

23. A Pre-Cambrian Metabentonite(?) of Hydromuscovitic Composition

By

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Introduction

On several occasions during his continuous investigations of the Ordovician strata in Dalarna, Sweden, P. THORSLUND has been led to study the locality of Djupgrav, 1 km to the west of the Chapel of Skattunges. In 1958, he had the opportunity to take a representative sampling from new outcrops made available by recent road-work. This paper is entirely based upon samples from this collection, kindly put at my disposal by P. THORSLUND.

In an earlier paper, the stratigraphic sequence of Djupgrav was described by P. THORSLUND (1936), but the vertical profile shown in Fig. 1 is based upon his more recent observations, still unpublished. The Paleozoic suite of rocks is underlain by Jotnian sandstones of grayish and reddish colours. Even if no definite proof has been established, the late Precambrian age assigned to these rocks is most likely for diverse reasons, primarily the location of a vast area of Jotnian sandstone immediately to the north of Djupgrav, and the supposed non-existence of Cambrian deposits in the Siljan region (P. THORSLUND, 1960).

This paper will deal only with the light-coloured, massive-looking clay horizon, 1 dm thick, embedded in the sandstone and showing all the megascopical features generally attributed to a true clay material. Still another and quite similar clay bed of lesser thickness, not shown in Fig. 1, has been observed farther to the east but this has not been subject to investigation.

The coarser material

In accordance with a bimodal distribution of the grain size frequency of the clay rock, it can be looked upon as composed of two disparate fractions. On one hand there is essentially fine-dispersed colloidal matter, on the other a coarser fraction with a maximum frequency of grain size just below the limit silt-sand (< 0.05 mm). In the later discussion we shall return to this dual compositional property of the material.

No strictly statistical comparison between the coarser detrital material in the clay rock and in the sandstone has been achieved but even an incomplete exami-

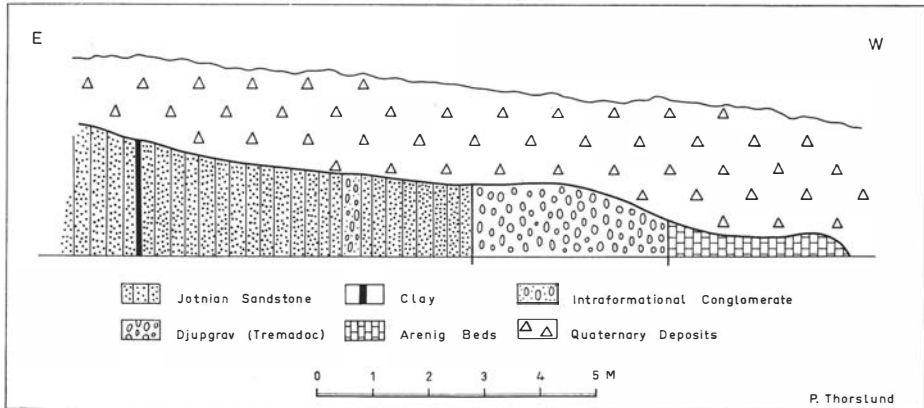


Fig. 1. Diagrammatic view of the Djupgrav road-cutting.

nation indicates a striking resemblance in mineralogical and granulometrical respect. The following characteristics are in common. The grain size does not exceed a value of about 0.25 mm. The proportion between the two chief minerals, quartz and potassium feldspar, seems to vary within a restricted interval, a medium ratio being about 2:1. Finally, the contents of plagioclase and heavy minerals are extremely low.

Apparently the development of the silty-sandy constituents of the clay bed is determined by the same sedimentation conditions prevailing during the deposition of the adjoining sandstones. The same relations are not valid for the colloidal material. On the contrary, it must be considered as quite a strange element in the recorded sedimentation course.

The clay fraction

As already stated, the clay-like appearance is most striking and dominates the rock under discussion. Nevertheless, it has been shown on closer study that less than half the material is made up of clay. A very rough estimate of the total mineral content will yield 40 % quartz, 20 % potassium feldspar, and mostly 40 % clay minerals. However, the clay portion shows every sign of occurring in a very fine-grained state.

The following analyses concern only the clay fraction of less than 2μ , thoroughly dried at 110°C .

The *X-ray diffraction data* for the clay fraction are given in Table I. The predominant mineral is evidently a dioctahedral mica displaying decidedly more reflexions than illite, while the crystallinity is considerably lower than in the case of muscovite. The line profile of the first-order basal reflexion is very asymmetrical with a sharp boundary towards higher angles, but a diffuse halo facing inwards. In any case, studies of the basal reflexions of glycerol-treated samples exclude the interlayering of any expandable component.

Table I. Lattice spacings and estimated intensities.

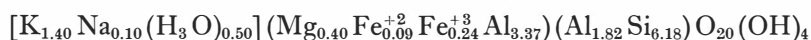
(M = mica clay mineral, Q = quartz, G = goethite).

d Å	I	mineral	d Å	I	mineral	d Å	I	mineral
~ 10	st	M	3.22	m	M	2.122	m	M
4.91	w	M	2.95	w(b)	M	1.979	mst	M, Q
4.48	st	M	2.767	w	M?	1.811	st	Q
4.24	st	Q	2.562	st	M	1.734	vw	M?
3.86	vw	M	2.444	m	M, Q	1.694	vw	G?
3.69	w	M	2.381	m w	M	1.666	m	M, Q
3.49	w	M	2.271	m	M?	1.536	m	Q
3.34	vst	Q, M	2.228	m w	M	1.500	mst	M

Besides the micaceous mineral only quartz can be positively identified. On overexposed photograms some feldspat lines may also be traced. The identification of the strongest goethite reflexion is most uncertain.

The total *chemical composition* of the clay fraction is given in Table II. To ascertain the composition of the predominant hydrous mica the content of other minerals present must be considered. The only important impurity is quartz which has been determined by the method of HIRSCH-DAWIHL (1932) and amounts to 8.4 %. Some of the iron (0.9 % Fe₂O₃), being easily soluble in strong hydrochloric acid, has been assigned to a non-silicate phase. The small amounts of titanium and manganese have been omitted from the calculations as well as calcium, the major part of which evidently occurs as carbonate and phosphate. The presumed existence of potassium feldspar in the clay fraction has not been corrected for but cannot have any great influence.

After these corrections (cfr the right column in Table II) the structural formula of the mica has been derived assuming a full occupation of the inter-layer positions. In this way the following formula is obtained:



A scrutiny of the water content shows that 5.52 % is required for the "structural" water of the mica, leaving at the very most 0.48 % for loosely adsorbed water, a most likely figure.

The dioctahedral character of the mica is already indicated by X-ray data and additional evidence is furnished by studying its dissolution in strong hydrochloric acid. Only five per cent of total potassium is released which is in good agreement with published experimental data for muscovite (S. STÅHLBERG, 1958).

In comparison with a true dioctahedral mica the above formula exhibits slight discrepancies. The number of octahedral ions is somewhat too high as is the ratio of silicon to tetrahedral aluminium. None the less, it may be well justified to call this mineral a hydromuscovite as distinguished from a "stand-

Table II. Chemical composition (Analyst: B. Almqvist).

	The clay fraction	The micaceous mineral
SiO ₂ , in %	49.77	41.36
TiO ₂	0.27	
Al ₂ O ₃	29.52	29.52
Fe ₂ O ₃	3.07	2.17
FeO	0.76	0.76
MnO	0.10	
MgO	1.82	1.82
CaO	0.42	
Na ₂ O	0.36	0.36
K ₂ O	7.36	7.36
H ₂ O > 110°	6.00	6.00
P ₂ O ₅	0.05	
CO ₂	0.20	
Sum:	99.70	89.35

ard" illite, which in the classification applied by the author is to be reserved for clay micas with a distinctly lower degree of substitutions of Al for Si in the tetrahedral group.

Disregarding the sources of error from the analytical procedures, the deviations from the ideal muscovite composition with respect to the octahedral and tetrahedral configurations may well be explained as a result of mixing with illite and/or trioctahedral mica; while, on the other hand, the author is of the opinion that there are no transitional members between hydromuscovite and illite (in the restricted sense). This does not prevent their combining in the form of mixed-layer minerals, but the non-expandable properties of both components leave this possibility unexplored.

The determination of the cationic exchange capacity has yielded a value of 16 meq per 100 g hydromuscovite. Assuming that the exchange capacity in this case is only caused by broken bonds along the edges of the structural units this value must be considered a very high one; it is most likely due to the very decreased particle size. It may be contrasted with the low figure of 2.5 meq per 100 g reported by H. HEYSTEK (1955) for a chemically analyzed hydromuscovite from South Africa.

Discussion of the origin

The occurrence of well-preserved clays intercalated with Precambrian rocks is not necessarily sensational in itself. In this case, however, the more immediate explanations of such an anomalous behaviour are not valid. Hence an alteration

deriving from hydrothermal activity is altogether out of question as well as a recent selective weathering process. Late fillings of open fissures parallel to the bedding of the sandstone is a tempting proposal, but may also be rejected if one bears the character of the coarser detritus in mind.

The alternatives are, no doubt, reduced to some kind of syngenetical mode of formation. The sudden shift from arenaceous to lutaceous sedimentation is, perhaps, the most readily available explanation. B. COLLINI (oral communication) who has had considerable experience with the extensive Jotnian rocks of Western Dalarna, testifies that clay material often occurs in the sandstones but always in a clearly metamorphic state. H. v. ECKERMANN (1937) also reports the occurrence of "clayey layers" interbedded with Jotnian sandstone; likewise, this matter seems to be concerned with metamorphic equivalents. Notwithstanding the difference in the degree of metamorphism, other facts negate the interpretation of the clay bed as an integral component of an epiclastic sedimentation sequence. The extreme fineness of the colloidal material and the simultaneous intermingling with silt and sand are not to be fitted into this conception.

The pattern of grain size and especially the episodic features of the material will be more comprehensible by assuming a partially pyroclastic origin of the rock. Accordingly the latter is to be looked upon as a vitric ash deposit subsequently altered to bentonite. Turbulent motions at the bottom of the sea may have whirled up the unconsolidated bottom sediments producing an unstratification. The volcanic activity as one of the prerequisites for the formation of bentonites is already evidenced in this stratigraphic position by the abundance of tuffitic intercalations in the contemporaneous sandstones.

As to the clay mineral relations it can be easily imagined that the original montmorillonite formed at the devitrification of the ash bed has been completely lost and changed to hydromuscovite. This transformation procedure may pass through several stages, one intermediate stage being the formation of randomly interstratified layers of montmorillonite and hydrous mica as reported by C. E. WEAVER (1953) and by A. M. BYSTRÖM (1954). Ordovician bentonites virtually composed of hydrous mica (illite?) are also known from Bornholm (H. GRY, 1948) and from the Oslo region (F. HAGEMANN & N. SPJELDNÆS, 1955). It is apparent that montmorillonite has a restricted stability region but the lack of stability data on the clay minerals and especially the hydrous micas does not permit further speculations about the alteration minerals and their mutual relations.

The point most in question is the non-metamorphic texture of the clay bed. In view of the incompetency of the layer, the primary condition precedent for the preservation of texture is the absence of major tectonical disturbances, that is, the strata must be unfolded or only weakly folded. Even in that case, it is rather remarkable that compaction has not affected the clay in a more impressive manner. In any case, it is evident, as witnessed by the Ordovician bentonites, that the bentonites possess some peculiar power of resistance to metamorphism;

and the author feels convinced that this is due to the primary montmorillonitic composition. Under the same circumstances, the texture of a mica clay deposit would certainly have been altered in a more conspicuous way.

Though the scantiness of observations is fully realized, the author has finally come to the conclusion that he is dealing with the unique occurrence of bentonite beds of late Precambrian age. The hydromuscovite is considered a metamorphic alteration product of original montmorillonite, which retains its highly colloidal properties as its only remaining inheritance. In moral support of this hypothesis, it can be mentioned that P. THORSLUND originally labelled the rock "bentonite" on the basis of its extraordinary megascopic appearance.

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