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A Laboratory Study of the Physical Properties of Colloids

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A LABORATORY STUDY OF THE PHYSICAL PROPERTIES OF COLLOIDS

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ABSTRACT

The colloidal state of matter exhibits phenomena due to its physical properties which may contribute heavily to the mechanical weathering of rocks and minerals. This paper is primarily a discussion, evaluation, and correlation of these phenomena as related to natural geological conditions.

The writer, upon completion of an experimental study of colloids, has decided that colloid plucking and colloid swelling are operative in nature and are important processes in physical weathering.

INTRODUCTION

This report is an attempt to evaluate the importance of the physical properties of colloids as a factor in mechanical weathering. These properties were studied mainly by means of a series of experiments, and include Brownian movement, the Tyndall effect, particle size, response to dessication, and response to hydration. Special emphasis was placed on the latter two.

Following a general discussion of the colloidal state of matter, are four somewhat separate reports, each discussing an experiment dealing with one of the afore-mentioned physical properties of colloids.

An attempt has been made in the conclusion of each experiment to parallel actual geologic conditions with the experimental results. These experimental results and comparisons are used as a basis for the general conclusions in the summary.

THE COLLOIDAL STATE OF MATTER

A colloid may be defined as a state of matter representing a degree of subdivision into almost molecular dimensions. In terms of actual dimensions, particles are designated as colloidal if their diameters are between one and 100 millimicrons (one to 100 millionths of a millimeter). Particles less than one millimicron in diameter are about the size of ordinary molecules, and when they are scattered through another substance, the mixture is a true solution.

A suspension, not a solution, results when particles of colloidal dimensions are scattered in another substance. This type of suspension, known as a colloidal dispersion, consists of a disperse phase and a dispersion medium. The former is the term applied to the suspended particles and the latter is the name given the material in which they are suspended.

Colloidal dispersions and true solutions have two common properties in that they both pass through ordinary filter paper. True solutions, however, have freezing points lower than the freezing point of the solvent, whereas colloidal dispersions have freezing points very close to that of the solvent (Meyer, 1951, p. 202).

Colloidal dispersions or suspensions are often clear and transparent as are true solutions, but may be distinguished as colloidal dispersions by the Tyndall test. If a beam of light is passed through a dispersion, its path is brightly illuminated since each of the colloidal particles reflects a portion of the light toward the observer. A true solution under the same conditions will exhibit no such beam. A searchlight beam in a foggy or smokey atmosphere will illustrate this effect.

When examined under a microscope, colloidal suspensions exhibit a restless, random, and very rapid movement of the suspended particles or micelles. This phenomenon, known as Brownian movement, results from the bombardment of the micelles by molecules of the dispersion medium and is believed to be a contributing factor in the indefinite suspension of the micelles.

Colloids and colloidal dispersions are thus the result of the division of matter into particles of micro-dimensions. It follows that colloids and colloidal dispersions could, and probably do, occur in nature as particles of any mineral or rock regardless of chemical composition.

Wentworth(1922), in a size classification of sediments, considered particles of colloidal dimensions as clay. The extreme fineness of clay results in a tremendous surface area, one gram of clay having been estimated to possess 200 to 900 square meters of surface area (Twenhofel, 1950, p. 325). Clay suspended in water is thus an example of a naturally occuring colloidal dispersion.

EXPERIMENT NO. I

Object: The object of this experiment was to gain a better knowledge of some of the physical properties of the colloidal state of matter by the actual making of a colloidal suspension. Special emphasis was placed on study of particle size by means of settling velocity. A comparison of the freezing points of true solutions and colloidal suspensions was also accomplished.

Materials and apparatus:

India ink	watch glass
water	funnel
test tubes	filter paper

shallow pan of ice cubes

Procedure: A colloidal suspension of India ink and water was made by dropping 10 drops of India ink into 10-15 cubic centimeters of water. An equal portion of this suspension was poured into each of five small test tubes, one of which was capped and set aside to remain undisturbed for a period of 10 weeks. This test tube was observed daily to determine if any of the particles were settling to the bottom. Another vial's contents was poured through a funnel lined with filter paper to determine whether or not the dispersed phase would be separated from the dispersion medium.

The freezing point of the suspension was compared to the freezing point of a true solution of salt and water by placing a test tube of each side by side in a pan of ice along with a third test tube containing water, and noting the order of crystallization.

Results: No particles settled out of the suspension and none were trapped on the filter paper. Ice crystals formed simultaneously in the test tubes containing water and the dispersion, and some time later in the test tube containing the true solution.

Conclusions: The dimensions of particles of colloidal dispersions are of microscopic size and remain suspended almost indefinitely. Deposition of clays in marine environments is probably caused by chemical not physical means. Colloidal dispersions are able to pass through permeable barriers without loss of particles. Meyer's conclusion that freezing points of colloidal suspensions are very nearly the same as the freezing point of the dispersion medium is borne out in this experiment. Naturally occuring suspensions such as clay in water would presumably pass through a permeable stratum without loss of particles.

EXPERIMENT NO. II

Object: The object of this experiment was to demonstrate the force that is exerted on adjacent materials by a colloidal dispersion upon dessication or "setting". Reiche, (1950, p. 14) in a discussion of a mechanical weathering process which he termed colloid plucking, stated that small flakes of glass are pulled from the walls of glass containers containing drying gelatin. This experiment is essentially a simple test of Reiche's statement.

Materials and Apparatus:

gelatin (Knox's unflavored)

water

1 common tumbler

Procedure: A colloidal suspension consisting of ordinary gelatin and water was mixed in a water glass and set aside to dry out. After the first two days, part of the material (then partially set) was spread over the concave walls of the glass in thicknesses varying from about one millimeter to about five millimeters.

Approximately three-fourths of an inch of the material was left in the bottom of the container.

Results: After a period of 32 days, the resultant residue was removed from the glass and examined. The thinner layers which had been spread on the walls of the glass proved more difficult to remove than the bottom residue which was removed by merely inverting the glass. A colored tumbler should have been used as the contrasting color would have simplified the task of distinguishing between glass particles and geletin residue which resembled each other closely.

One flake of glass was found in the material that had been in contact with the bottom of the glass. The dimensions of this flake were approximately 3x2 x 0.1 millimeters.

Conclusions: Colloidal suspensions, upon dessication, have the ability to scale off flakes of material with which they are in contact. As Reiche has pointed out, if this process is operative in nature, the amount of work done would contribute tremendously to mechanical weathering.

EXPERIMENT NO. III

Object: In this experiment, which is a sequal to Experiment II, an attempt was made to extend the principle of colloid plucking to five different rocks and minerals.

Materials and Apparatus:

1 specimen of each of the following:

sandstone limestone

obsidian shale

muscovite

5 water tumblers

1 small pail filled with sand

gelatin (Knox's unflavored)

water

Procedure: The 5 tumblers were half filled with a colloidal suspension of gelatin and water. To each of these tumblers was added a specimen of one of the rocks listed above. These specimens, approximately one inch square, were steel brushed to remove any loose surface particles. Care was taken to insure that the specimens were completely surrounded by the suspension.

Dessication was facilitated by heating a pail of sand in which the water glasses were half submerged. After a thorough drying of the suspension surrounding the samples, the residue was carefully peeled off and examined with a hand lens. Dessication required only 12 days in this experiment.

Results: Several dozen flakes each of obsidian and muscovite were found in the residue which had surrounded these materials. These flakes, however were only about one tenth the size of the glass flake scaled off the water glass in experiment II. No particles or flakes were found in the residue surrounding the limestone and sandstone specimens. The shale specimen was badly crumbled in the process of removing the residue, thus rendering this portion of the experiment invalid.

Conclusions: A drying colloidal suspension of gelatin and water will pluck off particles of adjacent materials of smooth surface texture more readily than materials having rough surfaces. This is conceivably due to some function of the surface area of the material involved. Reiche's belief (1950, p. 14) that strong surface convexity of small grains may protect them from colloid plucking seems to have been borne out in this experiment by the negative results in the case of sandstone.

If, granted the critical but seemingly reasonable assumption that, naturally occuring colloidal suspensions such as clay and water act similarly to gelatin and water suspensions, the process of colloid plucking would be of extreme importance in the mechanical weathering of rocks and minerals having smooth surface textures.

EXPERIMENT NO. IV

Object: The object of this experiment was to investigate the characteristic of colloids to swell when wet with a liquid such as water. Kruyt and Van Klooster (1927, p. 224) state that when a dry gel (colloid) is placed in a closed space and covered with a liquid, the liquid is taken up with a great intensity and results in an increase in volume along with a tremendous pressure of swelling.

Materials and Apparatus:

1 test tube

1 hard rubber stopper

1 wood clamp

dried peas

water

Procedure: A test tube was filled with nearly equal volumes of pulverized dried peas and water and a rubber stopper inserted in the open end of the test tube. A wood clamp was utilized to hold the stopper securely in the test tube. This apparatus was then set aside for observations.

Results: After 8 hours, the hard rubber stopper had been considerably compressed as was evidenced by indentures where it had been in contact with the clamp. Approximately 12 hours later, the pressure due to swelling completely shattered the test tube.

Conclusions: Forces of great magnitude result from the swelling of confined dry colloids when saturated with a liquid. A time honored method of splitting the trunk of a tree consists of exactly the same procedure described above. (Kruyt and Van Klooster, 1927, p. 224).

Kruyt and Van Klooster (1927, p. 226) report that Posnjack, who in 1912 investigated the swelling of raw Para rubber in different organic minerals,

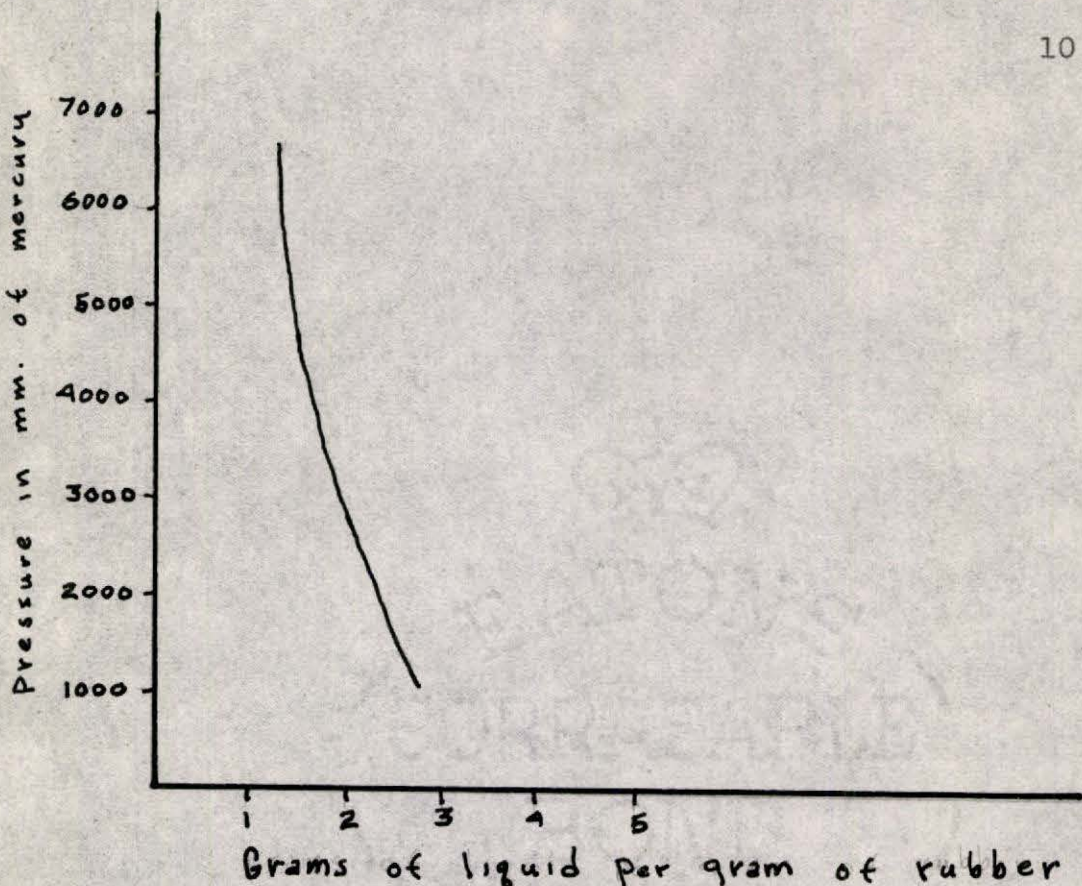

Fig. 1. - Swelling Pressures in Para rubber (modified from Kruyt and Van Klooster, 1927, p. 225).

concluded that the resulting pressures were a function of the ratio of the liquid taken up to the grams of colloidal particles. His results, reproduced graphically in Figure 1, show a pressure of 7 atmospheres when the rubber particles contain one and a half times its own weight of absorbed liquid.

This principle would presumably apply geologically to a bed of clay if underlain by hard, impervious strata and overlain by permeable, brittle strata. Surface waters, percolating through the upper permeable strata and wetting the clay would cause swelling and the resulting pressure could conceivable arch or break the overlying strata.

SUMMARY AND GENERAL CONCLUSIONS

Colloidal dispersions occurring abundantly in nature in the form of clay and water probably behave much like the disperions studied experimentally in this project. This seems certainly true in the case of colloidal swelling as is evidenced by the behaviour of bentonite when wet with water.

As has been pointed out in the conclusions of the experiments above, geological conditions do exist where processes such as colloidal plucking and colloidal swelling could occur. It is the writer's opinion that these processes do operate under natural conditions and are of noteworthy importance as a factor in mechanical weathering.

The fact that bentonite has the ability to absord as much as eight times its dry volume and to swell to a greater extent (Twenhofel, 1950, p. 338), certainly lends support to the writers conclusions, especially to those concerning the importance of colloidal swelling as a weathering process.

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