were fitted with screw feeds and the cylinders were connected to the driving cylinders by flexible metallic tubing permitting convenient remote control. Large and small controlling pistons which gave a coarse and a fine feed were used. The systems were filled with a heavy oil. Such an instrument operated free from vibration, drift and annoying lag when movement was observed through a microscope at 800 to 1,100 diameters magnification.

As a further and more critical test of such a mechanism a mirror was attached to a piston of 0.875 inches diameter and this made the movable arm of a Michelson interferometer. The controlling piston was 0.125 inches diameter and fitted with a screw feed of forty threads per inch. This made the fineness of movement the equivalent of a screw with about 2,010 threads per inch, and a hundredth turn of the controlling piston would move the larger piston about 0.000005 inch, or one two-hundred-thousandth of an inch. The use of parallel fringes with the mercury line 5,460.74 A. U. as a source showed the vibration to be less than a millionth of an inch, the drift imperceptible and the lag less than 0.000005 inch. Measurements showed an error which was well within the probable error of the screw feed so that errors due to the hydraulic system *per se* were not apparent in this setup.

Because of the incompressibility of liquids at ordinary pressures and the ease of introducing remote control such hydraulic systems are especially adaptable for producing vibration-free movement, and apparently when the liquid wets the walls accurate movements are possible. Apart from the value of such devices in micromanipulator construction the question arises as to whether or not certain periodic errors inherent in screw feeds might not be minimized by using an hydraulic ratio such that they became negligible. Periodic errors might also be eliminated by using several controlling pistons operated simultaneously with each forcing fluid into the driving cylinder, producing a summation of the individual periodic errors.

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RAPID DETERMINATION OF THE MOISTURE CONTENT OF SOILS

ONE of the greatest needs in soils investigations, both in laboratory and under field conditions, is a simple and very rapid method for determining the moisture content of soils. The same need is undoubtedly felt in many other branches of science and industry. For the methods we have at present for determining moisture content of materials are laborious, slow and time-consuming.

In having developed and used in this laboratory the hydrometer method for estimating the mechanical composition of soils and also for determining the colloidal content of soils in only a few minutes, the idea occurred that the hydrometer method might be also used in determining the moisture content of soils. This could be done, it was thought, by mixing a definite volume of pure alcohol of known specific gravity and a definite amount of moist soil and determining again the specific gravity of the liquid. The difference in specific gravity between the pure alcohol and the mixed liquid ought to give the amount of water in the soil since the alcohol extracted the moisture from the soils which went to dilute its strength.

This idea was subjected to an investigation and it proved to be perfectly correct and successful. The experiments showed that the alcohol can extract the moisture from the soil from any moisture content down to considerably below the air-dry condition, and it indicates the amount so extracted correctly on its specific gravity. When the soil mass is in such a structure so the alcohol can penetrate it easily, the extraction of the moisture is accomplished almost instantaneously. The soil particles not being deflocculated by the alcohol, they settle to the bottom of the vessel very readily. On the other hand for more rapidity in operation the soil can be shaken vigorously and immediately filtered and taking the specific gravity of the filtrate. The results showed that whether the alcohol mixture was allowed to clear up by standing or filtered through a filter paper, the specific gravity was the same.

By means of this method the moisture content of a soil can be determined in only a few minutes. At this laboratory the moisture content of many soils have been determined in less than five minutes. The only soils which take more time are those which are puddled and the alcohol can not penetrate them. Vigorous shaking or stirring with a rod, however, hastens their breaking up.

This method seems to be absolute and not arbitrary. It seems that it is almost as absolute as the oven-dry method. With a very sensitive and accurate hydrometer, which is being made, the method can be very accurate.

The method ought to find a very wide application, not only in soils work, and possibly in plant tissues, but also in many other sciences and industries. It is somewhat strange that it has not been used long before this, because its principle we have known for so long.

A more detailed report is being prepared.

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SPECIAL ARTICLES

ZEOLITE FORMATION IN SOILS

The presence, in soils, of zeolites (basic hydrated aluminum silicates) possessing the property of base replacement, has been known and studied by chemists for a great many years. The source or origin of these chemical compounds is unknown, although most authorities, either by direct statement or by intimation, have given us the idea that, as they make up an important part of the clay fraction of soils, they are chiefly formed by the slow natural processes of decomposition, hydration and trituration under water, over long periods of time and are of great age.*

During the researches being conducted in this laboratory upon the aluminates and silicates occurring in alkali soils, the following question arose. Having shown that black alkali soils contain sodium aluminate and sodium silicate in the soil solution and having found that these two compounds will unite in the cold to form sodium zeolite, may we not consider such a union possible within the soil complex under natural conditions? The present paper constitutes a brief summary of detailed work which shows to our satisfaction that the zeolites now present in soils have not necessarily existed for untold ages but may be of very recent origin—in fact, may even now be in process of formation.

In preparing a synthetic zeolite by the above method, namely, from solutions of sodium aluminate and sodium silicate in the cold, the resulting colloid was found to possess extremely active base replacement properties. Also, upon adding small amounts of solutions of the above compounds to soils and allowing the latter to dry in the air at room temperatures we obtained a notable increase in their zeolitic content as indicated by quantitative base replacement studies. We have thus built up the zeolite content of a soil by adding the two compounds which we had previously shown would combine to form a zeolite, and which two compounds we have also shown to be present and to be often in process of formation within black alkali soils.

On mixing concentrated solutions of sodium aluminate and sodium silicate the resulting solution will almost instantly solidify to a gel. Dilute solutions, N/50 for example, showed no gel formation even on long standing. By titrating such a dilute solution with acid, however, it was found that zeolite formation occurred and, in dilute solution, is a function of reaction. Continuing this line of experimentation, we found that at strongly acid or strongly alkaline reactions a high concentration (due to high solubility) is essential to the formation of the colloidal zeolitic gel, while in dilute solutions the components combine within a definite pH range only. The maximum precipitate, or range of lowest solubility, is on the acid side of neutrality, pH 5 to 7. At pH 3.6 the zeolite was completely soluble. Our results to date indicate that it is far less soluble in alkaline than in acid solutions, although it has an appreciable solubility in both.

We thus obtained data in the above titrations showing that zeolites are completely soluble in dilute acids.[1] On titrating back with alkali, however, the colloid was again formed and its typical base replacement property restored. To prove that the colloidal zeolite molecule had been broken down into its acidic constituents (silicic acid, aluminum chloride and sodium chloride) an acid solution of the zeolite was dialyzed through a paraloidion membrane, the dialyzed solution neutralized to a reaction of pH 6.0, and evaporated until a gel was again formed. This zeolitic gel had reacquired its base replacement property.

After having formed the basic zeolite from its alkaline constituents, which we have shown to be present in black alkali soils, the acid zeolite was then synthesized from the acid constituents which are known to be present in acid soils. These are silicic acid and soluble aluminum and sodium[2] salts (chlorides). The physical and chemical properties of all of these zeolites are being studied and their formulae determined.

The next step in our investigations was to extract the components of the zeolites from both alkaline and acid soils and cause them to recombine to again produce zeolites. Thus, a soil was leached with 3 per cent. hydrochloric acid, the leachings evaporated upon the water bath to a gel, and this gel shown to possess the property of base replacement. A similar experiment using water or a solution of sodium hydroxide was carried out with a black alkali soil, with the same typical property of base replacement showing in the colloid obtained. In the latter case there

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* Gedroiz claims that more recent "secondary absorbing complexes" in the form of "absorption compounds" may be formed by the union of particles of colloidal silicic acid carrying negative charges with those of colloidal aluminum hydroxide carrying positive charges, but that such "new formations" are extremely unstable, "decomposing easily into their constituent parts."

[1] This would confirm the results obtained by Kelley, Gedroiz and others who have shown that in attempts to use acids as a carrier of H ions in base replacement there is a disruption of the zeolite molecule.

[2] Soluble potassium, calcium or magnesium salts may be used.