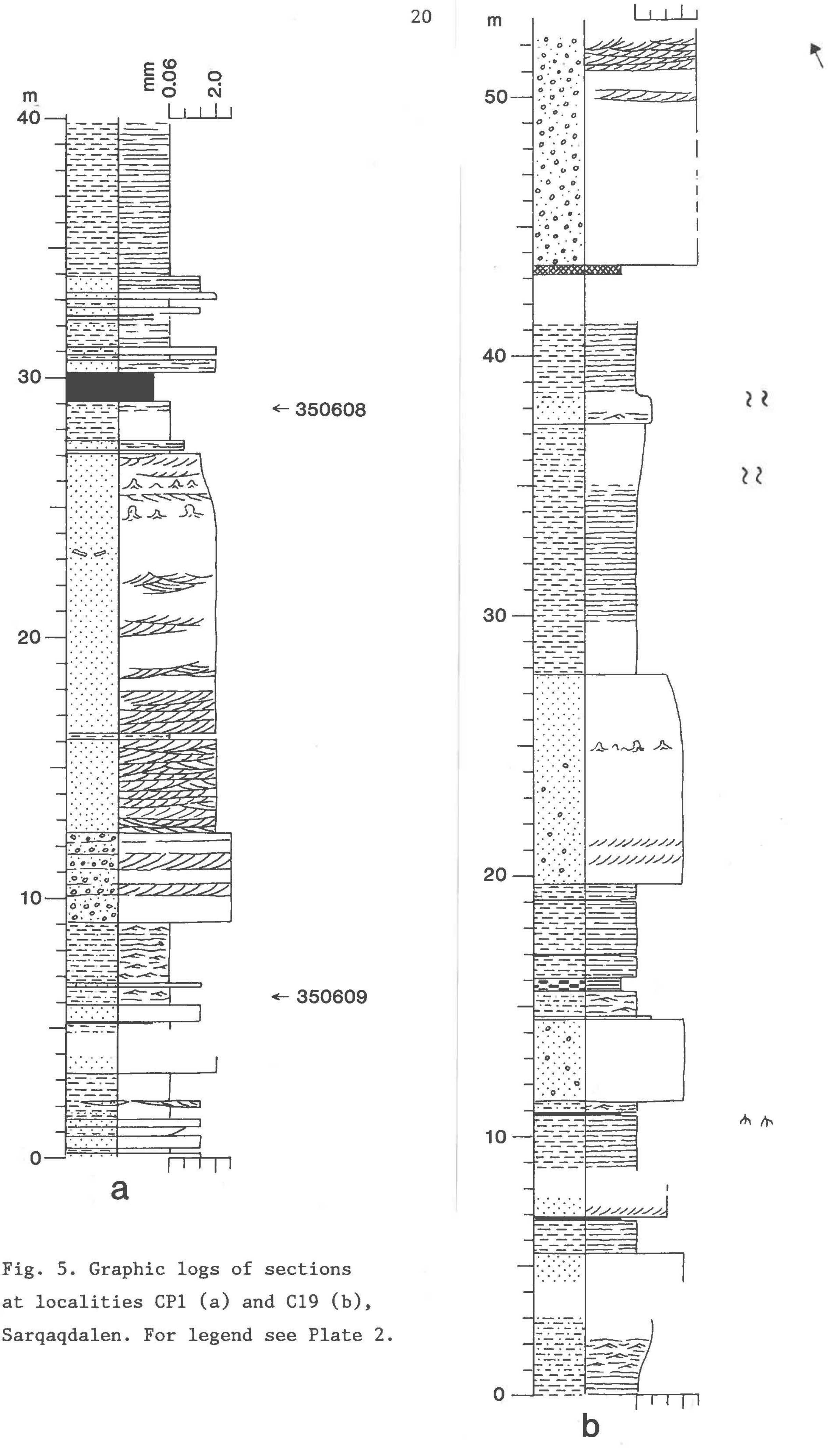


Fig. 5. Graphic logs of sections at localities CP1 (a) and C19 (b), Sarqaqdalen. For legend see Plate 2.

Palaeoenvironment

The six facies A-F are encountered throughout Sarqaqdalen but not everywhere in the same proportions. As Shekhar et al. (1982) documented, there is a decrease in the sand:mud ratio (effectively the facies B:facies E ratio) from south to north and also, in inner Sarqaqdalen, from the lower to the upper part of the succession. The same general trend was noted by Schiener (1975). Unfortunately there are no biostratigraphic data from inner Sarqaqdalen, so there is no knowing if the lateral change in the B:E ratio northwards reflects the original environment at any one time or is the result of a decrease in the B:E ratio in time coupled with a northwards decrease in the age of the sediments. However, since the south-to-north trend in the B:E ratio is consistent with regional models for the Cretaceous palaeogeography in West Greenland (Rosenkrantz & Pulvertaft, 1969; Schiener, 1975; Ehman et al., 1976; Surlyk, 1982), it is regarded as reflecting a regional change in the palaeoenvironment.

The data presented in the foregoing sections are completely consistent with the models for the palaeoenvironment in the area described by Schiener (1975) and illustrated by Surlyk (1982, fig. 6). These workers indicate that during the Late Cretaceous a northward-flowing braided river system covering east Disko and outermost Sarqaqdalen passed northwards into a delta plain with meandering river-courses and widespread swamps. This gave way in turn to a barrier bar-delta front situation along a line running approximately north-east from Alianaitsúnguaq on the south coast of Nûgssuaq. North-west of this lay a pro-delta - shallow marine area in which dark mudstones with oil and gas source-rock potential were deposited.

Since Schiener (1975, p. 380), without any documentation, originally suggested that the southern, proximal part of the fluvial system was braided, evidence and arguments supporting this suggestion have been coming forward. Johannessen & Nielsen (1982) have presented a fairly thorough case for interpreting the lowermost 300 m of the section at Pingo, east Disko, as the deposits of braided rivers. Their interpretation of the graded tangential cross-laminae in their facies 1 does not quite accord with the results of newer work on such cross-strata (Hunter & Kocurek, 1986), but this does not affect the overall validity of their proposal that facies 1 (equivalent of facies B of this report) was deposited from migrating transverse bars in a braided river environment. Pedersen & Jeppesen (1988) describe sections from Gule Ryg, also in east Disko, in which laterally aggregated point bar deposits are intercalated with typical braided river sands. They propose a modified South Saskatchwan River depositional model in which sinuous channels giving rise to point bars developed during periods of low-stage flow.

Returning to Sarqaqdalen, it seems reasonable to interpret facies A and B in the outer part of the valley as deposits from transverse, possibly linguoid, bars in a braided river system. Where, as is sometimes seen, facies B shows trough cross-bedded sand overlain by tabular cross-bedded sand, the transverse bars have migrated over a dune field deposited in a deeper channel (cf. Cant & Walker, 1978). Facies E is a flood plain deposit laid down outside the area of braided channels. Facies D can have arisen in a number of ways, on sand flats or bar tops, during final infilling and shallowing of channels prior to abandonment, on levees, or during flooding of the alluvial plain, depending on the position of the facies in the sequence.

In central and inner Sarqaqdalen where facies E becomes more important, more extensive interchannel plains developed, with vegetated swamps and peat bogs (represented by facies F - coal), and probably also lakes.

Well-developed fining-upwards sequences such as at CP1 and C22, and at C15 in Shekhar et al. (1982), may be the products of meandering river belts, but lack of good lateral exposure at these localities makes it impossible to recognise lateral accretion (epsilon cross-bedding). The fining-upwards sequence at the bottom of the measured section at E15 is exceptional because of the wave ripple cross-lamination in facies D in this sequence. This suggests channel abandonment or deposition in a shallow lake or lagoon; however, *fining*-upwards sequences are not characteristic of lacustrine deposits.

In a general alluvial plain environment coarsening-upwards sequences can be the product of prograding crevasse splays or lacustrine deltas. The thickness of the coarsening-upwards sequences in Sarqaqdalen suggests that they arose in lacustrine deltas.

The unusually coarse-grained section at CP12 (fig. 5) at Akínaq was deposited in a powerfully flowing braided river system. The bars were at least once broken through by a major channel. The remainder of the outcrops at Akínaq are so poor that no conclusions can be drawn from them. As far as could be seen, facies B dominates the Cretaceous of this area, while facies A and E are subordinate.

The section that remains to be accounted for is that at CP8. Intense bioturbation, ?herring-bone cross-bedding, and anomalous foreset dip directions are the features that distinguish the sequence here from any other seen in the Cretaceous of Sarqaqdalen. The presence of *Ophiomorpha*-like burrows is suggestive of marine conditions, but on its own *Ophiomorpha* is no proof of such conditions (Stewart, 1978). In the present context a tidal channel-lagoon-estuary situation can be suggested, in which the organisms that created the *Ophiomorpha*-like burrows lived in the sand underlying a lagoon. Abundant burrowing organisms inhabited the fine sediment that filled in the lagoon which finally was overrun by the fluvial system. Facies G, which makes up the lowest unit in the section at CP8, is not easy to account for. The well-sorted fine sand forming the facies was deposited in bedforms that migrated towards the hinterland of the basin, which suggests that these bedforms might have been longshore or small barrier bars, but cross-bedding in such bars is usually planar and relatively high-angle (Davidson-Arnott & Greenwood, 1974).

Comparison with the Cretaceous at Kûk

The Cretaceous sediments at Kûk on the north side of the Nûgssuaq peninsula have been described by the writer (Pulvertaft, 1979). Just as in Sarqaqdalen, the sediments at Kûk lie close to the Cretaceous boundary fault system.

The Cretaceous sediments at Kûk belong to three different facies associations. The dominant association, facies association A, is dominated by coarse, cross-bedded subarkosic sandstone and dark laminated silty mudstone (facies A1 and A4 of Pulvertaft (1979) respectively). While the facies A4 mudstones are overbank deposits of the flood plain, just as they are in Sarqaqdalen, the cross-bedded sandstone of facies A1 is trough cross-bedded and occurs mainly as channel fill. Furthermore foreset dip directions and trough and channel axes are towards the north-west, i.e. oblique to the inferred margin of the basin. On the other hand facies association C at Kûk with its tabular-tangential cross-bedded medium-grained sandstone (facies C1) can be called a finer-grained version of facies B in Sarqaqdalen. Facies C1 shows generally northward-dipping foreset dips, and the facies association was interpreted by the writer as deposited in the distal part of a sandy braided river flowing northwards parallel to the axis of the basin. Having now seen the Cretaceous sediments in Sarqaqdalen the writer reaffirms his interpretation of facies association C at Kûk, and regards this association as representing periods when the braided river system which dominated the scene in east Disko and Sarqaqdalen encroached the delta plain at Kûk which, unlike that farther south, was fed by streams flowing north-westwards from the gneiss hinterland.

The coarsening-upwards sequences of facies association B at Kûk are not like those seen in Sarqaqdalen or at Pautût to the west, a locality the writer visited under the guidance of Helle Midtgaard and Torben Olsen. The sediments in facies association B at Kûk are finer-grained, better sorted, and show much more delicate structures than the coarsening-upwards sequences on the southern side of Nûgssuaq; the coarsest facies in association B shows large wave ripples and is probably a storm deposit. The writer believes that the coarsening-upwards sequences of facies association B at Kûk were not developed at the front of a major delta, but rather represent small deltas that developed in secluded lagoons and interdistributary bays, or perhaps in lakes.

TERTIARY

Sediments

The Lower Tertiary (Paleocene) sediments in outer Sarqaqdalen and above Atanikerdluk were described by Koch (1955, 1959), who divided them into 5 members which together make up the Upper Atanikerdluk Formation. The lowest of these members is the Quikavsak Member, a fluviatile unit which was deposited in wide channels incised in the underlying Cretaceous. The Quikavsak Member is overlain by the Naujât Member, a dark, organic-rich shaley mudstone of lacustrine origin (see also Schiener & Leythaeuser (1978) and Pedersen (1987)). Since the Naujât Member is the subject of detailed sedimentological and palynological investigations being carried out by Gunver K. Pedersen and Birgitte F. Rasmussen respectively, the present writer only cursorily examined the Tertiary sediments. However, their boundary with the Cretaceous was mapped and the Naujât Member was found to extend farther north than hitherto known. As already described by Koch (1955, 1959), the Tertiary sediments in Sarqaqdalen are virtually horizontal, and hence there is an angular unconformity between the Tertiary and the underlying Cretaceous (see Koch 1955, fig. 15).

Quikavsak Member

This member was only recorded in outer Sarqaqdalen. In spite of the angular unconformity at the base of this unit, its recognition is not always easy because lithologically the member resembles facies A and B in the underlying Cretaceous. There is thus little contrast between the Quikavsak Member and the underlying Cretaceous where the latter is dominated by facies A and B. Shekhar et al. (1982) did not record the Quikavsak Member in their profiles E13 and E14, both of which should cross the member (Koch, 1959, plate 5). Ehman et al. (1976) recorded 6.5 m of sandstone and conglomerate belonging to the Quikavsak Member in their profile N-1 which crosses the member between E13 and E14. In their notes they state that the base of the member cuts deeper into the Cretaceous as one passes southwards from N-1 (i.e. moves towards E13). The present writer's observations accord with those of Ehman et al. (1976).

Naujât Member

The Naujât Member consists largely of laminated dark mudstone. In the uppermost part of the member sandy layers appear. Thin tuff horizions occur in the unit (Gunver K. Pedersen, pers. comm.). On most slopes the mudstone disintegrates into small chips, both grey and yellowish brown in colour. Where the Naujât Member directly overlies the Cretaceous, there is a thin pebble conglomerate with clasts entirely of vein quartz; blocks of clay ironstone with plant fossils are strewn around near the contact but this lithology was not seen *in situ*.

Cretaceous-Tertiary boundary surface

As already mentioned, the Tertiary sediments overlie the Cretaceous with angular unconformity. Although the Tertiary sediments are virtually horizontal, the surface of the unconformity is not.

The altitude of the surface of unconformity is ca. 360 to 450 m between E13 (above Naujât) and Tarajornitsoq. In the hills north-east of Tarajornitsoq the surface shows considerable relief and in one place climbs from 580 to 820 m a.s.l. in a distance of one kilometre (heights based on the 1:10 000 topographic map prepared from GGU by Aerokort A/S).

South-west of Uiarsâriaq the Cretaceous-Naujât Member boundary is at 630-650 m a.s.l. A Tertiary sill follows the boundary here for a few hundred metres.

Because of the marked relief shown by the Cretaceous-Tertiary boundary surface in the hills north-east of Tarajornitsoq, there is no reason to suggest that faults are the cause of the difference in the height of this surface across valleys such as Tarajornitsoq and Eqip atâ.

Basalts

Basalt lava flows and, locally, hyaloclastites and breccias, cap the Tertiary sediments on the west side of Sarqaqdalen and overlap onto the Precambrian basement north-west of Uiarsâriaq and also around the .1266 m summit north of Akínaq. Since basalts were inspected only in a few outcrops WSW of Uiarsâriaq, no attempt has been made to divide them into lithological divisions on the map.

The outcrops that were visited all lie east of the glacier on the south-east side of the .1569 m mountain called Eqe, west of Uiarsâriaq. The basalt flows here all dip towards the west at angles around 20°. This is completely anomalous in an area where the regional dip of the Tertiary sediments and overlying basalts is virtually zero. The explanation must be that the basalts south-east of Eqe belong to one of more major rotated landslide blocks which have slid on the underlying relatively plastic Naujât Member.

The lowest horizon of basalt is a hyaloclastite/breccia horizon within the Naujât Member. The base on the lowest of the basalt flow series overlying the Naujât Member has a 'ball-and-pillow' relationship with the underlying mudstones, indicating that the muds were wet and unconsolidated at the time the basalt was extruded.

The dominant basalt type in the landslipped mass(es) is an olivine-porphyritic basalt with olivine phenocrysts 1-2 mm long. Some of the flows are thick and massive, weather brownish, and from a distance cannot be distinguished from the other main basalt type present - a 'small feldspar'-porphyritic basalt. Exposures of the thinner olivine basalt flows have a greyish colour. The olivine basalt flows become vesicular and rich in zeolite minerals towards their tops.

The 'small feldspar'-porphyritic basalts form brown-weathering flows, some of which show columnar jointing. Vesicles in these flows are usually empty.

From the foregoing it would appear that the sequence of basalts represented in the landslipped mass(es) south-east of Eqe belongs to the upper part of the Vaigat Formation, in the transition zone to the overlying Maligât Formation, using the lithostratigraphic nomenclature for the West Greenland basalt province introduced by Hald & Pedersen (1975).

Dykes, sills and sheets

Dykes, sills and sheets of dolerite and basalt occur throughout Sarqaqdalen and cut all the rock units described in the foregoing sections. The only dykes *not* likely to the Tertiary are two large NNW-SSE trending dykes that cut the Precambrian basement north of Sarqap taserssua and east of Sarqaqdalen. These two dykes have the same orientation and order of size as the very prominent dyke farther east that has given a Rb-Sr isochron age of 1645 +/- 30 Ma (Kalsbeek & Taylor, 1986).

The most imposing basic intrusions in the area belong to the system of sheets described by Munck (1945). These sheets are particularly conspicuous around Naujât, at Sulugssugutit qáqâ, and in the inner part of the Sarqaqdalen valley where a large sheet follows the plane of the Precambrian-Cretaceous boundary fault for more than 20 km (see later). Major sheets, both apophyses from this sheet and later sheets, cut into both the Precambrian basement and the Cretaceous sediments. The rock forming these great sheets is a brownish-weathering medium-grained quartz dolerite. Its field occurrence and petrology have been described in some detail by Munck (1945), and interested readers are referred to this work. Note however that Munck is not correct where in one place (*op. cit.* p. 37) she states that "east of the fault the dolerite has not been able to penetrate the hard gneiss wall". At Sáningassoq it can easily be seen that a dolerite has done just this.

Smaller sills and sheets occurring in the sediments north-east of Tarajornitsoq are formed of plagioclase-porphyritic dolerite, a rock that is distinctly different from the dolerite of Munck's sheet complex.

Dykes cut not only the Cretaceous-Tertiary sediments but also the basalts. In the slopes around E13 and CP10 these are rather irregular, but farther north E-W and NNW-SSE directions seem preferred.

FAULTS

The main objective of the 1988 field work in Sarqaqdalen was to achieve a better understanding of the character and timing of the major fault system that marks the eastern boundary of the Cretaceous in this region. However, due to lack of exposure, little could be added to the account already given by Munck (1945) as far as the fault in Sarqaqdalen itself is concerned. That there must be such a fault is obvious, as Cretaceous-Tertiary sediments up to over 800 m a.s.l. on the west side of the valley face steep gneiss slopes up to over 1000 m high on the east side. There is no evidence whatever to suggest that such high gneiss slopes existed here during deposition of the Cretaceous or Tertiary.

One of the major features of Sarqaqdalen is the suite of major, largely interconnected, dolerite intrusions that has already been mentioned and that was described by Munck (1945). For a distance of about 22 km, stretching from Kitíngussaq (C22) in the south to Uiarsâriaq in the north-west, one of these intrusions coats the eastern and north-eastern side of the valley. The gneiss along the north-east contact of this dolerite was examined at Sáningassoq and Uiarsâriaq, and was found to show obvious effects of fault movement: fracturing and brecciation, chloritisation of dark minerals, and a general bleaching.

The west/south-west contact of this dolerite is nowhere exposed. The first outcrops one encounters on this side of the dolerite are of Cretaceous sediments. Thus there is good reason to accept Munck's conclusion that in this part of the valley dolerite was emplaced along the plane of a major fault separating the gneiss basement from Cretaceous sediments. The dip of the dolerite-crushed gneiss contact, which is taken to be the dip of the fault plane, is between 47° and 60° to the west or south-west. Where this dolerite has sent apophyses into the basement gneiss, these have a lower dip to the west and south-west than the fault plane, and in places can be seen to have a half-saucer shape.

The course of the Cretaceous boundary fault in Sarqaqdalen is shown on the map Plate 1. As can be seen from this map, the fault system takes a number of turns, but there is *no* evidence for branching of the fault. No connection exists between the Cretaceous boundary fault in Sarqaqdalen and that at Kûk on the north side of Nûgssuaq. There are some N-S features in the gneiss at Sáningassoq which are easily seen on aerial photographs, and it is presumably these that were misinterpreted as a branch of the main fault when the

1:500 000 map sheet Søndre Strømfjord - Nûgssuaq was drawn. No such branch of the main fault was drawn in A. Rosenkrantz's original sketch map of the fault.

In the Akínaq area, where exposures of the Cretaceous are otherwise very poor, the boundary fault is exposed in a gulley 6.5 km north-east of Sarqaq. The strike and dip of the fault plane here is 96/73 S. Approaching the fault the gneiss (a homogeneous medium-fine-grained biotite gneiss) becomes fractured and its biotite chloritised. A few centimetres of soft brown crush material separates the fractured gneiss from a 5-10 m wide zone of intensely brecciated and crushed gneiss, which in turn is bordered by strongly disturbed Cretaceous sand and pebble conglomerate. A few metres from the fault all signs of fault disturbance disappear in the sediments, which now strike 75° and dip 16° towards the fault.

The sediments bordering the fault belong to facies A and B, with facies B dominating. In facies A - conglomerate, the clasts are up to 6 cm long and are mainly of quartz, but also of gneiss and very fine-grained ?metasediment; one flint clast was found. The conglomerate forms layers parallel to set boundaries in the cross-bedded facies B sand (plane beds) and also single cross-strata and accumulations along toesets within facies B. In facies B cross-bedding, apparently all tabular, is ubiquitous, and foreset dip directions *seem* all to be towards ca. 295.

Crushed, brecciated and reddened gneiss outcrops at Augpilagtoq and in the banks of the river Augpilagtup kûa. These outcrops are believed to be very close to the boundary to the Cretaceous. A prominent plane with slickensides separates fractured gneiss from intensely crushed gneiss; this plane is almost vertical and strikes 96, which is about the strike of the fault plane where it is exposed 6.5 km north-east of Sarqaq. A line joining these two localities however strikes 110. The Precambrian-Cretaceous boundary fault at Akìnaq may therefore have an overall trend in 110 but in detail be made up of a series of en echelon faults striking 96.

The southern margin of the Cretaceous sediments at Akínaq is not exposed. It is believed that the sediments overlie the gneiss here without the intervention of a fault. However, no signs of Cretaceous weathering of the gneiss have been seen in this area.

As mentioned in an earlier section, the Cretaceous strata in Sarqaqdalen dip towards the east and north-east at 10°-16°, locally up to 27°. These dips suggest that the westward-dipping boundary fault is listric, the roll-over of the Cretaceous beds accomodating the effect of extensional displacement on a curving fault plane. The dip of 46°W at C22 is anomalous, but the outcrop is isolated and hence its structure cannot be properly accounted for.

The general dip of the Cretaceous strata in the Akínaq area is northerly, i.e. towards the boundary fault in this area, although the strike direction is not consistent from outcrop to outcrop.

Timing of the faulting

Cretaceous strata have been displaced and tilted by movement on the boundary fault system, and in one place are seen in direct fault contact with Precambrian gneiss. The Tertiary sediments and basalts on the other hand are virtually horizontal. This suggests that the main movement on the boundary fault system took place before middle Danian, the earliest reliable biostratigraphic age as yet obtained from the Tertiary of Nûgssuaq (Perch-Nielsen, 1973, Jürgensen & Mikkelsen, 1974; Hansen, 1980; see review by Pulvertaft (1987)). The question of whether there was any post-basalt movement at all on the fault system cannot be answered until the detailed study of the stratigraphy in the basalt province at present being carried out by Asger K. Pedersen and Lotte M. Larsen has been extended into the Sarqaqdalen area.

The timing of the initiation of the fault movements is not clear from the evidence available. The river system within which most of the Cretaceous sediments in Sarqaqdalen were deposited flowed northwards or north-northwestwards, implying that there was a major river valley in this direction in Late Cretaceous time. The almost complete absence of palaeocurrent data indicating flow from the east (apart from the outcrops at CP10 which have already been accounted for), and of conglomerates derived from this direction, indicates that no important tributary systems entered the valley from the gneiss hinterland to the east, and that the east slope of the valley was not steep. In other words: there is no evidence for the existence of a major fault scarp along the east side of Sarqaqdalen when sedimentation was taking place, i.e. in ?Albian-Cenomanian time (Ehman et al., 1976; Croxton, 1987a). The same seems to have been the case north-east of Akínaq where, however, the boundary fault and inferred river valley have a WNW course.

Since something must have determined the course of the depression that was to become a major river valley around mid-Cretaceous times, it is possible that the depression was caused by subsidence along the boundary fault system. If sedimentation kept pace with subsidence, no prominent fault scarps would develop. Alternatively there may only have been a sag in this area throughout most of Late Cretaceous time, faulting on Nûgssuaq not having begun until the end of the Cretaceous.

Comparison with the Cretaceous boundary fault elsewhere

At Kûk on the north side of Nûgssuaq Albian-Early Cenomanian (Ehman, 1977) or perhaps pre-Albian (Croxton, 1978b) sediments laid down in a braid-delta system flowing from the south-east are cut off sharply to the east by the Cretaceous boundary fault, without any change of facies approaching the fault (Pulvertaft, 1979). The sediments must therefore have extended east of the fault, and displacement on the fault seen here must be post Early Cenomanian. As has already been pointed out, the fault at Kûk is *not* a continuation of that in Sarqaqdalen, and the Kûk fault block may have a different history of subsidence and tilting than the remainder of the Cretaceous basin.

In south-west Upernivik Ø Upper Albian-Cenomanian fluvio-deltaic sediments show a general northeasterly dip. Foreset dip directions show considerable spread, but are mainly to the north-west (Croxton, 1978a). Cobble conglomerate occurs along the boundary fault at the only locality where this is exposed. The fault plane dips south at 60°. All lithologies known in the adjacent gneiss terrain are represented in the clasts in the conglomerate, but in the present context it is the occurrence of cobbles of gneiss that appear to have been affected by low-temperature shearing *before* incorporation in the largely undeformed conglomerate that is of interest. It appears here that movement on the fault took place before as well as during deposition of the sediments exposed at this locality.

On the north-west corner of Upernivik Ø there are small outcrops of Cretaceous sediments but no exposure of the fault contact with the gneiss basement. However, the occurrence of boulder conglomerate beds here, with boulders up to more than a metre in length, indicates very high energy conditions and the proximity of a steep gradient during deposition. This gradient may well have been established by faulting.

On the west side of Qeqertarssuaq a sequence of presumably fluviatile sediments of Late Albian - Early Cenomanian age (Ehman et al., 1976: Croxton, 1978a) is exposed. Dip directions are variable, but mainly to the east. Near the boundary to the Precambrian to the east, here metamorphosed flysch of the Nûkavsak Formation, layers of boulder conglomerate occur in which most boulders are of metagreywacke from the Nûkavsak Formation. Clasts vary from pebbles to ca. 50 cm long boulders, and are fairly well rounded and closely packed. The conglomerate appears to have been deposited in a fluvial fan fed by very fast-flowing streams flowing from the Nûkavsak Formation terrain to the east. As in north-west Upernivik Ø, the high-energy conditions require steep gradients which are likely to have been established by displacements along the Cretaceous boundary fault system.

The outcrops of Nûkavsak Formation lying closest to the outcrops of conglomerate show obvious effects of shattering and brecciation.

The Precambrian-Cretaceous boundary fault on Svartenhuk is complicated by the fact that there has been considerable Tertiary inversion in this area (Rosenkrantz & Pulvertaft, 1969; Münther, 1973). Furthermore, according to Croxton (1978b), the sediments that abut on steeply dipping gneiss surfaces on Svartenhuk may all be of Paleocene age.

QUATERNARY

Extensive Quaternary deposits occur in Sarqaqdalen. These include moraine, scree, rock glaciers, solifluction deposits, glacio-fluvial and lacustrine deposits. Patterned ground is widespread, particularly in inner Sarqaqdalen.

On the map Plate 1 only historical moraines are distinguished. These mark the position of glaciers during the period of maximum advance in historical time which in this area was towards the end of the last century (Weidick, 1968). It is noticable that where the material in the historical moraines is dominated by basalt debris, vegetation is far more advanced that on the virtually bare gneiss-dominated moraines. Very much older moraine features are identifiable in places.

On aerial photographs pale 'showings' are seen that can be mistaken for outcrops of Cretaceous sand but in fact are of Quaternary sediments. On the south-west side of Sarqap taserssua these are of glacio-fluvial gravel consisting entirely of more or less angular gneiss pebbles and granules.

South of Sáningassoq there are stream gullies near the large river in which interlaminated dark mud and silt, and pale very fine to fine sand are exposed. The dark mud and silt alternate in plane-parallel laminae up to 3 mm thick which show slight grading and might be small-scale varves. The pale very fine to fine sand is very well sorted within the scale of a few metres thick intervals. Both planar and small-scale ripple-drift cross-lamination are seen in this sand. Small abraded coal fragments are scattered along some horizons.

It is thought that these sediments were deposited in an ice-dammed lake during the waning of the Wisconsin glaciation, but the position of the ice tongue that dammed the lake could not be ascertained.

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Plates

Plate 1

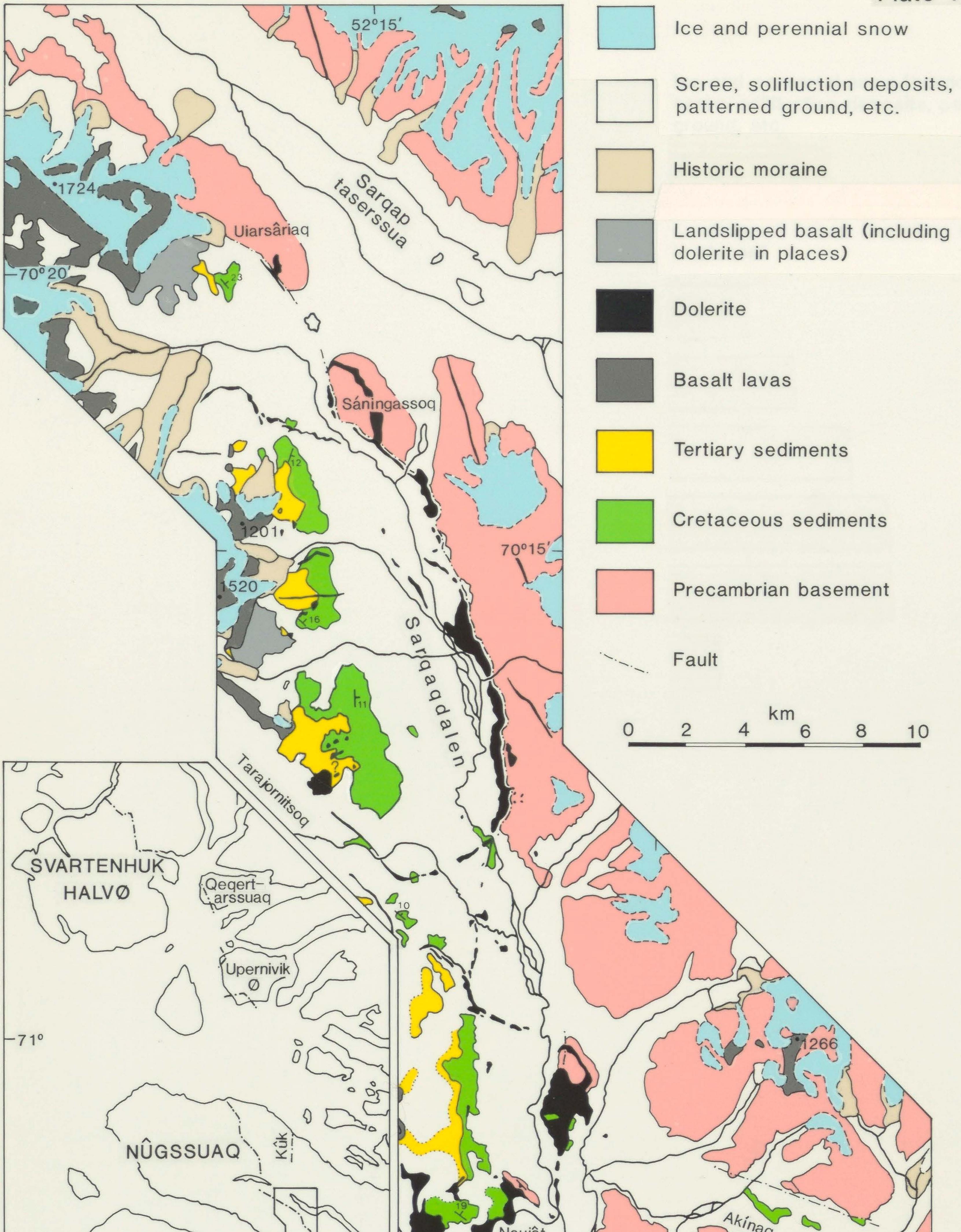
Ice and perennial snow
Scree, solifluction deposits, patterned ground, etc.
Historic moraine
Landslipped basalt (including dolerite in places)
Dolerite
Basalt lavas
Tertiary sediments
Cretaceous sediments
Precambrian basement
Fault
km
0 2 4 6 8 10
52°15′
Sarqap taserssua
1724
Uiarsâriaq
70°20′
Sáningassoq
1201
1520
70°15′
Sarqaqdalen
Tarajornitsoq
Naujât
Akínaq
1266
Sarqaq
52°
SVARTENHUK HALVØ
Qeqertarssuaq
Upernivik Ø
71°
NÛGSSUAQ
Kûk
70°
DISKO
53°
a
b

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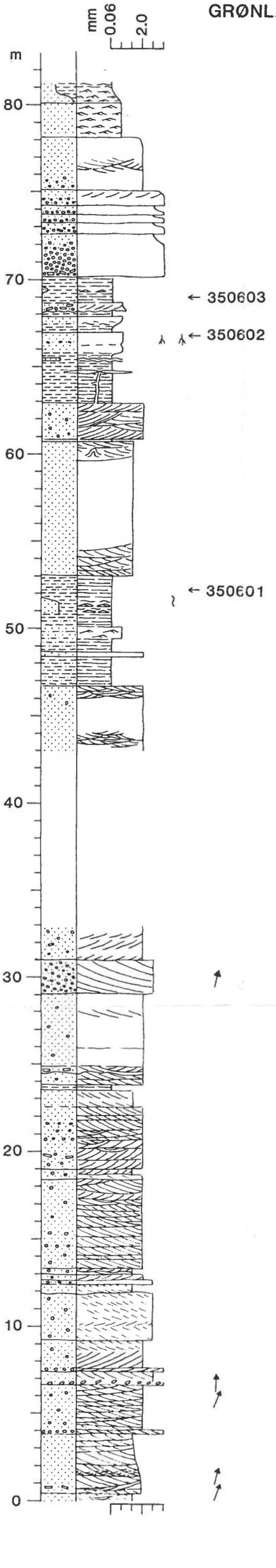
Plate 2

Locality C 22



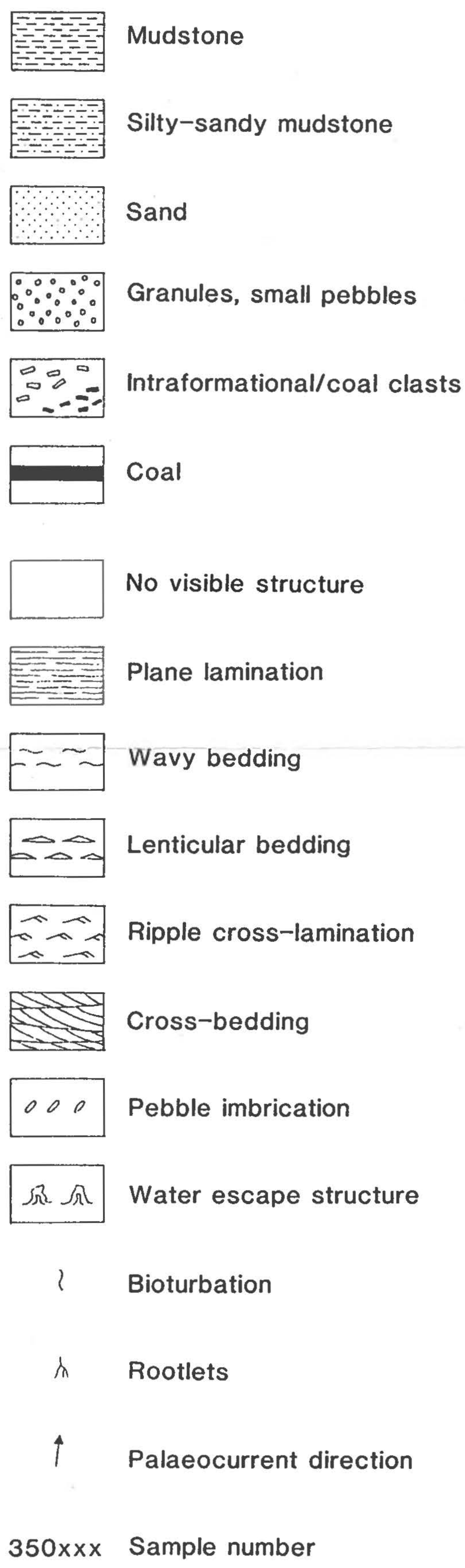


Plate 3

Locality E 15

(for legend see Plate 2)