B.W. NELSON: Environmental Significance of Clay Minerals

On August 13th the GSM sponsored a talk entitled "Environmental Significance of Clay Minerals" by Professor Bruce W. Nelson, at the Geology Department, University of Malaya. It was well attended by about 65 members. Prof. Nelson is attached to the Department of Geology, University of Malaya for 1982-83 as a visiting Fulbright lecturer sponsored by the Malaysian-American Commission on Educational Exchange (MACEE). His home base is the Department of Environmental Sciences, University of Virginia, USA.

In his talk Professor Nelson discussed the implications of clay mineralogy in weathering and sedimentation and described the role clay minerals play in determining the geotechnical properties of foundation materials. He also discussed clay minerals as indicators of environmental pollution and environments of deposition.

Clay minerals are silicate minerals belonging to one of three major types: the kaolins, the illites, and the smectites (or montmorillonites). Each has its own structure consisting of charged silicate layers, and each has a characteristic range of properties, such as surface area, hydration, ion exchange capacity, etc., which is determined by the layer structure and the magnitude of its charge.

Montmorillonites, for example, have the ability to adsorb large amounts of water under conditions of high humidity, compared to illite and to kaolinite. This affects the geotechnical properties. The plastic limits, the liquid limits, and the activity of foundation materials that contain montmorillonite are much greater than those of illitic or kaolinitic materials. Foundation problems in montmorillonitic soils are much more severe, because they have lower stability and are subject to greater expansion and contraction than other types of soil. Thus it is important to study the clay mineral composition in conjunction with the geotechnical properties of soils whenever they may be a factor in construction activity.

The ion exchange capacity of clay materials is also affected by their clay mineral composition, being greatest for montmorillonitic, less for illitic, and least for kaolinitic materials. The property of ion exchange makes clays sensitive to their external environment. For example, the cations dissolved in the water surrounding a clay particle are, in part, adsorbed by the charged clay mineral surface layer. Whenever the composition of the water changes, the number and kind of adsorbed ion is adjusted. A clay in fresh water may carry adsorbed calcium ions, whereas if it is exposed to sea water where the most abundant ions are sodium and magnesium these latter ions will replace the calcium adsorbed on the clay surface. It has also been shown that whenever a clayey sediment passes through a zone of pollution, trace elements that reflect the type and degree of pollution become attached to the clay and remain with it until the clay is deposited. In this manner, the chemical constituents associated with the clay complex in sediments may be used to indicate the types of environmental conditions to which the clay has been exposed.

Clay minerals are formed by the alteration of primary minerals, such as feldspars and pyroxenes. Typically such alteration takes place in weathering horizons and soil profiles on the land, although it may occur elsewhere. The progress of alteration and the final clay mineral products are influenced by the details of the chemical environment in the weathering zone. Recent advances in aqueous geochemistry have helped us to understand the chemical nature of the weathering environment and the processes that result.

In tropical soils the most common end product of weathering is kaolinite. This is a result of the low dissolved silica and low potassium compared to hydrogen in the water percolating through the soil. The primary minerals become unstable in the presence of such dilute solutions and change to secondary clay minerals. In some rocks, particularly mafic, the initial weathering products may be montmorillonite or illite, but eventually they too transform to kaolinite.

The lateritic weathering profiles developed over schist, granite, and volcanic rocks of dacite and andesite composition in Southeastern Johore illustrate the sensitivity of clay minerals to chemical conditions of weathering. The weathering profiles in this area have been studied by recent B.Sc. students in Geology at the University of Malaya (see particularly Yeow, 1971). They have shown that kaolinite is the weathering product whenever as little as ten percent quartz occurs in the weathering profile. On the other hand, when quartz virtually disappears from the profile, gibbsite develops. The occurrence of kaolinite and gibbsite correspond to equilibrium relations in the relevant chemical system. Kaolinite persists in the presence of dissolved silica associated with quartz, while gibbsite develops only when the silica level is much less. An understanding of this relationship is important to economic geologists, because ore grade laterites, i.e., bauxites, depend on the presence of abundant gibbsite.

A final illustration of the envrionmental significance of clay minerals may be found in the recent sedimentary environments of the coastal plain of Malaysia. The soils and sediments of this region have been studied by the Soil Survey (Division of Agriculture) and a Ph.D. candidate at the University of Malaya (R.R. Allbrook, 1974). The coastal plain of northwest Kedah and Perlis, as much of the western coastal plain of Malaysia, consists of recent marine alluvium, mature marine alluvium, freshwater swamp deposits, river alluvium, and colluvial deposits. These all lie west of the hilly, granitic hinterland which is blanketed by deeply weathered soils. Each type of deposit has a characteristic suite of clay minerals that allows it to be distinguished and assists in its environmental interpretation.

The colluvial soils, the river alluvium, and the freshwater swamp deposits are all very rich in kaolinite. This is most pronounced for the river alluvium which is derived directly from the kaolinitic soils of the hinterland. By contrast, the recent marine deposits are rich in montmorillonite. The more mature marine alluvium contain montmorillonite and kaolinite. It is reasonable to think that kaolinite has developed from montmorillonite in the mature marine alluvium as a consequence of its exposure to weathering conditions. Montmorillonite is typical of marine sediments in many parts of the world, so its occurrence is consistent with the interpretation of these deposits. But if these sediments are marine, where have they come from? What is their provenance? Kaolinite, rather than montmorillonite, develops in the granitic hinterland from which the river alluvium has been derived. The source of the abundant montmorillonite in marine alluvium of the Malaysian coastal plain is, therefore, an intriguing geological puzzle. Additional detailed study of the mineralogy and stratigraphy of the Quaternary section needs to be made to solve this puzzle.

This review of environmental aspects of clay minerals suggests that more studies of the clay materials of Malaysia are needed. They should provide valuable insights to the processes of weathering and soil formation, to the geological interpretation of the Quaternary section, to an understanding of the appropriate use of construction materials, and to an understanding of man's impact on the environment in this region.

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