CLAY MINERALS AND PHOSPHATE AVAILABILITY:
I. ADSORPTION OF PHOSPHATE IONS BY CLAY MINERALS*

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Recent investigations[5, 12, 17] indicate that clay minerals are not only important in cation exchange reactions in soils but they are perhaps a major factor in governing the availability of phosphate in many soils. From these data, it appears that the kind of clay mineral predominating in the soil is of considerable importance. Soils in which montmorillonite predominates have a high cation exchange capacity, while kaolinite clays have a high anion exchange. Kaolinitic soils have a high capacity to remove phosphate from solution and to fix applied soluble phosphate fertilizers. The recovery of superphosphate by crops is frequently not over 20 per cent, and a recovery of less than 3 per cent has been reported[12] where data showed the predominating clay mineral present in the soil was kaolinitic in character.

The silica-sesquioxide ratio of the colloid is not an entirely reliable index as to the type of clay present but is highly indicative of it. In kaolinitic clays[14] the silica-sesquioxide ratio is approximately 2. Gile[5] reports data showing low efficiency of superphosphate when applied to soils in which the colloid present has a low silica-sesquioxide ratio and a much greater efficiency when the ratio was higher. The types of clay minerals present were not further identified. Gans[4], about twenty-five years ago, suggested a relationship between colloid composition and phosphate availability. Roszmann[16] suggested the possibility of phosphate retention by clays in 1927.

Highly weathered soils are very often kaolinitic in character. In many soil series[1,11] more than one type of clay mineral is present. This is to be expected from the reports[6, 11, 14, 15] on clay mineral formation. Alexander, et al[1] report the presence of kaolin in appreciable amounts in several soils, including among others the Cecil, Greenville, Decatur, Dewey, and Hagerstown series. Many soils in the southeastern part of the United States have been shown to have a high phosphate-fixing capacity and to require heavy phosphate fertilization in order to get results[5]. Colloids from these soils generally have a low silica-sesquioxide ratio[5] and have been reported[9] to be halloysitic. Halloysite is a hydrous form of clay mineral of the kaolin type. The clay fraction of soils formed in warm humid regions is often kaolinitic in character.

Hardy[7, 8] states that the physical attributes and peculiarities of tropical red soils may be explained on the assumption that their colloids are kaolinitic. These soils are known to have a high phosphate-fixing capacity, which has been ascribed to reactive iron. It is highly probable that the type of clay mineral present is also an important contributing factor in this fixation.

Kelley and his coworkers[11] have shown that the colloids from certain California soils are kaolinitic in character, while previous studies by Burd

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* Contribution from the Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma. The author wishes to acknowledge the assistance of Mr. Herschel Ellerts with the analytical work.

and Murphy[3] showed these soils to have a low phosphate availability. Kelley et al[10] also report that granitic types of rocks appear to weather to kaolinitic types of clay under comparatively heavy rainfall. Hardy[8] similarly reports that under highly humid conditions, granite weathers to kaolinitic earth.

Grim[9] reports on the properties of clay and gives a very exhaustive reference on the subject.

EXPERIMENTAL

Kaolin was ground in charges of 125 grams for 7 days in a rubber-lined ball mill. Samples of 100 grams each of this ground material were shaken intermittently for 2 weeks with 1 liter of KH_2PO_4 solutions of the various concentrations indicated in Table 1. Treated in like manner were 100-gram samples of BC Micron Volclay bentonite dust* containing the clay mineral montmorillonite. The samples were then filtered and leached with distilled water. The last leachings from the kaolin samples gave no test for phosphate but those from the montmorillonite continued to give a positive test for soluble phosphate after more than 3 liters of distilled water had been passed through each of the respective samples. Further leaching, however, was not carried out on these samples. The samples were dried, pulverized, and analyzed for their total PO_4 content. The results are shown in Table 1.

TABLE 1

Adsorption of PO_4 from KH_2PO_4 solutions of various concentrations by different clay minerals.

Concentration of KH_2PO_4	PO_4 adsorbed by 1 gram of clay	
	By Kaolin	By Volclay
mg. PO_4/cc.	*mg.*	*mg.*
9.500	50.80	23.12
7.125	37.70	20.59
4.750	29.50	14.67
2.375	24.30	10.18
0.950	16.70	7.23

The kaolin-adsorbed samples contained practically no water-soluble phosphate as is further indicated by the plant tests reported in Part II. As has been stated there was water-soluble phosphate present in the montmorillonite complex. Other experiments[13] indicate montmorillonite fixes very little insoluble phosphate. In one experiment a finely divided sample of kaolinite fixed 110 mg. of water-insoluble PO_4 per gram while a finely divided montmorillonite fixed only 11.8 mg. of water-insoluble PO_4 per gram from a KH_2PO_4 solution of the same concentration. It is even questionable whether this was entirely water-insoluble in case of the montmorillonite. Part II will give further results on this point.

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* Furnished through the courtesy of The American Colloid Company, Chicago, Illinois.

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