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SELECTED GREAT BASIN PLAYA CLAYS

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ABSTRACT

Mineralogical studies of samples from Deep Springs Playa, California, Mud Lake and Humboldt Playas, Nevada, Sevier Playa, Utah, and the Animas Playa, New Mexico, indicate that the mica-type clay minerals illite, vermiculite, and montmorillonite are prominent in the playa crusts. The similarity of such widely separated localities suggests a general distribution.

The clay minerals display strong continuous scattering accompanying the normal Bragg reflections. Presumably an intensive disorder is caused in their structures by the weathering. The *b* dimensions and the high $MgO+FeO+Fe_2O_3$ contents of the clay minerals indicate that the nature of the mica-type layers is tetrasilicic.

The existence of sensitive layers like those of vermiculite and montmorillonite in the playas is important in explaining the physical behavior of the surface of the playas. These layers exfoliate when dried and also expand with an increase in humidity.

INTRODUCTION

Playas of the Great Basin[2] provide clay deposits of great thickness and unusual physical properties. Crustal samples from five widely separated playas have been selected for detailed laboratory study.

The playas represent accumulations of fine clay constituents deposited on the floors of former Quaternary lakes of widespread distribution. Surface drainage from surrounding areas contributed finely divided materials, detrital grains, and salts in solution. Repeated deposition, settling, and evaporation have combined to form successive beds on the lake floors.

Lakes Lahontan (Russell, 1885) and Bonneville (Gilbert, 1890) serve as classic examples of Quaternary lakes of the Great Basin. The samples selected for study (Fig. 1) are believed to furnish examples of clay deposition from several widely separated old lake floors of this type. The nine clay samples represented were collected from Deep Springs Playa, California, Humboldt and Mud Lake Playas, Nevada, Sevier Playa, Utah, and Animas Playa, New Mexico. All were cut more or less as a block from the flat playa surface. Lower Sevier Playa (Wah Wah Valley) is light gray to white, smooth, and forms a hard porcelain-like pavement when dry. Mud Playa is a circular, smooth, gray clay surface, 5 miles in diameter, occasionally used as an alternate landing field for high-speed air-

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[2] The historic name "Great Basin" or the geomorphic term "Basin and Range Province" (Fenneman, 1931) applies to the broad belt of intermontane basins of the western United States.

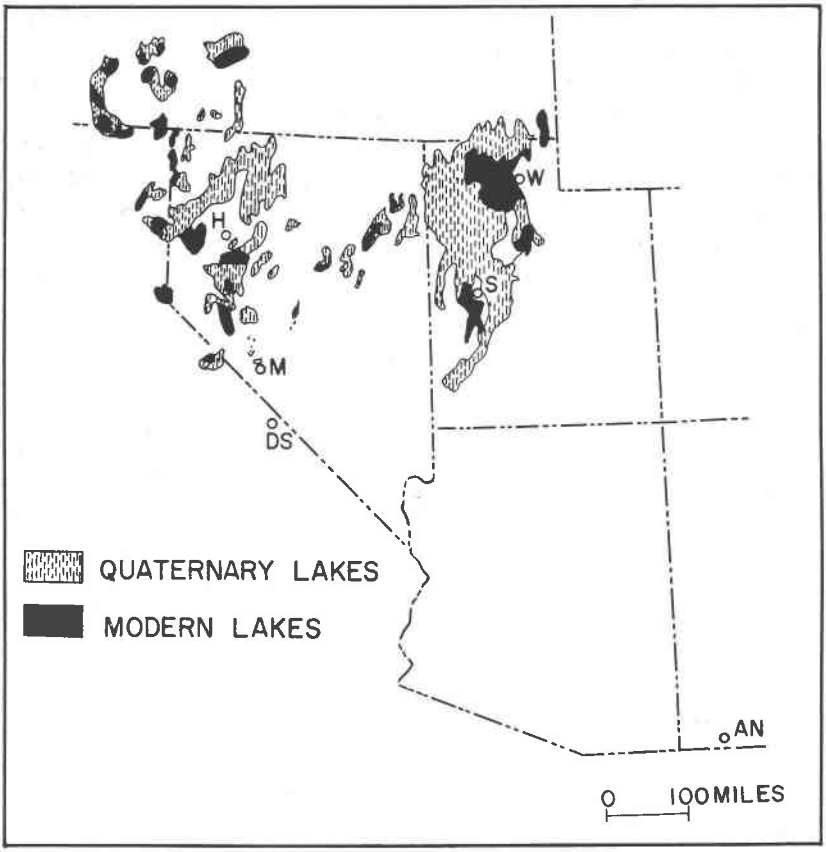

FIG. 1. Distribution of the playas. DS, Deep Springs, California; M, Mud Lake, Nevada; H, Humboldt Playa, Nevada; S, Sevier Playa, Utah; W, Willard Reservoir, Utah; AN, Animas Playa, New Mexico.

craft. Deep Springs Playa is in part wet because of marginal springs and where dry yields an uneven, "puffy" surface. Humboldt Playa, the terminus of the Humboldt River, which meanders for 1000 miles through an enclosed basin in northern Nevada, is a smooth, more or less moist, ancient saline-clay playa, considerably influenced by flooding and evaporation. Animas Playa represents a group of smooth gray clay surfaces, mostly smooth and hard when dry. All playa surfaces represent accumulations in enclosed basins.

SALINES

Table 1 shows the main saline minerals of the playa samples and the total loss by leaching salines and carbonates with a weak organic acid (a

5% solution of monochloracetic acid). The relative intensities of the x-ray reflections of the saline minerals are also given in the same table. The weight percentage of the saline minerals has been calculated for two of the samples with a high saline content (Table 2).

As shown by the x-ray diffraction diagrams, dolomite and less abundant calcite are the main saline minerals in the dry sample from Deep Springs Playa. In a wet sample from the same playa halite, dolomite, and thenardite are the major saline components. Mud Lake and Humboldt Playas have a low saline content. Calcite is the major saline mineral in

TABLE 1. DISTRIBUTION OF SALINES IN PLAYA SAMPLES AS INDICATED BY THE RELATIVE[1] INTENSITIES OF THE STRONGEST REFLECTIONS ON THE X-RAY DIFFRACTION PATTERNS

Sample	Halite I_{200}	Thenardite I_{113}	Gypsum I_{020}	Calcite I_{104}	Aragonite I_{111}	Dolomite I_{104}	Total loss by leaching (weight %)
Deep Springs No. 1	—	—	—	50	—	100	38.5
Deep Springs No. 2	100	35	—	10	—	100	49.1
Mud Lake, Nevada No. 3	5	—	—	100	—	—	9.8
Humboldt, Nevada No. 4	90	—	—	100	—	—	10.0
Lower Sevier No. 5	5	—	—	100	15	10	36.5
Upper Sevier No. 6	10	—	80	100	25	10	55.3
Middle Animas No. 7	5	—	—	100	—	—	11.3
South Animas No. 8	5	—	—	100	—	—	16.8
North Animas No. 9	—	—	—	100	—	—	9.1

[1] The intensities of the saline minerals are compared within the same sample by taking the strongest reflection in each sample as 100. This is not strictly quantitative but it gives an approximate indication of the relative abundances.

both playas, but Humboldt Playa also has a considerable amount of halite.

Carbonates (calcite and aragonite) are the main saline minerals in the two Sevier Playas. The Animas Playas in New Mexico have a low saline content, and calcite is the chief saline mineral.

PARTICLE SIZE ANALYSIS

The particle size distribution and measurement in the playa clay samples have been obtained by using the A.S.T.M. Hydrometer Method (1961) D422-61T. Salines, such as Cl^- and SO_4^{4-}, and also carbonates in highly calcareous samples were removed before analysis. The summation curves obtained are given in Figs. 2A and 2B. A general feature of these curves is that all show that nearly 90 per cent of the constituent particles are less than about 100 microns in diameter. Thus, the sediments are predominantly silt and clay. However, the amount of clay with a diameter of less than 2 microns ranges for different playas. In the Deep Springs, Mud, and Humboldt Playas the -2 micron fraction is approximately 60 to 70 per cent, whereas in the Sevier and Animas Playas it decreases to about 30 per cent. However, there are some samples from the last-mentioned playas with a high clay content, such as from Upper Sevier Lake, Middle and South Animas.

TABLE 2. THE PER CENT DISTRIBUTION OF THE SALINE MINERALS AS CALCULATED FROM THE PARTIAL CHEMICAL ANALYSES OF TWO SAMPLES

Sample	Halite	Thenardite	Gypsum	Calcite	Aragonite	Dolomite	Total weight
Deep Springs No. 2	7.83	12.05	—	1.33	—	49.17	70.38
Sevier No. 6	4.60	—	5.41	27.69	6.92	11.06	55.68

Analyst, Silve Kallman, Ledoux and Company, Inc., New Jersey.

CLAY MINERALS

Mica-type clay minerals—illites (which may also be grouped under the term hydrous micas), vermiculites and montmorillonites—are the predominant layer silicates in the playas. The x-ray diffraction of these materials has been studied, including separately both $(00l)$ and (hk) reflections. The $(00l)$ reflections yield direct information about the variations in the basal spacings of the layers and thus diagnostic criteria for

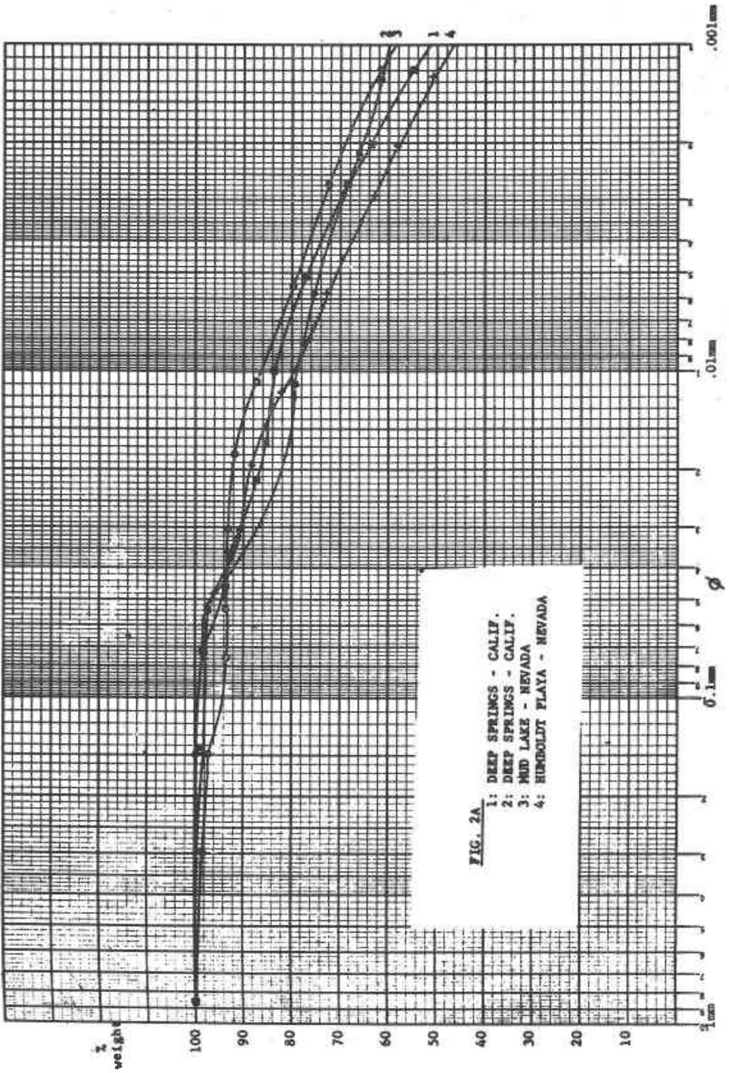

FIG. 2A. Particle size distribution of the playa clays.

differentiating between them. The (*hk*) reflections give direct information about the octahedral occupation of the layers.

The (00l) reflections of the playa clay minerals. The (00*l*) reflections of clay minerals are obtained by *x*-ray diffraction of oriented flakes. Such flakes have been prepared from untreated −1.5 micron fractions and also from

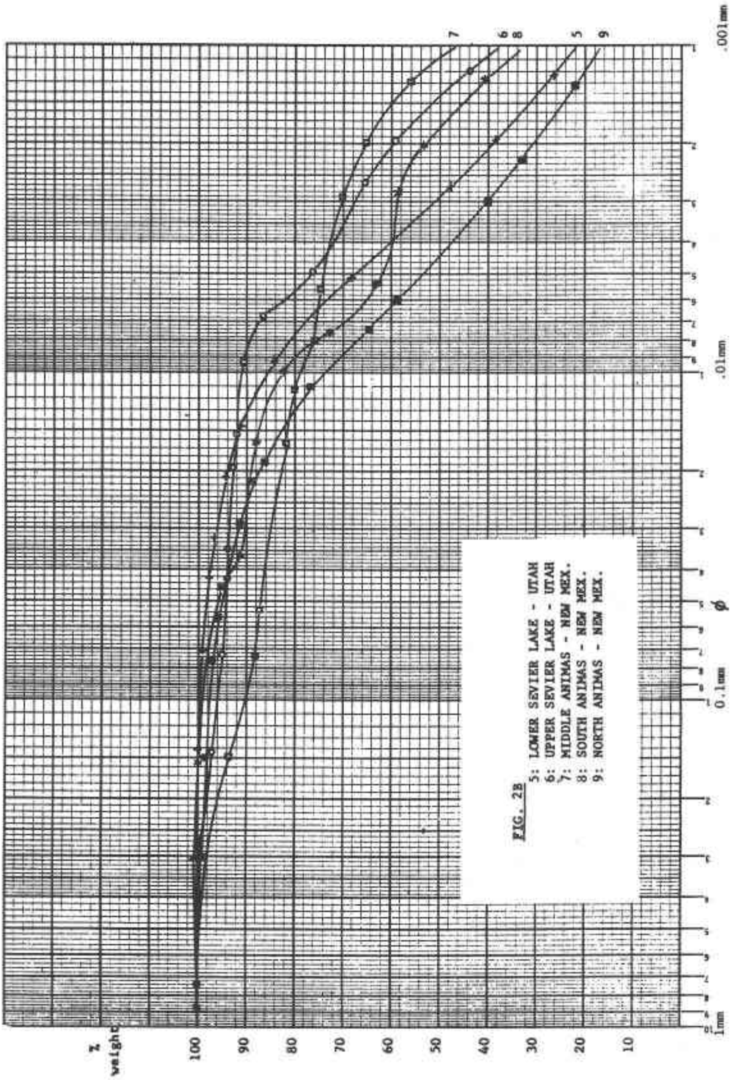

FIG. 2B. Particle size distribution of the playa clays.

acid-leached samples. The clays of the −1.5 micron fractions have also been subjected to ion exchange with cations K^+ and Mg^{2+} (Walker, 1961). The mounts were run on a Phillips-Norelco diffractometer (Ni filter, Cu radiation, scale factor 4, multiplier 1, time constant 4, scanning speed 1°/min.).

Illite. Illite occurs in all the playas as the main clay mineral with its characteristic reflections at 10.0, 4.9, 3.32, and 2.0 Å. Considering the structure factors calculated by Brown (1955) for the mica layers, the low intensity for the 3.32 Å reflection does not correspond to the muscovite-type layers. The most interesting feature of the illites in playa clays is the continuous scattering at the lower angle region $2\theta = 4\text{–}9.0°$ (Fig. 3A–B), with some superimposed sharper maxima. The intensity of the 10 Å reflections is the strongest compared with the intensities of the other reflections in the lower angle region. The continuous scattering shows that the 10 Å mica layers are randomly intercalated with the different cation-water layers in the following form: MMAMMBMAMBMC. . . . M represents the 10 Å mica layers and A, B, C··· the different cation-water layers. The *x*-ray diffraction from such a random mixed layering will

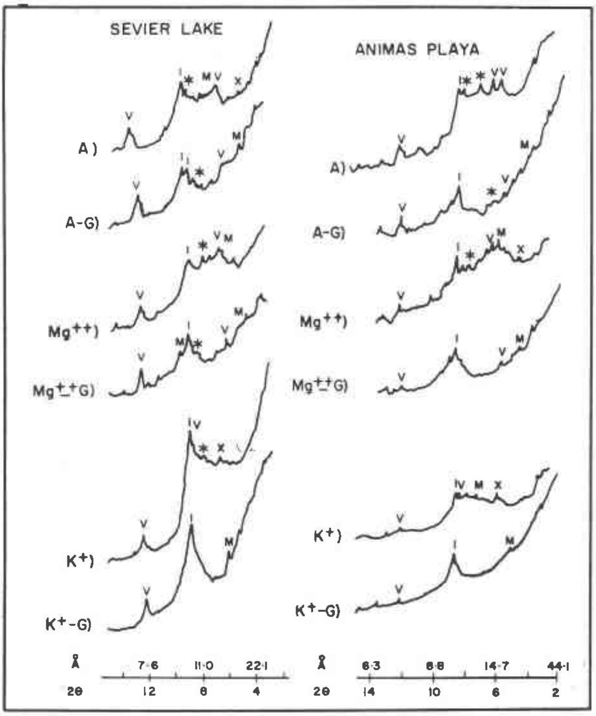

FIG. 3A. Lower angle region of *x*-ray diffraction patterns for oriented playa clays (−1.5 micron fraction in natural state). I, illite; V, vermiculite; M, montmorillonite; *, intermediate spacings; X, mixed layer with partial stacking order. (A, air dried sample; A–G, air dried+glycerol; Mg^{2+} treated; Mg-G, Mg^{2+}+glycerol; K, K^{+} treated; K-G, K^{+}+glycerol.)

show "apparent intermediate spacings" determined by the relative amounts of M, MA, MB, MC type layers. The pronounced continuous scattering shows that the mixed layering is generally random. There are, however, weak reflections with long spacings over 20 Å indicating that a partial order in the mixed layering is present; i.e. MMAMMA, MAMBMAMB . . . type regular stacking sequences are formed which give superstructure reflections with spacings between 20 and 30 Å. These reflections are designated on the *x*-ray diffraction diagrams by the letter *X* (Figs. 3A and 3B). Illites of Humboldt Playa form the only exception where continuous scattering related to the 10 Å reflection is absent (Fig. 3B). In Mud Lake, Sevier, and Animas Playas the continuous scattering in the lower angle region is very well developed.

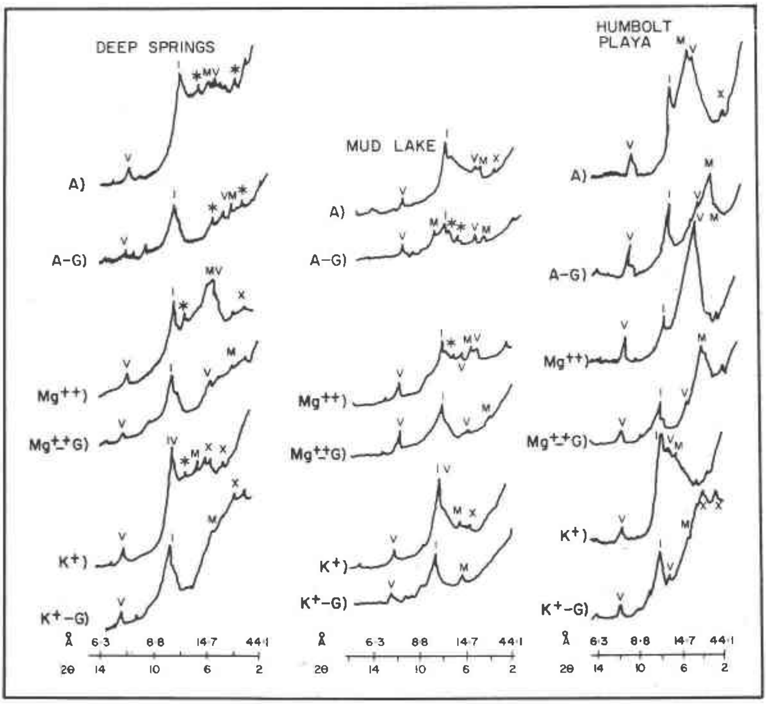

FIG. 3B. Lower angle region of *x*-ray diffraction patterns for oriented playa clays (−1.5 micron fraction in natural state). For explanation of symbols see Fig. 3A.

Vermiculite and montmorillonite. Vermiculite occurs in all playa clays with typical 14.2, 7.1, 4.74, and 3.56 Å reflections. The very low intensities of the 7.1 and 3.56 Å reflections, compared with the intensity of the

14.2 Å reflection, distinguish vermiculite from chlorite (Weiss and Rowland, 1956). Further increment heat treatment from 110° to 450° C. shows that there is already at 110° C. a shift of 14 Å reflections at the lower angle region towards 10 Å with an increased intensity of the 10 Å reflection. At 250° and 350° C. this shift is further intensified. Upon exposure to the air, weak reflections occur at 10.6 to 14.8 Å and 16 to 21 Å; these reflections are, however, not reproducible. These are rehydrated phases of vermiculites and the 16 to 21 Å reflections indicate the mixed layers associated with these rehydrated phases. This thermal behavior clearly distinguishes vermiculite from chlorite and shows that no chlorite is present. Further the 7.1 and 3.6 Å reflections disappear at 450° C., indicating that there is no kaolinite in these playa clays.

Mg^{2+} treatment increases the 14 Å reflection considerably. This reflection gives rise, upon glycerol saturation, to reflections at 17 to 20 Å and at 14.2 Å. The non-expanded 14.2 Å reflection indicates the presence of vermiculite, whereas the expanded layers correspond to montmorillonite (Walker, 1961). Further K^+ treatment leads to an increase in intensity of the 10.0 Å reflection, but still leaves weak reflections over the 10 to 14 Å region. The layers contracted to 10 Å belong to the layers with higher charges (vermiculite-illite), whereas partially contracted layers (10 to 14 Å) indicate the presence of the layers with lower charges (montmorillonite).

The (hk) reflections and the b dimensions of the playa clays. In order to obtain the (*hk*) reflections oriented clay flakes were mounted parallel in the periphery of a focusing asymmetrical Guinier camera ($R=40$ mm). With this camera it is possible to resolve very closely spaced lines. Table 3 gives the intensity and spacing data (the lines of quartz in samples have been used as an internal standard) of the reflections obtained from the Guinier films.

An interesting feature of the Guinier films is the presence of a pronounced continuous scattering accompanying the (02,11) diffraction band. This continuous scattering shows that the mica-type layers in the clay mixtures of playas have a highly random stacking sequence of the layers. Because of this irregularity in the stacking sequence the reflections will be two dimensional as assigned by (*hk*) indices.

The *b* dimensions are calculated from these (060) reflections, which are not affected by the above random stacking of the layers. The *b* dimensions so obtained have values between 9.00 and 9.02±0.01 Å for the playa clays (Table 3). On the Guinier films of the Deep Springs clays, it was not possible to observe the (060) reflections; hence, the *b* dimensions of these clays could not be calculated. The above values of the *b* dimensions show clearly that the octahedral occupation in the playa clays is dioctahedral.

CHEMICAL ANALYSES

In order to obtain further information on the composition of the mica-type layer silicates, partial chemical analyses of three samples have been made. To avoid uncertainties about exchangeable ions, contaminants, and other components, the samples were treated with a weak organic acid (a 5% solution of monochloracetic acid) and the −1.5 micron fraction was separated. Table 4 gives the weight percentage of the important elements affecting the layer structures.

TABLE 3. THE (*hk*) REFLECTIONS AND THE *b* DIMENSIONS OF THE PLAYA CLAYS

Sample	$d_{(hk)}$	(*hk*)	Int.	*b*, Å
Deep Springs	4.48	(02, 11)	VS	
No. 1	2.59	(20, 13)	W	
Mud Lake, Nevada	4.51	(02, 11)	VS	
No. 3	2.57	(20, 13)	S	
	1.50	(060, 330)	M	9.00±0.01
Humboldt, Nevada	4.49	(02, 11)	VS	
No. 4	2.58	(20, 13)	W	
	1.503	(060, 330)	VW	9.02±0.01
Upper Sevier, Utah	4.49	(02, 11)	VS	
No. 6	2.57	(20, 13)	M	
	1.503	(060, 330)	W	9.02±0.01
	1.30	(40, 26)	VW	
Middle Animas	4.49	(02, 11)	VS	
New Mexico	2.58	(20, 13)	M	
No. 9	1.503	(060, 330)	VW	9.02±0.01

SUMMARY AND CONCLUSIONS

Argillaceous sediments with a fine particle size have been accumulated in the playas of enclosed desert basins. In the following, the discussion is restricted to the mica-type layer silicates.

Surface drainage contributes fine materials which have already been subjected to the natural weathering agents in their previous deposits and have been further finely ground during the transport. The natural weathering of the mica-type layers will generally start from the interlayer regions involving K depletion. Thus, fine particles with dissatisfied layer charges will form colloidal systems in the salt solutions of the enclosed playa basins. As given by the saline contents of the samples Na^+, Ca^{2+}, and less Mg^{2+} are main cations in these solutions. The ratio of the activities of these cations on the clay surfaces will depend on their concentrations in the outer solution, as given by Marshall (1964), for instance for two cations like Na^+ and Ca^{2+}:

$$(a_{Na}/\sqrt{a_{Ca}})_{clay} = (a_{Na}/\sqrt{a_{Ca}})_{solution}$$

The concentrations of the different cations vary continuously as the playas undergo repeated flooding and desiccation. Therefore the insertion of the cations between the mica-type 10 Å layers will be quite heterogeneous, which will be further enhanced as the charges of the layers will also be quite different owing to their previous weathering. During the precipitations of the salines and clays, some salt molecules may be inserted between the layers, as suggested by Langer (1965) in infrared spectra of the carbonates in the playa clays. All these factors may explain the continuous scattering by a stacking sequence of layers MAMMBMCMA . . . where A, B, C are not equivalent. In Humboldt Playa in the terminus of the Humboldt River the clays are in continuous contact with water and show more or less uniform distribution of the different cations between the layers. The weathering of the mica-type layer silicates shows features very similar to the Willard saliniferous and blue clays; the mechanism of the weathering of the latter has been discussed in detail by Güven and Kerr (1965).

TABLE 4. ANALYTICAL DATA IN WEIGHT PER CENT

	Sample No. 1 (Deep Springs)	Sample No. 6 (Upper Sevier Lake)	Sample No. 7 (Middle Animas)
FeO	1.48	1.45	1.29
Fe_2O_3	3.07	2.96	4.58
CaO	0.75	2.86	0.85
MgO	8.37	4.07	3.65
Na_2O	0.81	1.36	1.14
K_2O	3.28	3.09	3.44
Al_2O_3			20.10
SiO_2			55.50

Analyst, Silve Kallman, Ledoux and Company, Inc., New Jersey.

The existence of vermiculite and montmorillonite layers in the playa clays is important in affecting the physical condition of the playa surfaces, for these layers are sensitive to changes in humidity. The vermiculite may partially exfoliate with increasing temperature by sudden contraction of the layers. The expandable layers may also induce appreciable pressure in the crust of the playas as humidity increases.

The *b* dimensions of the playa clays show their dioctahedral nature. The chemical analyses show the presence of appreciable amounts of divalent cations; at least 5 per cent $MgO+FeO$, and probably more if oxidation of $Fe^{2+} \rightarrow Fe^{3+}$ is considered. These amounts of $MgO+FeO$ Fe_2O_3 (8 to 10 per cent) are not compatible with original muscovite-type layers. As available only from sample No. 7, the SiO_2/Al_2O_3 ratio is very high for the muscovite-type layers.

The chemical analyses and the *b* dimensions of the mica-type clay minerals in the playas indicate that the nature of the layers is tetrasilicic and dioctahedral. Micas of this type have higher internal strains in the layer structures, caused by the octahedral charges, as shown by Zviagin (1957) for celadonite. They are therefore easily attacked during the weathering.

ACKNOWLEDGEMENTS

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