CLAY MINERAL DISTRIBUTION IN THE SOIL AREAS OF ARKANSAS[1]

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ABSTRACT

Studies on clay types in the soils of Arkansas show differences that are important to the soil properties in the soils of the various regions. Part of the agricultural importance of these soils may be related to their mineralogical composition.

The Mississippi River delta area has deposits of soil materials high in montmorillonite-type clay and possessing strong expansion and shrinkage properties. The Arkansas River valley has materials high in illite clay types with montmorillonite. Soils of the Coastal Plain predominate in kaolinite mineral but have sufficient quantities of vermiculite clay to dominate the chemical properties. The Ozark upland soils contain kaolinite and illite in varying proportions.

Much of the state is covered with a silt mantle of varying thickness in which the clay mineral composition is mainly that of montmorillonite and illite.

INTRODUCTION

The importance of the clay minerals in the soil is well founded and established. Such discussions are included in many textbooks on the science of soil and also in most of the lecture material of teachers in the field.

An adequate knowledge of the clay is needed to appreciate fully both the chemical and physical soil problems. This has been discussed by Page (1955) and by Buehrer (1955), who illustrate the need for an understanding of the role of clays in the complex system that is recognized as the soil. Studies of pure clay, while of significant value in other phases of clay technology, are of limited direct value in evaluating and predicting soil behavior, especially from an agricultural standpoint. Clays, as they are found in the soil, are mixtures of the various types and include many intermediate stages or degrees of weathering. Thus, since the properties and reactions of the clay are best studied in pure systems, these so-called pure clays may serve as a basis for the study of what occurs in the soil and for interpreting the soil conditions. Studies of the physical and chemical properties of the individual clay types are of limited value in evaluating their role in the natural soil conditions in the field. Their effects are modified owing to the presence of other clay types and to dilution and mixing with various quantities of sand, silt, and organic materials.

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The relative amounts of the various clay minerals in the soil may greatly affect the properties, depending on both the types and amounts of the different clays present. Thus, in soil studies, investigations are usually confined to an identification of the dominant minerals present and to an estimation of their relative amounts. That the study of these clays as mixtures in the soil is important has been well illustrated by Brown (1955), who demonstrated that in a binary mixture of types of clay, only 5 percent montmorillonite or 10 percent illite was necessary to dominate the chemical properties of the kaolinite clay minerals. Also the amounts of the various plant nutrients absorbed from these systems by plant roots were greatly influenced by the clay type, and when the type exceeded the above value the relation between amount of clay and nutrient uptake of a given ion by a plant was linear.

Further, studies of the origin, classification, and interpretation of soil, particularly from the agricultural standpoint, are closely associated with the mineralogical make-up of the soil. (Jackson and others, 1948; Gieseking, 1949; Winters and Simonson, 1951).

A limited number of studies have been made for the purpose of determining the clay content of the soil types that are found in the South. Those studies have not produced uniform results as to the properties of or the specific types of minerals present. Little or no actual work had been done in Arkansas on soil clay identification until about 1951 (Lee, 1954).

The areas of the state of Arkansas differ widely in their agriculture, topography, soil regions, and (as would be expected) mineralogical make-up. A study of a major soil area map points up four main separations—the Coastal Plain reworked ocean deposits, the Mississippi Delta flood plain, the Arkansas and Red River deposits, and the Ozark and Ouachita mountains.

MATERIALS AND METHODS

Soil samples from a number of locations in each of the soil areas have been collected for various purposes. Clay analyses have been run on many of the samples in considerable detail and much is now known of the mineralogical make-up. Much of this work has been done in a cooperative regional project in the southern United States.

The soil samples were prepared by crushing the air-dried sample past a 20-mesh sieve. The organic matter was first removed by peroxide oxidation before the clay material less than .002 mm in diameter was separated from the silt and sand by sedimentation. This clay separate was then further divided into a coarse fraction (2 to 0.2μ) and a fine fraction ($< 0.2\mu$). The dispersion and the separation were carried out at a pH of 9.5 kept constant with NaOH and the fractionation was done with the aid of a supercentrifuge.

The clays were flocculated with HCl, then saturated with calcium by repeated washings in a centrifuge before final study.

All clay samples were analyzed by x-ray diffraction in both powder and oriented form and with differential ion saturation and after heating. The powder samples were prepared and x-rayed in accordance with the procedure of Jeffries and Jackson (1949).

The oriented specimens were prepared by drying the calcium- or other appropriate ion-saturated clay in air on a glass slide and then expanding the clay lattices with glycerol before x-radiation. Samples to be heat treated were prepared in the same manner except that the glycerol was omitted. Samples were heated for 30 minutes at 600°C as recommended by Brindley (1951) and Kelley and others (1939) for detection of chlorite and kaolinite, prior to making the x-ray diffraction pattern.

Samples for differential analyses were prepared by saturation with calcium, washing in a centrifuge with water and ethanol, and drying. The thermal curves were obtained with the equipment of Smothers and Chiang (1952).

Cation-exchange capacities of the clays were determined by a micromodification of the ammonium acetate method of Peech and others (1947) and also by the potassium replacement method of Rendig (1947).

RESULTS AND DISCUSSION

The Mississippi Delta Flood Plain

The clay minerals in this area appear to be those predominantly of the montmorillonite type and to possess strong expansion and contraction properties. The coarse clays seem to be dominated by montmorillonite or interstratified montmorillonite-illite or both. They also contain appreciable amounts of kaolinite and quartz. Estimation of the relative amounts of the important clay mineral groups is presented in Table 1.

The x-ray diagrams showed a broad peak between 10 and 17A with a small side peak at 10A. This all collapsed to 10A upon heating. The coarse fraction also showed considerable amounts of quartz and kaolinite.

In the fine fraction both the oriented x-ray patterns and the differential thermal curves, coupled with the high exchange capacity, indicate that the dominant clay mineral is of the montmorillonite type. The x-ray patterns give some indication of an interlayered mixture of montmorillonite and hydrous

TABLE 1. — AVERAGE MINERALOGICAL CHARACTERIZATION AND QUANTITATIVE ESTIMATION OF THE CLAY IN SOIL MATERIALS REPRESENTING DIFFERENT SOIL AREAS IN ARKANSAS

Soil Series	Clay Fraction (micron)	Exchange Capacity (meq/100g)	Clay Mineral Group, Estimated Percent			
			Kaolinite	Illite	Montmorillonite	Quartz and Others
Coastal Plain	2.0-0.2	21.3	40	T	15	40
	< 0.2	49.5	35	40	20	5
Mississippi Flood Plain	2.0-0.2	24.5	15	20	25	40
	< 0.2	80.6	10	10	70	10
Arkansas River	< 2.0	44.9	15	30	40	15
Ozark and Ouachita Mountains	< 2.0	23.9	35	35	10	20
Silt Deposits	< 2.0	38.7	30	20	30	20

mica. Upon heating these clays, the wide, expanded spacing collapses to a sharp peak at 10A, indicating expansion clays, and the illite at 5.0A remains. There seems to be little or no vermiculite either present in the sediments or formed by weathering in these soils. The shape of the D.T.A. curves possibly indicates beidellite, by comparison with the curves of that mineral made by Grim and Rowland (1942). There was typically a deep peak on the D.T.A. at 125°C for expanding type clay and a small peak at 550°C. Oddly enough the coarse fraction has only a small low-temperature peak, raising some doubt as to the real nature of the wide spacings in the x-ray patterns. The material as found is obviously considerably mixed with unrelated types.

The exchange capacity of these clay separates in this area indicates either montmorillonite or beidellite, because it is too high for an interstratified mixture.

The Coastal Plain

The soils in this area contain clays that are largely of the kaolinite type, but their chemical properties appear to be dominated by vermiculite even though it is present in smaller quantities (Table 1). The most striking difference between the coarse fraction and fine fraction of these clays lies in the quartz. This mineral is present in large quantities as finely divided particles in the coarse fraction but is almost completely missing in the fine fraction. Even though the clay mineral in both fractions is largely kaolinite, both fractions show (by x-ray and D.T.A. methods) considerable amounts of expanding type minerals. The relatively high exchange capacity values can not be accounted for unless some high-exchange material were present.

In the coarse clay separate the oriented x-ray diagrams show that the 2:1 lattice expands to 14A and 17A upon solvating with glycerol, and the D.T.A. curves show a small water loss at low temperatures. Upon heating, the expanded lattices all collapse completely to 10A, leaving no peak at 14A. It is believed that this high-exchange material is vermiculite, which might easily dominate the properties of the whole clay (Brown, 1955).

In the finer clay fraction the moving of the 2:1 peaks and production of a 10A peak in the x-ray pattern upon heating are not clearly defined. A rather broad peak is produced between 10 and 14A, indicating possibly some interstratification here in this size range. There is a relatively greater proportion of expanding minerals in the fine fractions than in the coarse fractions.

Arkansas River Deposits

The deposits along the Arkansas River are of particular interest because of the remarkable uniformity of clay mineral composition over a long distance.

Samples of soils taken at Fort Smith, both on sands and clay sources and those collected on sands and clay soil downstream from Little Rock and classified as the same soil series, actually contain the same clay minerals and in about the same proportions (Table 1). They are dominantly montmorillonite and illite.

The clay soils called Portland clay show montmorillonite, illite, kaolinite, and quartz in decreasing order of importance. The quartz and kaolinite are present in about equal quantities. When the clay is separated into the two fractions of coarse and fine clay, the relative importance of each clay type changes somewhat. In the coarse clay the quartz becomes dominant with kaolinite and illite following in that order. Some montmorillonite is also present. In the fine fraction of this clay, montmorillonite is dominant while illite and kaolinite and quartz respectively are present in minor amounts.

The x-ray patterns of the Portland are similar to those from the soil known as Lonoke—so similar in fact, that one may be superimposed upon another with little difference. The similarity holds true even though some sample locations for the same soil are over 150 air miles apart. The clays are the same and only the proportions vary slightly.

The Arkansas River flows through the state from Oklahoma, Kansas, and Colorado. Wilkinson and Gray (1954), using surface-area measurements, have shown that soils of Oklahoma that could contribute to these river sources are dominantly montmorillonite and illite. Thus, it is conceivable that this same clay material composition would extend further west into Oklahoma.

Ozark and Ouachita Mountains

The limited sampling conducted in this area leaves much to be desired as a basis for generalization. The dominant clay minerals, however, are kaolinite and illite. Some of the expanding-type minerals may be found in small amounts and contribute to the whole clay properties as shown by the data in Table 1. Interstratification of minerals in these soils is not great and the presence of intermediate weathering products does not interfere with the production of rather sharply defined x-ray patterns.

Silt Deposits

Studies are being made of loess soils and other silt deposits in the state. Selected samples from different depositional areas were used for clay analysis. The dominant clay minerals are a poorly defined montmorillonoid with kaolinite and some hydrous mica. The expansion of the 14A line on x-ray diagrams appears to be very poorly defined with the main peak occurring just above 14A. When the samples are heated this 14A line returns to a spacing of 10A, characteristic of vermiculite.

A portion of the material must be more truly like montmorillonite since a definite small side peak is present at 17.7A spacing. The relative amounts of kaolinite and montmorillonoids are about equally balanced (Table 1).

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