Aggregate Formation in Soils with Special Reference to Cementing Substances

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Many investigations (1, 2, 3, 5, 25) have shown that organic matter is an important factor influencing the aggregation of soils. The microorganisms using this organic matter as a source of energy have been considered by some to be the responsible aggregating agents. Kanivetz and Korneeva (9) showed that bacterial contamination increased soil aggregation and Peele (22) prepared water-stable aggregates from quartz sand with bacterial mucous. Martin and Waksman (15) found fungus mycelia had a binding effect on soil particles. Martin and Anderson (16) also showed that fungi would form soil aggregates.

A direct binding action of clay particles by polar organic materials was found by Sideri (24) and Myers (20). Ensminger (7) and Ensminger and Gieseking (6) showed that montmorillonitic clays absorbed proteins within the crystal lattice and these proteins to some extent were shielded from the action of bacterial enzymes. These investigations indicated that microorganisms may be more important as indirect agents in being responsible for the production, through the decomposition of fresh organic matter, of polar molecules which act as direct binding agents of the soil particles through physico-chemical bonds. This assumption was strengthened by Martin (12) who found that fresh materials caused greater aggregation than composts when incorporated with the soil. McCalla (17) reported similar results with fully decayed straw. The investigation of Myers and McCalla (21), in which organic materials were incubated in contact with soil materials, showed that maximum aggregation lagged behind maximum microbial activity. This also indicated that metabolic products were more influential as binding agents than the microorganisms themselves.

At the time this study was undertaken the beneficial effects of organic matter as regards soil aggregation were attributed to the direct binding action of the microorganisms and to the action of polar materials produced by them as metabolic products. The location of these substances with respect to the interior or exterior of aggregates had not been determined, although Kubiena (10) stated that a humic layer formed on or near the aggregate surfaces, thus forming a protective shell. These metabolic products were not described in the literature other than as possessing dipole moments. It was the purpose of this study to investigate aggregation processes in a soil and to characterize further the active organic substances and to locate their position within the aggregates.

The investigation reported in this paper was divided into three parts, viz., electron microscope studies of natural and synthetic microaggregates, soil stabilization by decomposition products of different types of organic matter, and a study of microbial binding action of chemical and physical nature.

ELECTRON MICROSCOPE STUDIES

The electron microscope was used in an attempt to discover the nature and location of the binding agents in microaggregates and whether there was any orientational effect of particles.

Natural aggregates were obtained from a Brookston clay loam from Ohio and a Davidson clay from North Carolina. Small portions of these soils were shaken in distilled water, allowed to settle for 12 hours, and a few milliliters of the suspensions removed from which specimens were prepared.

Synthetic aggregates were produced by flocculating bentonite with dilute solutions of iron and aluminum or suspensions of gelatin and humus preparations. A soil was secured from composts of alfalfa, corn stover, and a mixture of corn stover and alfalfa, by electrolyzing them from portions of these materials which had been allowed to remain in water for 3 days. The bentonite suspension (particles 160 μ) which received Fe+++ ions had a pH of 7.5, and the suspension which received the Al+++ ion, a pH of 5. Low pH values were needed to prevent the formation of aluminum hydroxides. The flocculated material was washed twice with distilled water, dried at 45° C, and similarly dried. The bentonite-gelatin system was flocculated to pH 4.7 before flocculation occurred. The bentonite systems did not flocculate over a wide pH range, but either evaporation to dryness, water-stable aggregates were formed. A kaolinite-humus system did not produce stable aggregates when similarly dried.

All specimens for the electron microscope were prepared by the method described by Humbert and Shaw (8).

NATURAL BROOKSTON AGGREGATES

Fig. 1—1, 2, 3, are electron micrographs of natural Brookston aggregates. Organic material is present throughout, coating the individual particles. No particular type of crystal orientation was evident. The organic matter does not act in a capsular form but is thought to be combined with colloidal material.