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THE FOX CLAY DEPOSIT, UTAH

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ABSTRACT. The Fox Clay deposit is located about 40 miles southwest of Salt Lake City. The clay occurs as a sedimentary lens. Tertiary (?) limestones which lie conformably below and above this bed, dip gently to the southwest. Flat-lying Tertiary basalt flows overlie the southern half of the area.

Differential thermal analysis indicates that the Fox Clay contains more water than typical halloysite $2H_2O$. Indices and differential thermal analysis curves vary with the degrees of hydration of the mineral. X-ray powder pictures, however, are constant regardless of degree of hydration, and compare favorably with powder pictures of authentic halloysite. The Fox Clay halloysite therefore contains adsorbed water which so affects all properties other than X-ray as to make it appear to be endellite $4H_2O$.

INTRODUCTION

A LARGE clay deposit, locally known as the Fox Clay, situated in the Lake Mountains, Utah, has been mined intermittently for several years. It contains one of the largest potential clay sources so far discovered in Utah, but the clay seriously shrinks and cracks on firing, making its industrial use, without treatment, impractical. It is located about 15 miles west of Provo on the lower southwestern rolling slopes of the Lake Mountains (fig. 1). The maximum relief within the area does not exceed 500 feet and the annual rainfall amounts to about 10 inches.

GENERAL GEOLOGY

The Lake Mountains constitute a north-south trending, typical Basin Range bordered on either side by broad alluvial-filled valleys. The rock units exposed consist of (a) Paleozoic rocks in the Lake Mountains proper, (b) a sequence of Tertiary (?) sediments and volcanic flows on the south-west flank of the range, and (c) Quaternary alluvium and lake sediments in the adjoining valleys. The Fox Clay is interbedded with the Tertiary (?) sedimentary rocks.

The Paleozoic rocks have been folded into a broad syncline with an axis trending northwest, oblique to the mountain range. The Tertiary (?) rocks are only gently folded and though no contact was found, are believed to rest unconformably on the Paleozoic beds on the lower flanks of the mountain.

STRATIGRAPHY

The oldest rock unit mapped in the area shown in figure 2 is a limestone presumably of Tertiary age. Due to the overlap of valley alluvium, the lower contact of this formation was not found and its full thickness, therefore, is not known, but at least 100 feet of it is exposed. The rock is a fine-grained, dense, tan, unfossiliferous limestone which weathers pale bluish. Microscopic examination shows it to be composed of an aggregate of calcite with an average grain size of about 0.25 mm. Oolites, ranging in diameter from 0.1 to 0.3 mm. are found in scattered patches throughout the aggregate.

The Fox Clay bed overlies the lower limestone conformably and occurs as a lenticular bed with a maximum thickness of 18 feet at the main excavation near the center of the mapped area (fig. 2). It thins rapidly to the south and east, while to the northwest the thickness is not determinable since the outcrop is there covered by valley alluvium.

The bedding in the white clay is expressed by faint pink to brown laminations and banding. Locally, the upper part of the

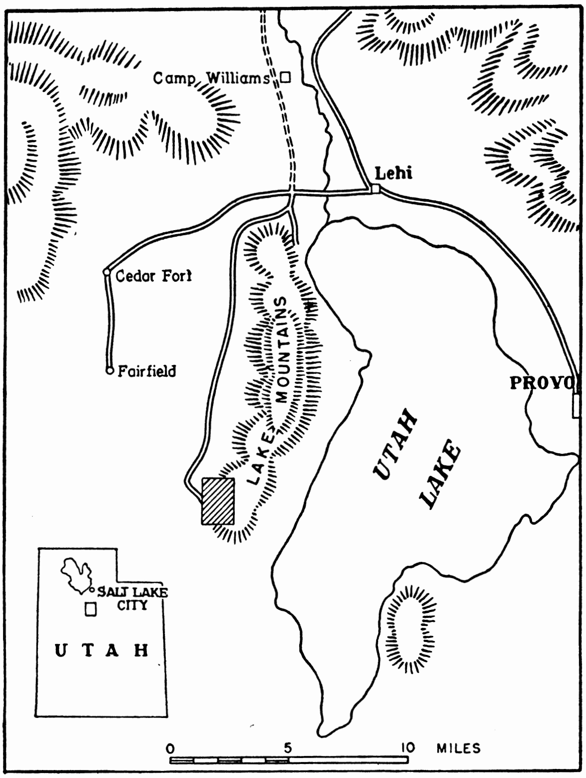


Figure 1. Index map showing the location of the Fox Clay deposit, Utah.

bed is stained by concentrations of hematite in broad pink to maroon bands which make an acute angle with the bedding laminations, giving it a false appearance of crossbedding. The clay is contaminated with varying amounts of detrital quartz, and in the central part of the area near the excavations it contains angular quartz grains up to 5 per cent, while near the borders 15 per cent of quartz in rounded grains is noted locally. A limestone which is identical lithologically to the lower limestone overlies the Fox Clay bed conformably and overlies the lower limestone where the clay lenses out.

A basalt flow overlies these Tertiary (?) sediments with moderate angular unconformity. It rests directly on upper limestone, Fox Clay, and lower limestone in different parts of the area. The flow is about 50 feet thick and caps some higher hills to the south.

STRUCTURE

As stated above, the Tertiary (?) sedimentary rocks are all conformable with each other and maintain a general dip to the southwest of 5° or less. The beds dip locally as high as 40° on two small anticlines whose axes trend north 30° west. These folds disappear under the alluvium to the northwest and die out toward the southeast.

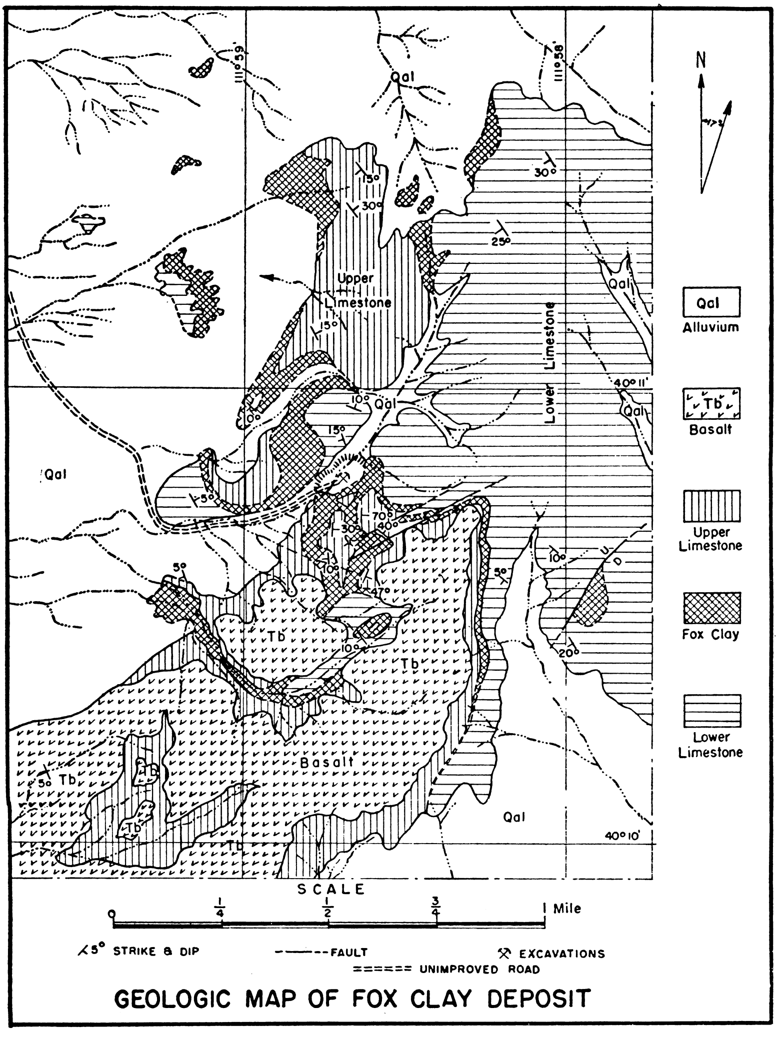
Three faults displace the clay bed. Two of these which are found southwest of the main excavation are parallel and strike north 65° east, with a total displacement of approximately 200 feet.

AGE OF THE CLAY

No fossils of any kind were found within the entire area mapped; hence only an estimate can be made as to the age of these rocks. They have been tentatively assigned to the early Tertiary because of their unconformable relationships to the underlying Paleozoic rocks which presumably were deformed during the Laramide movements. The limestones and clay beds themselves are folded to an extent comparable to that of the Flagstaff limestone of Eocene age in the Central Utah area described by Spieker (1946, pp. 136-137). The Fox Clay is definitely older than the undeformed overlying basalt which is probably the same age as the late Eocene or Oligocene basalts north of the Lake Mountains described by Gilluly (1932, p. 66).

MINERALOGY

Through the kindness of Sterling B. Hendricks of the Bureau of Plant Industry, U. S. Department of Agriculture, a fresh sample of authentic endellite $4H_2O$ from Lawrence County, Indiana, was obtained for purposes of comparison with Fox Clay. Mineralogical examinations, therefore, were made on fresh endellite $4H_2O$ (sample A), dehydrated endellite (sample B), obtained by allowing ground-up fresh endellite to dehydrate at room temperature for 48 hours, untreated Fox Clay



GEOLOGIC MAP OF FOX CLAY DEPOSIT

(sample C), and dehydrated Fox Clay (sample D), obtained by allowing ground-up material to dehydrate at room temperature for 72 hours. Examination of these samples by X-ray, differential thermal analysis, electron microscopic and optical methods yielded sufficient information to establish the mineralogy of the Fox Clay.

X-ray Investigations.—Debye-Scherrer diffraction pictures were taken of all of the different samples. Pictures of dehydrated endellite (sample B), untreated Fox Clay (sample C), and dehydrated Fox Clay (sample D), showed lines essentially identical. The *d* values and intensities of the line patterns of these samples are nearly equal to the *d* values given for halloysite $2H_2O$ (Nagelschmidt, 1934, p. 131, table V, no. III) except for line number 1 which shows a value considerably less than the value given by Nagelschmidt. If this figure had been greater than Nagelschmidt's there would have been reason to think that some excess water for halloysite $2H_2O$ was still present between the layers; however, the lower figure for hydrated Fox Clay halloysite $2H_2O$ and its similarity to dehydrated authentic endellite $4H_2O$, seems to point out clearly that this mineral has the true structure of halloysite $2H_2O$ regardless of degree of hydration. Authentic endellite (sample A) was ground, mounted on the X-ray camera and a picture taken all within 50 minutes. This proved to be successful in producing a pattern different from halloysite $2H_2O$ and similar to that of endellite $4H_2O$ (table 1; A. S. T. M. index; and Mehmel, 1935). The information obtained thus establishes that the Fox Clay, both hydrated and dehydrated, is halloysite $2H_2O$ and that the excess water of the hydrated sample is simply adsorbed and does not occupy a position in the structure.

Differential Thermal Analysis Investigations.—Curves were obtained on a number of samples of the material investigated. Conventional apparatus for this determination was used, and the results thus obtained show the same curves for dehydrated endellite $2H_2O$ and for dehydrated Fox Clay. Both have a large definite endothermic peak at 600° C. and a smaller sharp exothermic peak at 980° C., corresponding very well to published curves for halloysite $2H_2O$ (Kerr and Kulp, 1948, p. 400).

In the curves for the hydrated samples of each clay the expected large endothermic peak between 100° and 200° C. is present and represents the expulsion of lattice water in the case of endellite $4H_2O$ and adsorbed water in the case of the halloysite $2H_2O$ of the Fox Clay. Otherwise the curves are the same as for halloysite $2H_2O$.

Optics.—The immersion method of determining index of refraction was used on all specimens and the liquid employed was checked with an Abbé refractometer at the time the measurement was made, thus assuring a more accurate observation. The untreated Fox Clay (sample C), was found to be isotropic with an index of 1.543. In recent investigations by Alexander *et al.* (1943), the index of refraction of pure endellite $4H_2O$ was calculated as $1.49 \pm .005$. They indicate that the index of completely dehydrated endellite (halloysite $2H_2O$) may range as high as 1.556. All halloysites $2H_2O$ and endellites $4H_2O$, therefore, should fall between these extremes. The Fox Clay, with an index of 1.543, falls below the index of pure halloysite $2H_2O$. This anomaly is believed to be due to an envelope of water surrounding the halloysite grains as found by Alexander *et al.* (1943). The index of a dehydrated sample of Fox Clay was determined to be 1.556 as expected.

Electron Microscopic Observations.—Professor Tom F. Bates of Pennsylvania State University was kind enough to take an electron micrograph of the Fox Clay. The picture shows that the clay is made up of the tube-shaped particles typical of halloysite $2H_2O$.

Mineralogical Conclusions.—From the above data, it seems clear that the mineral composing the Fox Clay is halloysite $2H_2O$ and that the extra water is simply adsorbed water present interstitially and surrounding the grains. MacEwan (1947) presumes that naturally occurring halloysites may be intermediate in water content between true halloysite $2H_2O$ and true endellite $4H_2O$, and proposes a terminology based upon this concept. The results of this study support the view, however, that there are two separate and distinct minerals existing, *i. e.*, halloysite $2H_2O$ and endellite $4H_2O$, that there is not an isomorphous or continuous series between the two, and that what appears to be hydrous halloysite is nothing more than true halloysite $2H_2O$ with adsorbed water and this condition causes the index of refraction and differential thermal curves to simulate those of true endellite $4H_2O$. The nomenclature of Alexander *et al.* (1943), in using only the two terms endellite and halloysite therefore is preferred.

ORIGIN

The Fox Clay occurs between two sedimentary beds and lenses out within the small area studied. It contains clastic quartz grains in varying amounts and no evidence of volcanic ash is observed. The clay must therefore be sedimentary in origin. It is believed that the original material was formed as endellite and was derived through the process of weathering. This was finally transported and deposited as clastic material in the clay bed along with some quartz grains. It is believed that during transportation dehydration was effected, changing the endellite to halloysite. The hydrated condition now existing is presumed to be the result of saturation at the time of deposition or through subsequent ground water activity.

ACKNOWLEDGMENTS

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TABLE 1

Line Number	Endellite $4H_2O$ Indiana Sample A d	I/I_1	Endellite $4H_2O$ Mehmel (1935) d	I/I_1	Endellite $4H_2O$ Dehydrated to Halloysite $2H_2O$ Indiana Sample B d	I/I_1	Halloysite $2H_2O$ Fresh, hydrated* Fox Clay Sample C d	I/I_1	Halloysite $2H_2O$ Upper Silesia Nagelschmidt (1934) d	I/I_1
1	10.08	1.0	10.1	1.0	7.28	.8	7.24	.7	7.43	.6
2	4.36	.8	4.46	.8	4.40	1.0	4.40	1.0	4.44	1.0
3	3.31		3.40	.6	3.61		3.54		3.61	.8
4	2.54		2.56	.6	2.56		2.53		2.57	.8
5	2.42				2.43		2.45			
6	2.36		2.37	.5	2.36		2.31		2.36	.8
7	2.21		2.23		2.20		2.25		2.23	.2
8	2.14				2.14					
9					2.06					
10	2.01				2.02				2.01	.4
11	1.97				1.96		1.96			
12	1.90				1.90					
13	1.77				1.78		1.77			
14	1.73				1.73				1.71	
15	1.66		1.67	.5	1.67		1.67		1.63	.8
16	1.62				1.62					
17	1.46	.7	1.48	.6	1.47	.9	1.47	.8	1.47	1.0
18	1.44				1.44					
19	1.27		1.28	.6	1.27		1.27		1.29	.8
20	1.22		1.23	.4	1.22		1.22		1.23	.6

* Dehydrated Fox Clay (Sample D) shows same lines and intensities as sample C.
Intensity figure given only to three most intense lines in samples A, B, and C.

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