

24. What is the Origin of the Hydrous Micas of Fennoscandia?

By

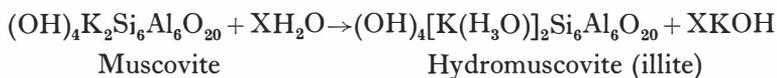
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When, in 1953, ERIK NORIN described the formation of illitic mica minerals in the sediments in the central Tyrrhenian Sea, he was fully aware of the fact that such minerals, which form the main mass of the active minerals in the Scandinavian clays, can be formed from non-mica minerals within a, geologically speaking, very brief space of time. The great similarity between the illitic micas and the rock-forming micas has otherwise in Scandinavia led to the opinion that the illitic minerals in our Fennoscandian Pleistocene clays have essentially been formed by a slight chemical transformation of finely ground mica freed from the solid rocks by mechanical erosion mainly during the Ice Age. It has, however, always been difficult to explain the great quantities of hydrous mica minerals in the thick Scandinavian clay deposits exclusively by the separation of rock-forming mica from disintegrated rock material. A reasonably well-founded calculation of the quantities of clays below the surface of the Baltic Sea and the North Sea, together with the quantities that are found upon the terrestrial surface of Scandinavia, shows that we have to do with quantities of hydrous mica of an order of magnitude of 10^{12} m³. If, at the same time, we take into consideration the relatively sparse content of micas in gneisses, granites, and gabbros compared with the content in these rocks of quartz and feldspar, we are driven to the conclusion that the purely mechanical disintegration required to supply this entire mass of hydrous mica must simultaneously have resulted in immense quantities of sand and silt. Altogether, such a calculation will be uncertain, in part very uncertain, but it seems nevertheless as if the known quantities of sand could hardly be brought into agreement with the great masses of hydrous mica minerals, if these latter are supposed to be derived exclusively from the disintegration of crystalline rocks.

The problem loses some of its difficulties if we admit the possibility that the clays have been formed essentially by the disintegration of unmetamorphosed or little metamorphosed Cambro-Silurian clay sediments. But this train of thought also leads to geological difficulties, since the areas of low metamorphic or unmetamorphosed Cambro-Silurian rocks that now are available in Scandinavia constitute a comparatively small portion of the Scandinavian rock-floor. Their erosion in the course of the Last Glaciation has not been particularly

deeper than that of the surrounding crystalline rocks. Unless, therefore, the Cambro-Silurian clayey slates and shales formed some kind of highland prior to the Ice Age, they can hardly have supplied more than a limited part of the material which has been dislodged during this age. We shall thus be forced to assume that a great part of our Scandinavian clayey masses is derived from soils that covered Scandinavia before the Ice Age, and that the fluvial and glacial erosion has to a great extent transported previously existing material that contained hydrous micas. In doing so we move the genesis of the clay minerals back in time with the result that millions of years become available for their formation.

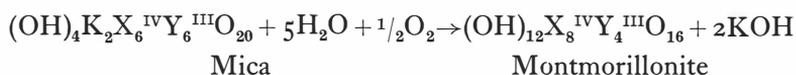
So far everything appears satisfactory. NORIN has, however, shown that related minerals can be formed comparatively quickly. Is it then possible to believe that at least part of the mica-like minerals in the Fennoscandian Quaternary clays could have arisen in Quaternary times from feldspars and other non-clay materials? Investigations carried out at the Geotechnical Institute of Norway by J. MOUM and I. TH. ROSENQVIST (1955 and 1957) and by I. TH. ROSENQVIST (1955 *a, b*) have shown that in Postglacial times important processes of chemical weathering of the minerals containing potassium have taken place *in situ* in our clays. This unmistakable chemical weathering is particularly strong in the uppermost 5–6 m, and is concentrated around root holes and fissures which may extend to greater depth. As a result of the weathering processes the ion adsorption capacity as a rule increased in our soil profiles, and the ratio between adsorbed potassium and sodium is greatly increased, except in the uppermost layers of the soil, where the plants have removed the potassium. In many of our clays we find that their aqueous phase contains more dissolved potassium than the sea-water from which the clay was deposited. This shows unmistakably that potassium minerals must have undergone chemical processes of disintegration, and that alkali ions must have been liberated. The weathering process has led to an increased “activity” of the clay minerals in the sense given to this word by SKEMPTON (1953). In the course of granulometric and differential thermal analysis of the clays we have found that in spite of the facts that the grain size did not change considerably with depth and that the content of hydrous mica did not vary appreciably, the hydrous mica had nevertheless changed its properties. In certain cases small quantities (2–5 %) of montmorillonite seem to have been formed *in situ*. The normal weathering of rock-forming dioctahedric mica to hydrous mica may be expressed by the following equation:



In general the potassium content of the hydrous micas lies between 50 and 90% of the potassium content of rock-forming mica. In isolated cases, e.g. that described by BENGT LINDQVIST (1959), the potassium content in hydrous

mica can drop below 30% of that in the rock-forming mica. Such far-reaching leaching out has in general been assumed as leading to "mixed-layer" minerals between montmorillonite and illite. It seems, however, as if under specific conditions a fairly thorough removal of K^+ and replacement by H_3O^+ with retention of the mica structure could be obtained.

Even if from the formal point of view the change from mica to montmorillonite seems to consist in a replacement of aluminium by silicon, while at the same time the univalent cations are removed, this phenomenon is nevertheless a typical process of oxidization, since it implies a change from a trivalent to a tetravalent ion. In processes that take place according to the following equation, the access of oxygen constitutes a controlling component:



It is therefore imaginable that the minerals dealt with by LINDQVIST have been formed under less oxidizing conditions than in the uppermost crust of the Norwegian soils examined by us, where we believe we have demonstrated the occurrence of a certain amount of montmorillonite of secondary type.

Recently ODD GJEMS (1960) at the Soil Laboratory of the Agricultural University of Norway has found montmorillonite as dominating clay mineral in fractions finer than 2μ in the A₂ horizon in a number of podsol profiles in Fennoscandian clays even where the soil profile is no older than 300 years. Under the conditions that led to the development of podsol profiles the development of montmorillonite is thus definitely established in the Fennoscandian climate. It is, on the other hand, well known that montmorillonite minerals with access to alkalies, especially potassium, can in their turn easily be transformed into mixed-layer minerals, as shown, e.g., by ANNE MARIE BYSTRÖM (1957) for the bentonites in Mount Kinnekulle in South-western Sweden. It has therefore to be considered a very simple chemical process that ultrafine montmorillonite which has been transported by fresh water into the sea can under reducing conditions easily be recrystallized with the formation of mixed-layer minerals, or hydrous mica.

Since each link in such a chain of development is known from nature, it seems reasonable to assume that also a greater or smaller part of our clays has originated in this way. We are still in need of quantitative investigations, and it might be a worth-while task for future sedimentologists to study the complex of problems linked with the mineral weathering of the temperate climate and the sedimentation along our coasts, under oxidizing as well as under reducing conditions. The work inaugurated by ERIK NORIN demands a continuation.

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