Early Proterozoic Shallow-marine Albite-rich Sandstone in the Karasjok Greenstone Belt, Norway

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A remarkably little-deformed sandstone in a roadcut near Karasjok shows sedimentary structures characteristic of a subaerially exposed tidal environment. The fining upward sequence displays flaser bedding, parallel lamination, mudclasts, bimodal cross bedding, and mudstone layers with shrinkage cracks. The sandstone is stratigraphically in about the center of the Karasjok Greenstone Belt, and indicates a shallow-marine environment for at least some of the deposits.

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Introduction

The Karasjok Greenstone Belt is a sequence of sediments and intermediate to ultramafic volcanic rocks, highly deformed and metamorphosed during the Middle Proterozoic Svecokarelian orogeny (Often 1985, Krill 1985 and Siedlecka et al. 1985).

Volcanic and volcanoclastic textures are locally well preserved in structurally competent ultramafic rocks (Henriksen 1983, Often 1985), but few sedimentary structures were known within the greenstone belt, and none had been studied or described in detail.

Recent mapping and research, including detailed study of the sedimentary structures described below, is forming the basis for an improved understanding of the regional geology.

Structural and Stratigraphic Setting of the Oal'gejåkka Sandstone

The sandstone locality includes roadcuts on both sides of highway E6 about 4 km north of the town of Karasjok (UTM coordinates 40201130, mapsheet M711 2034 II). The highway there follows the small creek Oal'gejåkka. Exposure is limited, and individual beds can be observed for a length of only a few meters. About 400 m south of the description locality the sandstone is tectonically overlain by a strongly foliated amphibolite. The sandstone is extensively brecciated within a few meters of the contact. The northern contact of the sandstone is not exposed, but a coarse-grained gabbro is seen in roadcuts about 800 m north of the sandstone locality. The gabbro is somewhat brecciated, sheared and altered in these exposures. The gabbro is a large body, about 25 km^2 in area, surrounding the small area of sandstone on the west, north and east. The sandstone was apparently engulfed by the gabbro before or during the main orogenesis, and the structurally competent gabbro served to shield this part of the sandstone from intense penetrative deformation. About 2 km to the south, the same sandstone is strongly folded, foliated and recrystallized. Only traces of cross-bedding can be recognized and the original thin mudstone layers are metamorphosed to medium-grained biotite schist.

Because the sandstone and amphibolite are surrounded by gabbro on three sides, and their southern limits are not fully mapped, the stratigraphic position is not certain. However, the sandstone is apparently part of the Gål'lebai'ke Formation and not related to the quartzitic sandstone of the Skuvvanvarri Formation at the base of the Karasjok Greenstone Belt. Mainly within the Skuvvanvarri Formation had sedimentary structures, including conglomerate and large-scale cross-bedding, been recognized

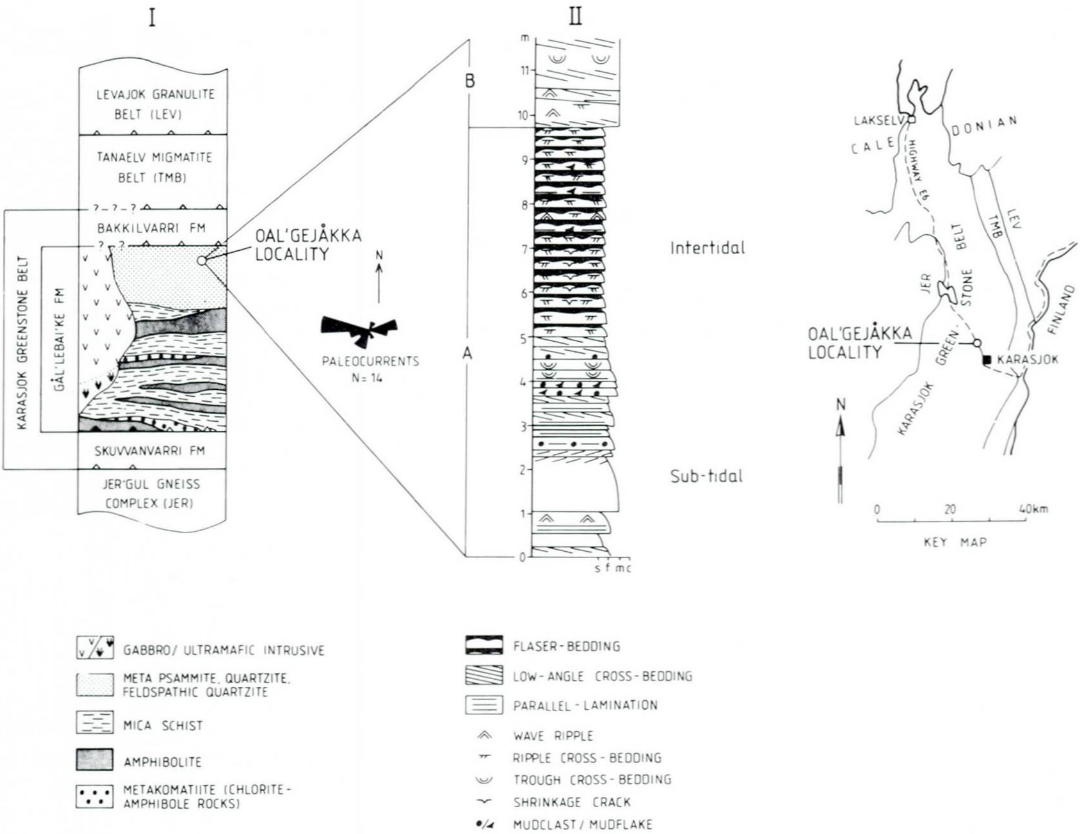

Fig. 1. Schematic stratigraphic section of the Karasjok Greenstone Belt (I) showing the position of the Oal'gejåkka sandstone locality, and measured stratigraphic section of the sandstone exposure (II).

(Skålvoll 1964, Wennervirta 1969, Siedlecka 1985). The assumed stratigraphic position is shown in Figure 1.

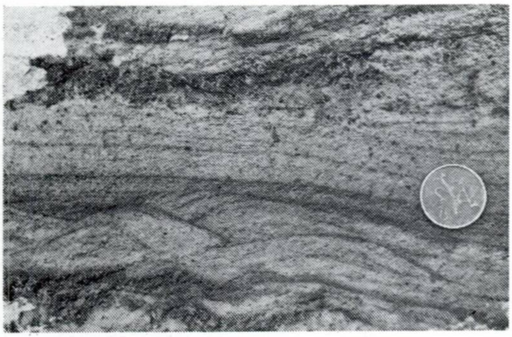

Fig. 2. Parallel-lamination and ripple cross-bedding in sandstone. Coin diameter is 2 cm.

Description and Interpretation of the Measured Section

The measured section at the Oal'gejåkka locality is 11.5 m thick (Fig. 1), and can be divided into two main depositional units, A and B. Unit A is a sequence of sandstone and mudstone about 9.75 m thick. The overlying Unit B, c. 2 m thick, consists of 25-50 cm thick sandstone beds. Only the lower part of unit B was studied and measured, and this description and interpretation focus on unit A.

Unit A is a fining upward sequence in which both thickness of sandstone beds and the average grain size decrease upward, while the amount of mudstone increases upward (Fig. 1). The lowest 5 meters of the section consists almost entirely of sandstones, which show medium sized (10-30 cm) low-angle and trough cross-bedding, parallel-laminations (Fig. 2) and scat-

Fig. 3. Polished rock slab from wavy flaser-bedded section, showing ripple cross-bedding, climbing ripple cross-bedding, parallel-lamination, loading and bifurcating flasers. Scale in centimeters.

tered mudstone clasts. Thin mudstone layers may separate some of the sandstone beds. This section passes gradually into a flaser-bedded sequence characterized by both current and wave ripples (Fig. 4), ripple cross-bedding, climbing ripple laminations and loading (Fig. 3). Shrinkage cracks (Fig. 5) are abundant in the flaser-bedded sequence. Plummer & Gostin (1981) show that shrinkage cracks may form subaqueously, but that cracks such as those at the Oal'gejåkka locality indicate subaerial exposure.

Fig. 4. Wave ripples and linguoidal current ripples on exposed bedding surface from the wavy flaser-bedded section. Bottle is 4 cm wide.

Paleocurrent measurements (Fig. 1) show two opposite-directed vectors. Opposite-directed dips of ripple cross-bedding are seen in Figure 3. Such current patterns are frequently recognized from recent tidal environments, due to ebb and flood tidal currents. Isolated examples of opposite-directed current patterns have been described from reçent fluvial environments (Alam et al. 1985).

Flaser-bedding indicates deposition alternating between bed-load and suspension, and is recognized from many different depositional environments. The flaser-bedded section (Fig. 3) shows bifurcating flasers which Alam et al. conclude are most likely formed in tidal environments. Both wave and current structures occur particularly in the flaser-bedded section (Fig. 4). Visher (1975) interprets such a section as indicating a tidal environment. As a conclusion, the sedimentary structures and paleocurrent patterns make a tidal depositional

Fig. 5. Shrinkage cracks on exposed bedding surface. Coin diameter is 2 cm.

environment most likely.

Shrinkage cracks show that the flaser-bedded section has been deposited in an aerially exposed environment. Reineck & Wunderlich (1968), Reineck (1972, 1975), Klein (1971), Visher (1975) and Evans (1975) describe fining upward sequences consisting of flaser, wavy and/or lenticular bedding from progradation of tidal flats. Such deposits, as in the measured section, are dominated by current structures. Wave ripples may be formed during periods of strong winds, as described by Evans (1975) from recent tidal flats.

Tidal channels and creeks move laterally and thereby play a major role in deposition in shallow tidal areas. They cut down below tidal flat deposits, and once formed, they may be quickly filled by sediments and preserved. Weimer et al. (1982) describe tidal channels as fine- to medium-grained, fining-upward sandstones with small- to medium-sized cross-bedding, which also show opposed dip of the cross-bedding, and with abundant erosional truncation. They show that thin mudstones may be deposited during periods of slack water. Lag deposits occur frequently within tidal channels. The lower 5 meters of the measured section shows many similarities with the tidal channels described by Weimer et al. Mudstone clasts are recognized at several levels within the lower 5 meters of the section. These clasts may represent the base of scour surfaces within the tidal channel. The lower part of the section also shows parallel-laminations, which may be formed during periods of spring tides or storms, when abnormally high energy conditions may exist in the channels. Alternatively, parallel-lamination in the transitional zone underlying the flaser-bedded section may represent beach laminations.

Load casts and climbing ripples (Fig. 3) occur in the upper parts of the tidal channel. Neither structure is diagnostic of depositional environment. Loadcasts form when heavier sand sinks down into soft mud. Climbing ripples form by rapid sedimentation. Bridges & Leeder (1976) describe rapid erosion and deposition from recent tidal creeks during spring tides, particularly when associated with heavy rain. Similar conditions in tidal channels may have given rise to the climbing ripples. Alternatively, large amounts of sediments may have been supplied to the channels during heavy storms, favouring climbing ripple development. The gradual transition from parallel-laminations to climbing ripple cross-bedding (Fig. 3) shows similarities with beds interpreted by Kreisa (1981) as storm beds. Such interpretation is favoured by the authors.

An alternative model for the lower part of Unit A is a shoreface environment, but this is less likely. Tidal-dominated shoreface environments consist of lenticular and flaser-bedded deposits with storm layers, but show few similarities with the investigated section, and a tidal channel model is preferred.

In conclusion, Unit A is most likely explained as a sequence developed by lateral migrations of tidal channels. The lower 5 meters of the section is the subtidal part of the channel, while the flaser-bedded section is a tidal-flat deposit.

Unit B shows similarities with the lower part of Unit A, and it may also represent a tidal channel. However, fluvial deposits have many similarities with tidal channels, and the restricted exposure of this unit makes detailed interpretation impossible.

Mineralogy and chemistry of the sandstone

The sandstone layers weather white due to the high feldspar content. Albite (55-70 %) and quartz (5-20 %) are the main minerals. Tremolite (5-15 %) gives a light green color to some layers, and disseminated hematite colors other layers red. Dolomite is always present, up to about 15 %, and minor sericite is common. Sphene, rutile, and apatite are locally found enriched in laminaes, indicating the clastic origin of these minerals.

The siltstone and mudstone layers are dark grey due to biotite (20-30 %) and hematite (5-10

%). The albite content is somewhat lower than in the sandstone layers, while the quartz content is nearly the same. Other minerals, including graphite, are present only in accessory amounts.

The microtexture shows complete recrystallization with no evidence of preserved primary quartz or albite grains. If present grain sizes reflect the primary, the sandstone layers consisted of fine sand (0.02 - 0.15 mm), while siltstone and mudstone layers consisted of medium to coarse silt (.007 - 0.07 mm). Tremolite and micas have grown randomly and the rock has no foliation.

Table 1. Average of 7 analyzed samples (M3983A-G) of albite-rich sandstone from the Oal'gejåkka locality (UTM 4020 1130), Karasjok Greenstone Belt. Analyzed at Geol.Surv.Norway by XRF. Na_2O, FeO, CO_2, H_2O^+, H_2O^- by wet chemical methods.

	Mean N=7	Range
SiO_2	61.8 %	56.1 - 68.2
Al_2O_3	12.8 "	11.5 - 14.1
CaO	4.4 "	0.9 - 6.9
MgO	4.4 "	0.9 - 6.4
Fe_2O_3	1.9 "	0.0 - 3.3
FeO	0.7 "	0.4 - 0.9
Na_2O	7.1 "	6.4 - 7.9
K_2O	0.2 "	0.1 - 0.6
TiO_2	0.4 "	0.4 - 0.5
MnO	0.01"	0.01
P_2O_5	0.1 "	0.04 - 0.17
CO_2	3.0 "	0.4 - 7.4
H_2O^+	1.1 "	0.6 - 1.6
H_2O^-	0.1 "	0.0 - 0.1
Nb	7 ppm	5 - 8
Zr	173 "	147 - 202
Y	13 "	10 - 18
Sr	17 "	< 5 - 29
Rb	6 "	< 5 - 20
Zn	< 5 "	< 5
Cu	< 5 "	< 5
Ni	28 "	< 5 - 49
Cr	103 "	58 - 140
V	66 "	13 - 164
Ba	< 10 "	< 10 - 25

Average chemical analyses of 7 samples from the Oal'gejåkka outcrop are presented in Table 1. No significant chemical differences were observed between sandstone- and mudstone-rich samples. The amounts of CaO and MgO vary, due to variable dolomite content, and the concentrations of the elements mainly reflect the very high albite content. Zr is relatively low for a clastic rock, and may indicate little reworking of the primary sediments, without enrichment of zircon grains.

The sandstones of the Gål'lebai'ke Formation have generally high albite content in other areas as well. Na_2O abundances are mainly 2-6%, but no other metasediments with as high albite contents are known among the greenstone belts of Finnmark. Fine-grained white felsites in the Kautokeino Greenstone Belt and Njallajåkka Complex have similar high albite contents, but are generally interpreted as volcanic rocks (Fareth et al. 1977).

The origin of the very high albite content in the Oal'gejåkka sandstone is not known. The gneisses of the Jer'gul complex are relatively high in albite, but weathering, erosion and transport of such gneisses would enrich the sediment in quartz, not feldspar, and albite contents as high as those in the Oal'gejåkka sandstone would not be formed.

A more likely source material would be Na-rich volcanic lava or ash, which was rapidly reworked and deposited as sediment. However, no albite-rich felsic volcanic rocks or felsites have been recognized from the Karasjok Greenstone Belt.

It is most likely that some metasomatic effects resulted in a local albite enrichment. Surdam & Boles (1979) show a model for diagenetic albitization of volcanic sandstone in which primary plagioclase and/or quartz react with Na^+ from seawater to form albite. Excess Ca from such a raction could have contributed to the formation of dolomite and tremolite in the Oal'gejåkka sandstone. Local development of evaporites in the tidal environment could have added to the availability of Na^+ in the alteration process.

Conclusion

The described Oal'gejåkka sandstone locality shows a combination of sedimentary structures strongly indicating a shallow-marine environment with formation of tidal channels. The composition of the sandstone with extremely high albite content is puzzling, but until further work has been done, a volcanic origin with possible diagenetic Na-metasomatosis is preferred.

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