

123. MOISTURE CONTENT AND DENSITY OF SOME
 CLAY MINERALS AND SOME REMARKS ON THE HYDRATION
 PATTERN OF CLAY

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It is a well-known fact that the density of clay particles, determining the velocity of fall in suspension, according to STOKES' law, is greatly affected by hydration of these particles (1).

We determined the density of some clay minerals in dependence of the moisture content, using pycnometer-technique, with a petrol fraction (boiling point 170—230° C) as suspension medium. The solubility of water in this is negligible. The hydration of the clay particles in aqueous suspension, moreover, was approximately determined from viscosity measurements.

The materials used were: montmorillonite (Wyoming bentonite; "thixoton"); illite (Winsum, Holland; "ordovician bentonite"); kaolinite ("Brocades"). The fraction $< 2 \mu$ was separated and converted into H-clay by percolation with 0.05 N HCl and subsequently the excess of acid was washed out.

The results of the density measurements are summarized in Table 1.

TABLE I.

Mineral	Rel. Hum.	Moisture content % oven-dry basis	Density *)
Montmorillonite "thixoton"	—	0.0	2.348
	0.00	—	2.608
	0.25	11.6	2.199
	0.50	16.6	2.134
	0.75	28.4	2.001
	1.00	46.0	1.772
	—	244	1.222
	—	301	1.186
Illite Holland	—	0.0	2.649
	0.0	—	2.660
	0.25	3.0	2.579
	0.50	4.85	2.504
	0.75	6.9	2.422
	1.00	18.8	2.128
	—	103.8	1.441
Illite "ordovician"	—	0.0	2.642
	0.0	—	2.688
	0.25	8.3	2.409
	0.50	12.0	2.310
	0.75	24.8	2.02
	1.00	76.0	1.48
	Kaolinite "Brocades"	—	0.0
0.0		—	2.682
0.25		0.4	2.663

From the density of montmorillonite with moisture content above 30 % we calculated a formula, expressing the relation of density (d) and moisture content (m , in %):

$$d = \frac{276 + 2.76 m}{100 + 2.76 \cdot 1.002 m}$$

where 1.002 represents the specific volume of water.

The formula does not agree with moisture contents below 30 %, the cause being the decreasing value of the specific volume of the bound water. From the density of the samples with moisture contents of 28.4 %, 16.6 % and 11.6 % on one hand and the density of oven-dry material on the other may be calculated a specific volume of the bound water of 0.76, 0.73⁵ and 0.71 cm³/g, respectively.

For the illite samples the relation between density and moisture content is:

$$d = \frac{271 + 2.71 m}{100 + 2.71 \cdot 1.002 m}$$

This formula holds good for the moisture range above 3 %. Only the calculated value of the density at moisture content zero does not agree with the observed value, the cause being again the decreased specific volume of bound water at moisture contents below 3 %. From our data may be calculated a specific volume of 0.72 cm³/g for the water bound below a moisture content of 3 %.

In aqueous suspension the clay particles must be considered fully hydrated. The "moisture content" of these fully hydrated particles exerts a decisive influence on the density of clay in aqueous suspension. From viscosity measurements we determined approximately the total volume of the hydrated particles (φ) in montmorillonite suspensions of different concentrations, according to EINSTEIN's formula (1):

$$\eta_s = \eta_w (1 + \frac{5}{2} \varphi)$$

The results are summarized in Table 2.

TABLE 2.

Mineral	Conc. g *) per 100 cc water	φ in cc per 100 cc water
Montmorillonite "thixoton"	0.499	8.2
	1.025	20.8
	1.919	54.9
Montmorillonite "Wyoming-bentonite"	0.471	8.0
	1.003	20.1
Illite "ordovician"	0.513	4.5
	1.085	17.1

*) oven-dry material.

At concentrations below 1 % the calculated hydration of the mineral appears to be practically independent of the concentration. From the data given and from our first formula it follows that the density of

fully hydrated montmorillonite practically does not exceed the density of water. The results of granulometric analyses of montmorillonite clays in aqueous suspension therefore seem extremely doubtful.

As to the pattern of bound water layers of hydrated clay two suppositions are prevailing in the current literature. HENDRICKS and JEFFERSON (2) suggested the hydrated montmorillonite to contain one or more water layers of a structure, similar to the ice pattern, but with lattice dimensions $2 \times 3.0 \cos 30^\circ = 5.2 \text{ \AA}$, equal to the a axis of the elementary cell of the Si_2O_5 plane. Assuming two water layers to be present (corresponding to 20 % moisture content) a value of 1.11 cm³/g may be calculated for the specific volume of this bound water.

MACEY (3) fitted the ice pattern in a different manner upon the Si_2O_5 planes of the 001 surfaces, and calculated a lattice dimension of $5.2 \cos 30^\circ = 4.51 \text{ \AA}$, exactly equal to the lattice dimension of ice. Again assuming two water layers to be present (here corresponding to 30 % moisture content), a specific volume of 0.73 cm³/g of the bound water may be calculated.

The latter value agrees much better with our measurements.

The details of these statements will be published elsewhere.

REFERENCES

- (1) BAVER L. D.: Soil Physics, (New York, 1948), p. 87.
- (2) HENDRICKS S. B. and M. E. JEFFERSON: Amer. Min. **23**, 863—875, 1938.
- (3) MACEY H. H.: Trans. Cer. Soc. **41**, 73—121, 1942.