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The Sandstones of the Precambrian Eriksfjord Formation in South Greenland

by

Valdemar Poulsen

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VALDEMAR POULSEN

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Abstract

The Precambrian continental sandstones in the Julianehåb district, South Greenland, are discussed with regard to distribution, lithology, structures, and origin. The sandstone/volcanics sequence, which was included as part of the Gardar formation by Wegmann (1938), is established as a separate formation - The Eriksfjord Formation. The formation is divided into six members, and a tentative correlation between the now separate sandstone areas is presented.

INTRODUCTION

The present report deals mainly with a Precambrian continental sandstone in a sandstone/volcanics series on both sides of Tunugdliarfik Fjord, known to the early Norse settlers as Eriksfjord, in the Julianehåb district, South Greenland.

The writer mapped the sandstones in the Tunugdliarfik area during the field seasons 1958-1959-1961. The volcanic rocks within the same area have been mapped by J. W. Stewart.

Essential contributions to the knowledge of the geology of that area are the works of Ussing (1912) and Wegmann (1938). The Igaliko sandstone was the name introduced by Ussing to comprise all the sandstones in the area.

The Gardar formation was established by Wegmann (1938, p. 60) to comprise "both supercrustal and abyssal members .... a kind of unfinished attempt to form a geosyncline". The terminology is not in accordance with current stratigraphical nomenclature, and during field work and in recent publications the GGU geologists have used informal terms like "Gardar age" or "Gardar period". The Gardar formation sensu Wegmann would possibly fall within the stage category, and lithostratigraphically ranks as a group.

The sandstone/volcanics succession, which is the subject of this report, constitutes the oldest element in Wegmann's Gardar formation. This element in all respects appears as a unit that should rank as a formation, for which the name Eriksfjord Formation is proposed.

Absolute age determinations (Moorbath, Webster and Morgan, 1960) give about 1600×10^6 years for the Julianehåb granite which is the basement to the sandstone, and about 1100×10^6 years for the Ilímaussaq intrusion which penetrates the sandstone/volcanics sequence.

THE DISTRIBUTION OF THE SANDSTONE/VOLCANICS SEQUENCE

The accompanying map shows the distribution of the sandstones and the volcanic rocks on both sides of Tunugdliarfik Fjord.

The boundaries of the separate areas are mainly determined by faults, and within the individual fault blocks erosion in many places has exposed the basement granite. The best preserved and most complete section, which is proposed as the type section, is seen between Mâjût and Ilímaussaq on the north side of Tunugdliarfik.

The northernmost sandstone exposures north of Tasiussaq are believed to have been deposited close to the boundary of the basin. The boundary environment is indicated by the presence of huge granite blocks forming part of the basal conglomerates - in this area possibly rather fanglomerates. Another striking fact is the extension of the explosive breccias - or intrusive volcanic breccias (J. W. Stewart, written communication) - separating the Mâjût and Mussartût Members. In the area west and northwest of Qagssiarssuk remnants of volcanic breccias - containing only granite and gneiss boulders - are found resting directly on the Julianehåb granite. This indicates that the explosive volcanism has also been active outside the basin of deposition. Identical "granite breccias" are found at Kiagtût at the coast just north of Narssarssuaq.

However the area of deposition was more extensive to the northeast. C. H. Emeleus (written communication) reports sandstones and lavas on the northeast side of the Igaliko batholith, some 35 km northeast of Igaliko village. These strata occur above the 1000 m contour and dip towards the southwest.

The southern boundary of the basin is not known. Upton (1962) found xenoliths of quartzite and basalt in the Central Complex of Tugtutôq, but otherwise no occurrences of the Eriksfjord Formation are known south of the map area.

After deposition of the sandstones and the extrusion of the basalt flows extensive faulting occurred, and the area was divided into a number of tilted fault blocks of different height. Erosion has since removed most of the sequence, although the Mâjût-Ilímaussaq section seems to represent the major part of the sequence. The upper part of the succession is predominantly volcanic, but a small remnant of a conglomerate bed on top of Ilímaussaq indicates that a new phase of sedimentation followed.

THE SANDSTONE

The major part of the sequence consists of a rather uniform, fine- or medium-grained sandstone varying in colour from greyish-white to dark red, but the predominant colour is a uniform orange-pink. The colouring matter is always hematite. Impregnation with quartz has taken place at many levels, so that the sandstone appears as a quartzite. The quartz grains are mostly well-rounded. The sandstone is fairly hard and resistant to weathering.

Bleaching of the sandstones is very common in the vicinity of dykes, along joints, and may be observed also at other places - as for instance in the section exposed in the coastal cliff at Sitdlisit. The sandstone here is white-spotted along joints, fissures, and bedding planes.

The grain sizes cover a wide range, the result being rocks ranging from coarse conglomerate to a dense, dark red jasper-like sediment.

The jasper-like beds do not exceed 10 cm in thickness and must be regarded as accumulations of windblown dust. Similar accumulations fill hollows and fissures in the surface of the basement granite. At certain levels the "jasper" beds are more like shales which crumble easily.

Coarse-grained varieties of the sandstones are mostly found associated with gravels and the remarkable, current-made conglomerates which are encountered at many levels, especially in the Mussartût Member.

The thickness of the conglomerate beds varies from 2 centimetres to about 20 metres. The matrix consists of ordinary sandstone, and the well-rounded pebbles and boulders are of pure quartz, quartzite, and sandstone - usually with a coating of hematite. Pebbles of volcanic material are extremely rare. The boulders may attain a size of 50 cm in diameter. Great velocities of transport are sometimes indicated. In some places 1 metre large blocks of the underlying sandstone have been torn up and now tilt in all directions, forming part of the conglomerate.

The basal layers of the sandstone have a composition like arkose. Ussing and Wegmann have stated that in some instances it is difficult to decide whether the rock is arkose or granite. This applies to localities where the arkose in fact is the disintegrated granite in situ. However, in most places the structure of the arkose suggests that the material has been subjected to transportation by water - presumably over a short distance.

The arkose-like rock is found as matrix in a rock comparable to conglomerates or fanglomerates. The rock contains numerous boulders of more or less disintegrated granite. The size of the boulders ranges from mere pebbles to blocks of more than 2 metres in diameter.

The large granite blocks in the basal layers are found north of Tasiussaq - possibly close to the margin of the basin. The size of the blocks rapidly decreases towards the south to an average of 5-10 cm in diameter. At the margin it is observed that the granite boulders and blocks in places constitute about 80% of the rock. Here the arkose in itself is quite subordinate.

PRIMARY STRUCTURES IN THE SANDSTONE

Original structures comprise primarily cross-bedding and ripple marks, and also imprints of rain drops and sun cracks.

Ripple marks are encountered in the whole area and at many levels throughout the sandstone sequence. Thus ripple marks may be observed in the bottom layers of sandstone overlying the arkose. All ripple marks seem to be wave-made or current-made, and the nature of the cross-bedding also suggests this mode of deposition.

The ripple index of both kinds of ripples is about 5, the wavelength goes from 0.5 to 5 cm. The crests of the wave-made ripples are nearly always rounded off. This should indicate a slight change in the strength of the wave action or a decrease in the agitation of the water. Such changes are also denoted by the adjacent layers. In these beds all sizes of ripple marks may be present, separated by a few centimetres of ordinary sandstone or sandstone showing mud-filled sun cracks etc. In some good exposures several horizons with ripples are laid bare, and they tell of wave propagation and currents striking in random directions.

The cross-bedding mostly consists of ordinary foreset bedding. A delta structure is indicated, and the deltas have probably been formed in shallow lakes. Cross-bedding is common in the basal part of the sandstone and in the Mussartût Member. The phenomenon apparently has a wide horizontal extension, and the area at the time of deposition of the deltas must have had a fairly low relief with numerous shallow lakes fed by relatively small streams - judging from the dimensions of the cross-bedding.

The state of low relief energy could undergo abrupt changes, as indicated by the associated conglomerates and coarse-grained sandstones. With tectonic uplift the increased velocity of the currents would result in a larger transport capacity.

Sun cracks are seen at several levels in the lower part of the sequence. Beds subjected to sun-cracking are usually strongly red-coloured, and they contain a fair amount of aeolian material. This feature occurs in fine-grained sandstones which were probably deposited in shallow pools. Imprints of rain drops are associated with the sun cracks.

Aeolian structures are very rare and by nature not likely to be preserved. Windblown dust and sand are seen at a few levels, and in some instances form part of the matrix in the conglomerates. During a period of emergence windblown material could easily accumulate in the cavities in the conglomerates.

A dune east of Ilímaussaq has been reported by J. W. Stewart. Here a basalt flow is abruptly stopped by sandstone. The dune structure has only been preserved on account of the flow.

No organic structures or signs of marine transgressions have been found.

ORIGIN OF THE SANDSTONE

The basin of deposition was evidently established as a graben, when a period of major faulting affected the deeply eroded basement consisting of Julianehåb granite.

At that time the land surface, intersected by numerous joints, was eroded to a not entirely level peneplain - the sub - Gardar peneplain. The granite was affected by weathering to a depth of several metres.

After the formation of the graben the products of weathering were washed out into the continental basin from the surrounding highland of Julianehåb granite.

The material was deposited in rivers and shallow lakes - possibly during short periods of submergence. During the prevailing periods of emergence the sediments, where unconsolidated, have been shifted around and redeposited by the wind. This would be possible if periods of submergence were short and conditions generally unfavourable for cementation.

Structures from wind-redeposition have not - with the exception of the above mentioned dune east of Ilímaussaq - had any chance of survival in the loose sands. During a subsequent submergence new material was deposited, and the aeolian structures were destroyed.

It is significant that all the associated volcanic flows are without any structures like pillow lavas which might have indicated rapid cooling under water. All the extrusives came to rest on a dry land surface.

The action of the wind during the dominating periods of emergence has had a smothering effect, and in this way breaks in the sedimentation are difficult or impossible to verify.

A parallel may be found in the Sahara desert today. The desert sands here are of fluviatile origin, deposited during the Quaternary. The pluvial conditions at that time favoured a large number of lakes and streams, forming the extensive deposits which due to the arid conditions are now being reorganized by the wind.

STRATIGRAPHY AND CORRELATION OF THE SANDSTONE AREAS

Stratigraphy

As already stated in the introduction the sandstone/volcanics sequence constitutes the Eriksfjord Formation which is divided into six members. The individual members are characterized by lithological differences which in all instances reflect changes in the tectonic activity - mainly vertical movements along marginal faults. The divisions presented here facilitate the correlation between the now separate exposures.

The name the Igaliko sandstone is abandoned as a formal term. It was introduced by Ussing to comprise the total bulk of sandstones, and accordingly the name would be in conflict with the proposed divisions of the formation.

The Eriksfjord Formation takes its name from Eriksfjord which is the old name for Tunugdliarfik.

It is safe to conclude that the orientation of the fjords is dependent upon the old tectonic structure which is also denoted by the trend of the dykes. In periods of activity along the marginal faults adjustments took place along northeast crush zones within the basin, thus permitting the extrusion of the volcanic material.

The Eriksfjord Formation comprises the following members (in ascending order): Mâjût Sandstone Member, Mussartût Member, Naujarssuit Sandstone Member, Ulukasik Volcanic Member, Nunasarnaq Sandstone Member, and Ilímaussaq Volcanic Member.

The type area is located on the peninsula between Bredefjord and Tunugdliarfik, and the type section is located between Mâjût towards northeast and Ilímaussaq towards southwest. The divisions are shown in fig. 1.

Mâjût Sandstone Member: Estimated thickness about 400 metres.

The Mâjût Sandstone comprises the section of sandstone between the underlying granite and the first manifestation of the volcanism, this being the intrusive volcanic breccia at Sitdlisit. The member includes windblown dust accumulated in the hollows and fissures in the Julianehåb granite, arkose and arkose-like rocks at the bottom of the section, conglomerates, and ordinary sandstone.

<table>
<tr><th>Wegmann 1938</th><th colspan="2">This report</th></tr>
<tr><td>Porphyry Formation</td><td>Ilímaussaq Volcanic Member</td><td rowspan="8">Eriksfjord Formation</td></tr>
<tr><td rowspan="3">Ipiutaq Section</td><td>Nunasarnaq Sandstone Member</td></tr>
<tr><td>Ulukasik Volcanic Member</td></tr>
<tr><td>Naujarssuit Sandstone Member</td></tr>
<tr><td>Naujarsuit Section</td><td rowspan="2">Mussartût Member</td></tr>
<tr><td rowspan="2">Musartut Section</td></tr>
<tr><td rowspan="2">Mâjût Sandstone Member</td></tr>
<tr><td>Nugarsuk Section</td></tr>
</table>

Fig. 1. Divisions of the Precambrian Eriksfjord Formation.

The granite material in the arkose represents remnants of the weathered mantle which covered the Julianehåb granite. When the faulting responsible for the formation of the graben occurred, the weathering products were washed out into the basin from the rising highlands surrounding it. The arkose first of all filled the hollows in the uneven peneplain, and sedimentation continued with deposition of conglomerates and sandstones. Thus a deepening of the basin is indicated.

Later the basin became shallower, as demonstrated by ripple marks, cross-bedding etc. at the top of the Måjût Sandstone Member. This was not the result of the filling up of the basin, but rather a consequence of tectonic uplift. This is indicated by the angular unconformity below the white-spotted sandstone at Sitdlisit. The strike of the beds changes from 80° to about 100°, the dip remains 10-15° towards south.

The white-spotted sandstone at the top initiated Wegmann´s Musartut section.

Mussartût Member: Estimated thickness about 650 metres.

The member comprises tuff and intrusive volcanic breccia, flows, sills, conglomerates and sandstones. The basal bed is an intrusive breccia and the top bed is a basalt flow which underlies a thick, uninterrupted sequence of light-coloured sandstone or quartzitic sandstone.

The Mussartût Member is characterized by tectonic unrest which is reflected in the alternating flows and conglomerates.

At Igaliko the lowermost breccia is underlain by a dark, dense but vesicular basalt flow, fragments of which are dominant in the overlying breccia. Thus it seems likely that the Gardar volcanism started here with a more quiet eruption. Due to increasing pressure a more explosive phase could follow. The explosive phase also produced beds of tuff and lapilli which are well-exposed at Qagssiarssuk.

The explosions responsible for the formation of the intrusive breccias and the agglomerates were most likely synchronous at all places and centred around local nuclei. As mentioned above the explosive volcanism also took place outside the basin - probably along the margin.

Naujarssuit Sandstone Member: Estimated thickness about 585 metres.

This member constituted an uninterrupted sequence of light-coloured quartzitic sandstones. The upper boundary is found northeast of Ulukasik.

At the coast some distance northeast of Ulukasik a single syenite sill of negligible dimensions occurs. A few outcrops of basalt flows at the coast appear to be down-faulted parts of the Ulukasik Volcanic Member.

The rather uniform sandstone indicates that tectonic movements were slow during the deposition. Possibly deepening of the basin kept up with the rate of sedimentation, although occasional ripple marks show that shallowing took place at certain stages. Full emergence may also have occurred.

Ulukasik Volcanic Member: Estimated thickness about 250 metres.

The member consists almost solely of basalt flows. A single, quite subordinate sandstone bed is seen in the upper part, below Nunasarnaq.

Tectonic movements were probably gentle during the formation of this member.

Nunasarnaq Sandstone Member: Estimated thickness about 400 metres.

An ordinary sandstone is the predominant part of the member. Some discontinuous flows, which may be quite local, are seen inland. The aforementioned dune structure at the end of a flow is also found in this member.

Ilímaussaq Volcanic Member: Estimated thickness about 1125 metres.

The member consists of an uninterrupted series of basalt flows. A small remnant of conglomerate is seen on the top of Ilímaussaq.

Correlation of the sandstone areas

The now isolated sandstone areas may be correlated with the type section Mâjût - Ilímaussaq (see fig. 2). In a few instances the lithology is without any diagnostic features, and thus the correlation of the Narssarssuaq and Agpat areas is doubtful.

The Qagssiarssuk - Tasiussaq area.

The Eriksfjord Formation in this area is delimited by tear faults striking about 110°. The formation is divided into three fault blocks. The boundary between the Julianehåb granite and the sandstone at Qagssiarssuk is determined by erosion (the arkose is seen along the boundary) but must be partly dependent upon a northeast-striking fault just outside the sandstone area.

The formation in the two major blocks comprises the Mâjût Sandstone

Member and lower part of the Mussartût Member. The level of erosion coincides with the horizons of volcanic breccias, and therefore only small remnants of agglomerates, tuffs, and lapilli beds are seen in most places.

The section in the third fault block to the south only contains the lower part of the Majût Sandstone Member. The basal arkose is seen at several places.

The Igaliko area.

The sandstone/volcanics sequence between Igaliko Fjord and Tunugdliarfik Fjord contains the Måjût Sandstone Member and most of the Mussartût Member. The sequence is in good agreement with the type section. The white-spotted sandstone with ripple marks and other dynamic structures ("the Igaliko sandstone") at the top of the Måjût Sandstone Member is also developed south of Igaliko.

The section contains two horizons of volcanic breccias separated by a sandstone-conglomerate-basalt sill sequence.

The individual beds of the two members are thinner than in the type section, and also the size of the pebbles in the conglomerates is less spectacular.

A large east-west fault forms the boundary towards the south. The Eriksfjord Formation north of this fault is intersected by a number of faults which are parallel to the main fault. The individual blocks are tilted with progressively increasing northerly dip in the southern part of the area.

Erosion has exposed the basement granite north of Igaliko. Typical arkoses are absent, and the Måjût Sandstone Member is introduced by conglomerates or normal sandstone. The area was evidently subjected to denudation at the initial stages of the Gardar period, but the continuous deepening of the basin soon resulted in the deposition of conglomerates and sandstone.

A small triangular sandstone area adjacent to the main fault at Tunugdliarfik Fjord belongs to the Igaliko main area. When the faulting was effective, a flexure was formed. Subsequent erosion has exposed the Julianehåb granite along the middle of the flexure.

The outcrops in the area between Igaliko Fjord and Qôroq Fjord belong to a unit which has been interrupted by the Igaliko syenite batholith and by erosion.

Typical arkoses are lacking here as in the Igaliko main area.

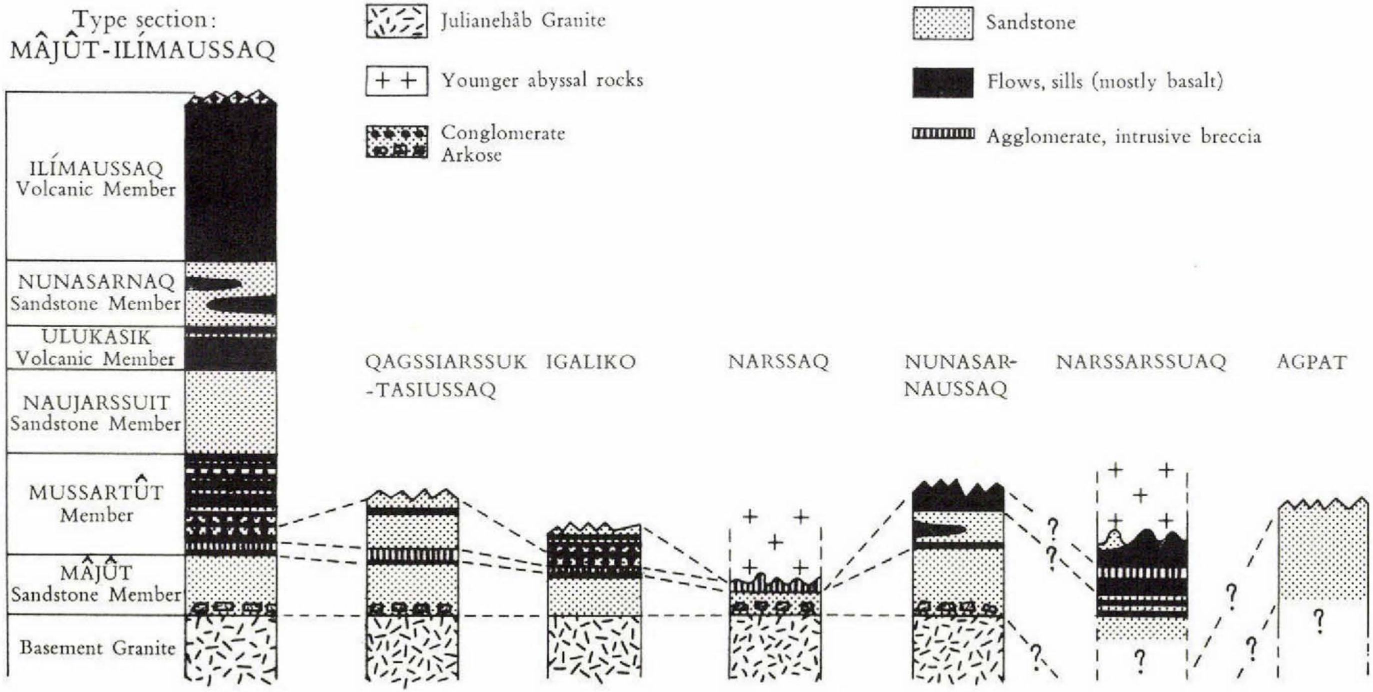

Fig. 2

Correlation of the different areas with exposures of the Eriksfjord Formation (see also map 1).

The northern area consists of the Mâjût Sandstone Member and the basal part of the Mussartût Member. A single basalt flow is exposed close to the syenite. The flow is strongly altered, and the large content of biotite scales is very conspicuous. The sandstone is only affected right close to the contact of the syenite.

The section east of the fjord, opposite Igaliko, comprises the Mâjût Sandstone Member and most likely the lower part of the Mussartût Member. The basal arkose is absent;the volcanic beds are flows. The position of the igneous beds in the sequence suggests that they may well be initiating the Mussartût Member. No agglomerates are seen, but as stated above, the agglomerates or intrusive volcanic breccias are probably centred around local nuclei of eruption.

The Narssaq area.

At Narssaq the Mâjût Sandstone Member and basal part of the Mussartût Member are developed. A typical arkose constitutes the basal layer. At the top of the sequence the volcanic breccias are cut off and partly enclosed in younger intrusive rocks.

The Nunasarnaussaq area.

In this area on the southern side of Tunugdliarfik the Mâjût Sandstone Member and the lower part of the Mussartût Member are developed.

The course of the boundary between the sandstone and the Julianehåb granite is determined by the present erosion surface. The members are cut off to the east by the Ilímaussaq intrusion.

The basal part of the Mâjût Sandstone is developed as arkose or arkose-like conglomerates. The member is about 300 metres in thickness.

In the Mussartût Member volcanic breccias are absent, and that also goes for the conglomerates. The basalt layer forming the top of the mountain is about 150 metres thick.

Tectonic movements must have been fairly slow, and the eruptions rather quiet. The development of the member in some respects resembles the sequence at Narssarssuaq.

The Narssarssuaq area.

The Eriksfjord Formation in this area is bounded by a fault, by the Igaliko batholith, and by fluviatile deposits from the Narssarssuaq river.

The formation is dominated by basalt flows. In the middle of the section an agglomerate bed separates two layers of tuff. Sandstone and basalt blocks occur in almost equal amounts in the agglomerate.

The sandstone beds at Narssarssuaq are of common, rather nondescript type.

As the series of flows is more than 100 metres in thickness, a comparison with the Nunasarnaussaq area is tentatively suggested. Some of the basalts may be sills, but dense vegetation obscures all contacts, and the nature of some of the beds cannot be ascertained. Anyhow, the basal volcanic bed at the coast is a typical vesicular flow.

The agglomerate in the middle of the section also suggests a correlation with the Mussartût Member. Possibly the period of quiet eruptions was of longer duration here. Only at a later stage did the increase in pressure first result in explosive volcanism.

The absence of conglomerates suggests quiet movements along the faults.

The Agpat area.

This small area is separated from the Julianehåb granite by faults, and it is cut off by the syenite intrusion to the west.

The sandstone in this area is without any distinctive features, and, accordingly, there are no criteria which can be used for correlation.

It is tentatively proposed to group this area with the Mâjût Sandstone Member on the grounds that the sandstones exposed in most other areas belong to the basal part of the sequence.

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