Where are the New Discoveries in Soil Science Leading?
I. The Physical Chemistry of Soil-Plant Relationships

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PHYSICAL chemists, as a rule, try to shy away from systems as complex as soils. In the early days, many of them tried to find out about soils by studying simple systems which they thought had properties something like soils — substances like charcoal, charred sugar, colloidal silica, iron, aluminum, kaolin, etc. In many cases such studies brought interesting facts to light. I have always felt, however, that the best way to find out about soils is to study soils, and this report will be confined almost entirely to direct studies on soils or materials isolated from soils.

One has to start somewhere in a review of this sort, and I have chosen to start with the development of methods for isolating the colloidal fraction of soils in large quantities. This was done for the first time in this country only a little over a quarter of a century ago. This step marked a distinct step forward in the development of the physical chemistry of the soil. It was a first step towards producing from the soil a material which was very active from the physico-chemical standpoint and which was more homogeneous, at least from the physical standpoint, than the soil as a whole. It had this additional advantage: This material could be put in a test tube or beaker and measurements with which the physical chemist was already familiar could be made on it with the equipment which the physical chemist had at hand. Here was a material which he could place in a bottle, handle with a pipette, run through a viscosimeter, flocculate in a test tube, and perform a whole host of similar operations which had been developed in the study of the colloidal properties of other systems.

This material had a number of very interesting properties. When in the form of paste, it looked like, and felt like, axle grease. When it was dry, it had the binding power of Portland cement. When in dilute suspension in water and stirred, it showed streamlines, indicating that the individual particles were not spherical. It was clear by transmitted light and turbid by reflected light. When the sol was placed in an electric field, the clay particles moved toward the anode, indicating that they had a negative charge. With most such materials it was impossible to reverse the charge by merely changing the hydrogen-ion concentration. These sols were easily flocculated by electrolytes, and the usual valence laws for coagulation of colloidal materials held true. It was found that the physical behavior of these materials varied widely, depending upon the nature of the salt with which they were saturated. This necessitated the necessity of simplifying the system still further. Systematic studies of the physical properties were to be made.

Fortunately, about that time colloid chemists developed a new tool for the purification of colloidal materials — electrodialysis. In the process of electrodialysis, the colloidal material extracted from the soil was treated with no chemical other than water. It was merely subjected to an electric current which seemed, at least, merely to accelerate the hydrolysis of the exchangeable cations combination of the clay and resulted in the formation of an electrically charged, hydrogen-saturated clay relatively free from foreign electrolytes.

The process of electrodialysis itself revealed many interesting properties of the clay. Under certain conditions it deposited on the anode membrane in the form of finger-like projections which, in other cases, completely bridged across the anode. Occasionally one could even observe small bubbles of gas at the end of these finger-like projections, indicating that they were serving in a way as anodes for the anode itself. The electrical conductivity of the clay when thus oriented was much greater than when the particles were uniformly distributed throughout the anode compartment, indicating there was a marked surface conductivity in the oriented clay system.

One of the most useful purposes served by electrodialyzed clays was their use in studying acidity. It had long been known that the acidity of soils was concentrated largely in the colloidal fraction, and when this isolated colloidal material was freed from all exchangeable bases and of ordinary purity, which could be used for many types of investigation. Numerous titration curves were made, indicating that this material behaved very much as ordinary complex colloidal acids.

Studies of the relationship between the concentration of the clay and its pH value gave the type of relationship expected. Studies of the distribution of the hydrogen ion of the clay indicated that reproducible results of this nature could be obtained.