FULLER'S EARTH OF BENTONITIC ORIGIN FROM TEHACHAPI, CALIFORNIA

Paul F. Kerr and Eugene N. Cameron,
Columbia University, New York City.

Introduction

Five miles east of Tehachapi Pass, between Bakersfield and Mojave, in Kern County, California, there occurs a deposit of Fuller's earth which has been developed by the Filtrol Company of Los Angeles for use in oil refining. The clay is mined by means of small tunnels and hauled on trucks to a siding on the Southern Pacific railroad, where it is stored for shipment to Los Angeles. A large bin has been built at the siding to provide storage for carload lots. Open construction of the bin permits air drying of the clay which at the same time results in a considerable amount of checking and cracking.

The locality was visited by the senior author during August, 1930, when samples were collected for laboratory study. Since that time other material has kindly been supplied by Mr. W. S. Baylis, formerly Vice-President of the Filtrol Company.

This material has been used for reference purposes in the study of other clay minerals, but only brief mention of the deposit has heretofore been made in the literature. Samples of the clay were furnished Dr. R. E. Grim as an example of Fuller's earth, and he included a brief petrographic description of the clay in his examination of the petrographic characteristics of Illinois Fuller's earths.[1] In addition, the activity and thermal dehydration curve of the clay have been studied by P. G. Nutting.[2] However, in view of the economic value of the clay, the lack of information as to its field occurrence, and the uncertainty expressed by Grim as to its origin, a more detailed discussion of the deposit appears warranted.

Occurrence and Lithology

The clay occurs as a bed about 8 feet thick contained in a flat-lying, predominantly volcanic, conformable series of strata forming a ridge in the Tehachapi Mountains. Overlying the clay and associated thin-bedded tuffs are several hundred feet of porphyritic volcanics, opalized in places and containing numerous amygdaloidal cavities. The clay bed has been traced by means of surface openings over a distance of about a mile. The section exposed at the mouth of a prospect tunnel is shown in Fig. 1. Figure 2 is a photograph of the same tunnel mouth.

[1] Grim, R. E., Petrography of the Fuller's earth deposits, etc.: *Econ. Geol.*, vol. **28**, No. 4, p. 356, June, 1933.

[2] Nutting, P. G., The bleaching clays: *U. S. Geol. Survey*, Circular **3**, 1931.

Below the clay are thin tuffaceous strata which are somewhat calcareous and contain a few fragmented plant remains. The origin of these strata is not as definitely determinable as in the case of the adjacent beds, but optical studies of thin-sections and crushed fragments from specimens representing these strata have shown the presence of montmorillonite and of scattered shard-like isotropic patches. Thus it appears that pyroclastic material has contributed to the formation of the beds. The white clay being mined appears to grade into this underlying bed.

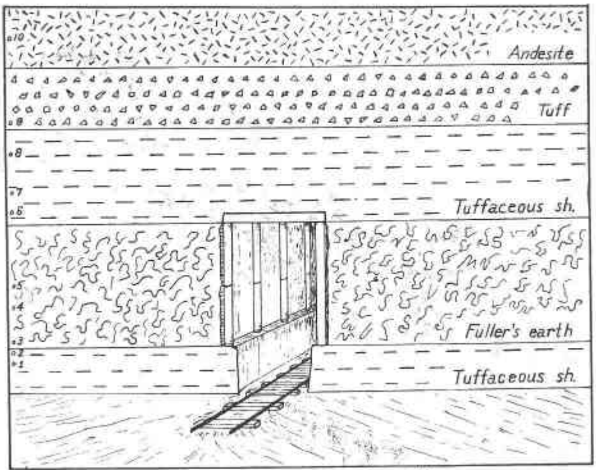
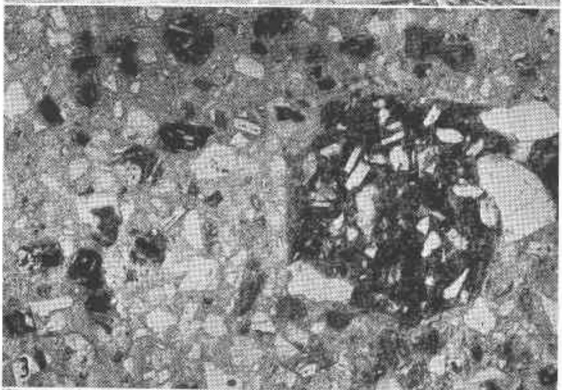


FIG. 1. A diagram illustrating the strata related to the Fuller's earth bed. Numbers at the left indicate the positions from which samples were taken for thin-section studies.

Above the white clay, with rather sharp contact, lie several feet of fine-textured, somewhat calcareous shaly strata similar in composition to the beds below, but more evidently pyroclastic in origin. Montmorillonite figures prominently in the matrix of the shaly strata, and shard-like forms are abundant. A few angular fragments of feldspar are also scattered through the matrix. Overlying these shaly beds are several feet of andesitic tuff (Fig. 3) containing abundant angular fragments of crystals, chiefly andesine, hornblende, and biotite, in a matrix of glass partly altered to montmorillonite. Lithic fragments of tuffs and of several types of felsites are also present. Occasional patches of opal replacing the groundmass may be observed. The exposure is capped by a porphyritic hornblende andesite flow (Fig. 4) several hundred feet thick, containing abundant phenocrysts of zoned feldspar (of average intermediate composition), hornblende, biotite, titanite, and magnetite in a hyalopilitic groundmass consisting of felted oligoclase-andesine microlites with some interstitial glass.



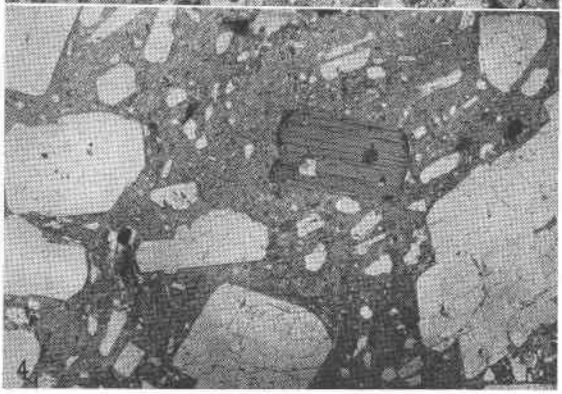


FIG. 2. Photograph showing an outcrop of the Fuller's earth. The white bed at the bottom of the cut at the same level as the tunnel entrance is Fuller's earth.

FIG. 3. Photomicrograph ×20. Angular crystals distributed through tuff together with one large lithic fragment and several small ones.

FIG. 4. Photomicrograph ×20. Coarse feldspar phenocrysts in a fine matrix, illustrating the andesite overlying the Fuller's earth deposit and associated tuffs.

The strata are flat-lying and seem to be little disturbed, aside from a few faults of minor displacement which appear to have no bearing on the present discussion. The age of the beds was not established but, judging from the history of the region, is probably late Tertiary. Fossil evidence was lacking in the samples studied.

Specimens for microscopic study were taken from each of the beds from the points indicated by numerals in Fig. 1, and in addition from various points along the outcrop of the clay bed. Microscopic studies have been supplemented with x-ray diffraction patterns and chemical analysis.

Characteristics of the Tehachapi Clay

The clay is typically white or light grayish-white, but some specimens show a greenish tint, particularly when moist. It is coarsely bedded and fractures irregularly into massive, structureless blocks. Freshly broken surfaces have a rough, gritty "feel," as a rule, although one of the specimens collected shows smooth surfaces with an approach to a conchoidal fracture, apparently due to extreme fineness of texture. The Tehachapi clay shows no tendency to swell when placed in water. Near the base of the bed the clay contains poorly preserved plant remains.

Grim[3] found it impossible to determine the origin of the clay from the material which he studied, although he found traces of what might be relicts of a vitroclastic structure. Most of the specimens examined in the course of this study present the same difficulty; but two, in which the original ash apparently had a coarser texture than is normal for the bed, show a well preserved relict "bogen" structure in thin-section. Figure 5 is a photomicrograph of a part of a thin-section of the coarser of the two specimens. The structure alone is sufficiently clear to leave no doubt that the clay has been derived by alteration of a volcanic ash. This conclusion is supported by the discovery of shards which have not yet been completely altered to montmorillonite. Indeed, all stages in the alteration of the shards have been observed in the section illustrated in the photomicrograph, from shards only slightly altered to those completely converted to montmorillonite and recognizable only by the "ghost" outlines of the originals. Occasionally a single shard is found to be composed partly of glass and partly of montmorillonite. Except in these two specimens alteration has been complete enough to destroy all but traces of the original ash structure, the result being an extremely fine aggregate of montmorillonite.

The chief component of the clay is montmorillonite of micaceous habit, occurring in wavy or twisted flakes which show a rude orientation

[3] Grim, R. E., *op. cit.*

parallel to the bedding of the clay. In the air-dried clay the montmorillonite has the following optical properties: $\gamma = 1.506$; $\gamma - \alpha =$ approximately .020; (−) 2V moderate; elongation postitive; extinction nearly parallel to the long direction of the flakes. Both index of refraction and birefringence decrease with increase in the moisture content of the clay.

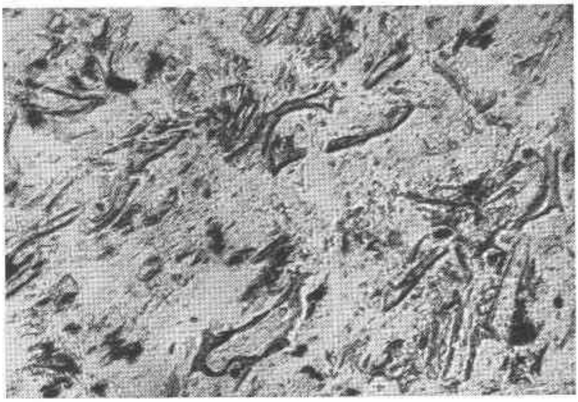


Fig. 5. Photomicrograph ×95. Shard structures preserved in Fuller's earth at the Tehachapi deposit.

In addition to montmorillonite, specimens of the material studied by the writers contain varying amounts of a clear, colorless, platy mineral. It is isotropic to weakly birefringent and has an index of refraction (about 1.475) which is too low for volcanic glass. Insofar as its properties could be determined, they correspond to those of clinoptilolite[4] as described by Bramlette and Posjnak.[5] Attempts to concentrate this substance by mechanical means sufficiently for *x*-ray determination were unsuccessful. A mixed *x*-ray diffraction pattern contains lines which agree with the pattern for heulandite as far as the two could be compared. The mineral is of interest because it appears to represent an intermediate stage in the alteration of volcanic glass to montmorillonite. It occurs as a constituent of the clear portions of certain of the less altered shards, some of which consist in part of this substance, in part of montmorillonite. The fine aggregate structure of the clay makes it difficult to estimate the percentage of this substance present, but it probably does not exceed 10%.

In addition to the components named above, the residue of the clay after crushing and washing contains angular fragments of sanidine,

[4] According to Hey, M. H., and Bannister, F. A., (*Mineral. Mag.*, vol. **23**, No. 145, pp. 556–559, 1934) clinoptilolite is a silica-rich heulandite.

[5] Bramlette, M. N., and Posjnak, E., Zeolitic alteration of pyroclastics: *Am. Mineral.*, vol. **18**, pp. 167–171, 1932.

oligoclase-andesine, hornblende, and chlorite. A little leucoxene and limonite have occasionally been observed. Grains of the minerals just mentioned attain a maximum size of .25 mm., but the average is much lower. In all they form less than 1% of the clay.

Chemical Analysis

The following is an analysis by Mr. A. M. Smoot, of Ledoux and Company, of an air-dried sample of Tehachapi clay:

H_2O at 110°C.	8.21%
H_2O above 110°C.	9.98
SiO_2	53.88
Al_2O_3	11.66
$FeO+Fe_2O_3$	4.60
MnO	0.18
CaO	1.56
MgO	8.61
TiO_2	0.44
K_2O	0.39
Na_2O	0.15
P_2O_5	0.16
CO_3, SO_3, ZrO_2	none
	99.82%

In view of the fact that the analysis includes the zeolitic constituent of the clay as well as montmorillonite, it agrees fairly well with the analyses of montmorillonite-bearing bentonite given by Ross and Shannon.[6] The silica content is higher than the average, presumably due to the presence of the zeolitic substance described above. The water is correspondingly low. Iron oxide and MgO are higher than the average, while Al_2O_3 and CaO are lower.

The optical data furnished by the clay mineral indicate a member of the montmorillonite group low in iron.[7] Also, the occasional patches of limonite present in thin sections of the clay seem insufficient to account for the excess of iron. Some of the iron oxide may be present as adsorbed iron, which may be responsible for the slightly brownish color of certain clay fragments under the microscope. However, the status of the iron in the clay is uncertain. The markedly high magnesium oxide presents a similar difficulty. Since no carbon dioxide was found by analysis of the clay, the magnesium oxide cannot be ascribed to finely divided magnesium carbonate. It may indicate a slight gradation toward saponite. The low percentages of calcium and aluminum oxides are interpreted as reflecting the high percentages of iron oxide and magnesia.

[6] Ross, C. S., and Shannon, Earl V., The minerals of bentonite and related clays and their physical properties: *Jour. Am. Cer. Soc.*, vol. **9**, No. 2, p. 79, 1926.

[7] Ross, C. S., and Kerr, P. F., The clay minerals and their identity: *Jour. Sed. Petrology*, vol. **1**, No. 1, p. 59, 1931.

X-RAY EXAMINATION OF TEHACHAPI BENTONITE

X-ray diffraction measurements of montmorillonite are already on record.[8] The material from Tehachapi furnishes *x*-ray diffraction patterns which agree with the recorded measurements and also exhibit additional lines which match the lines given by patterns of heulandite from West Paterson, N. J.; Iceland; and Cape Blomidon, N. S. Hey and Bannister[9] and Bramlette and Posjnak[10] have made *x*-ray studies of heulandite and related zeolites. The clinoptilolite of Bramlette and Posjnak yields an *x*-ray diffraction pattern indistinguishable from that of heulandite. Hey and Bannister find that such material also yields rotation photographs of similar agreement. Whether or not clinoptilolite is actually silica-rich heulandite as Hey and Bannister conclude, the material of the Tehachapi clay appears to correspond to their description and also to the description of the clinoptilolite of Bramlette and Posjnak. Too little material could be separated to attempt to reconcile the different viewpoints.

CLASSIFICATION OF TEHACHAPI BENTONITE

In 1926 Ross and Shannon[11] proposed the following definition of bentonite:

> Bentonite is a *rock* composed essentially of a crystalline clay-like mineral formed by devitrification and the accompanying chemical alteration of a glassy igneous material, usually a tuff or volcanic ash . . . the characteristic clay-like mineral has a micaceous habit and facile cleavage, high birefringence and a texture inherited from volcanic tuff or ash, and it is usually the mineral montmorillonite, but less often beidellite.

The clay from Tehachapi has been shown to satisfy each of the requirements of the above definition; hence from the petrographic standpoint it may be classified as a bentonite.

As stated at the beginning of this article the clay has been used as a Fuller's earth by the Filtrol Company of Los Angeles, California, in treating petroleum oil. Although a natural bleaching agent, it has been reported to be poorly responsive to the usual acid treatment applied to commercial adsorptive clays. In connection with his study of the bleaching clays, Nutting[12] tested the activity of Tehachapi clay. He makes the following comment on the tests:

> The rating of active minerals according to their bleaching efficiency is obviously a quite arbitrary matter, because the relative bleaching power of any series of clays will be different for every test liquid used. . . . Even with a specific clay and test oil there is the question of which cut to choose as standard. . . .

[8] Kerr, P. F., Bentonite from Ventura, Calif.: *Econ. Geol.*, vol. **26**, No. 2, p. 166, 1931.

[9] Hey, M. H., and Bannister, F. A., *op. cit.*

[10] Bramlette, M. B., and Posjnak, E., *op. cit.*

[11] Ross, C. S., and Shannon, Earl V., *op. cit.*

[12] Nutting, P. G., *op. cit.*, p. 43.

The tests here reported refer to complete filtration (to water-white), and the numerals under "Bleaching rating" . . . are the ratios of volumes of oil so filtered to the volumes of clay so filtering it . . . . The test oil was a high-gravity black natural petroleum, free from sulphur. Obviously this rating has little practical significance and was chosen partly for that reason.

On the basis of the above standard, the rating obtained for Tehachapi clay was 1.2, a value unchanged by treatment with acid. The ratings obtained for other active clays by this test ranged from .2 to 1.8 before, and .3 to 2.0 after treatment with acid.

Though arbitrary, these tests indicate the natural bleaching activity of the clay, and in view of the foregoing statements it seems proper to classify the Tehachapi clay as a Fuller's earth of bentonitic origin. The occurrence of montmorillonite as an essential constituent of Fuller's earth has already been mentioned.[13]

Origin of Tehachapi Bentonite

The relict bogen structure of the clay is the best evidence for its origin by alteration of a volcanic ash bed. The coarse plant remains at the base of the clay bed seem significant of moisture at least sufficient for normal plant growth at the time of deposition. The regularity of the bedding of the series of strata in which the clay occurs, which becomes a fine lamination in parts of the series, suggests deposition in shallow water perhaps in an old lake bed.

Summary

A commercial deposit of clay having the natural decolorizing properties of Fuller's earth occurs near Tehachapi, Kern County, California. The clay is essentially a mixture of montmorillonite and a zeolite, probably heulandite. Although commercially a Fuller's earth, study of thin-sections demonstrates that the clay has been derived from volcanic ash by alteration, and according to the petrographic definition it has the origin of a bentonite. It seems worth while therefore to place on record a description of the occurrence of a Fuller's earth of bentonitic origin.

[13] Kerr, Paul F., Montmorillonite or smectite as constituents of Fuller's earth and bentonite: *Am. Mineral.*, vol. **17**, pp. 192–198, 1932.