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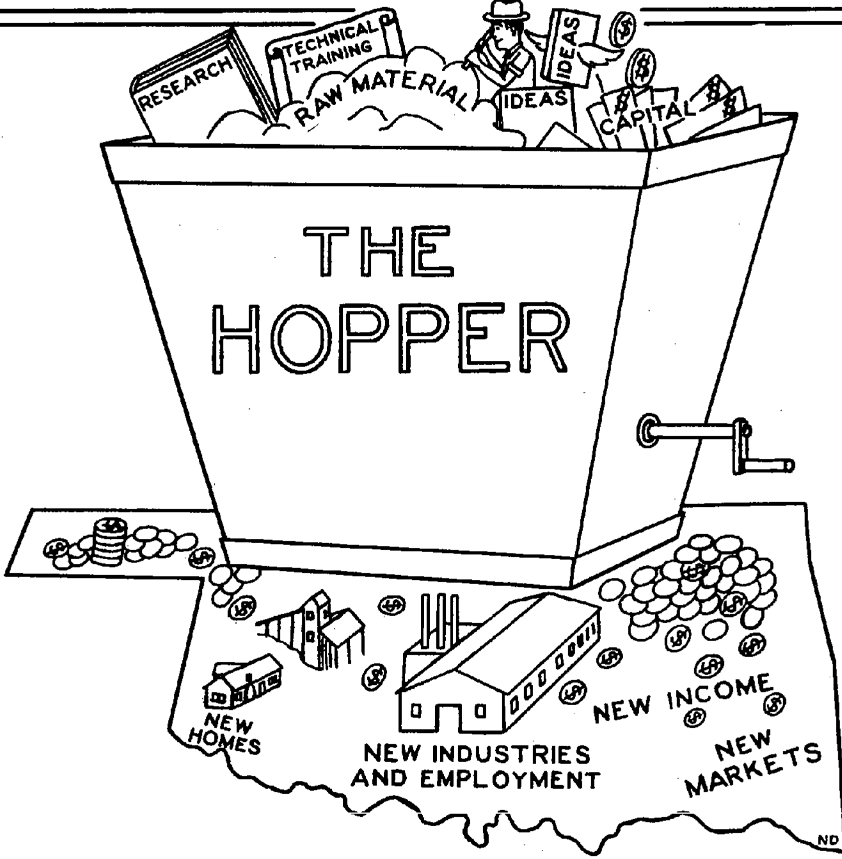

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KAOLIN AND MONTMORILLONITE
CLAYS OF THE WICHITA MOUNTAINS, OKLAHOMA

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The rocks of the Wichita Mountains of southwestern Oklahoma are mainly of igneous origin, that is, they have crystallized and solidified from molten material. Based roughly on color these rocks fall into two classes, light-colored and dark colored. The classifications of the geologist are too numerous and complicated to be of service here. It will suffice for our purpose to state that there are three general types of rocks present, namely: the granites wherein the principal components are potash-soda feldspars and quartz, the anorthosite wherein the lime-soda feldspar predominates and no quartz is present, and gabbro wherein we find lime-soda feldspars associated with a considerable number of other minerals, which usually contain large percentages of metallic oxides in relatively large proportions.

The outcrops of granitic and gabbroic rocks in the Wichita Mountains are numerous and extensive. These igneous rocks were subjected in early geologic time to a large amount of faulting and intense shattering, leaving them easily assailable by the elements, especially by percolating waters. Such waters have, in certain areas, caused considerable alteration of the silicate constituents of the rocks. As we have stated, the principal silicates are the feldspars and it is the alteration products of these feldspars that make up what is generally termed "clay". These alteration products are definite minerals. Because of the association they have been called "clay minerals" and sometimes "clay substances". For scientific purposes these clay minerals have been classified into four main groups, namely: kaolinite, halloysite, illite, and montmorillonite, based upon similarity of composition and molecular structure.

It has been said, "The composition and mineral relations of clay minerals are intimately related to the conditions under which they form. In general, alkalic feldspars and mica tend to alter to kaolin minerals, whereas the ferromagnesian minerals, calsic feldspars, and volcanic glasses commonly alter to members of the montmorillonite group. Presence of magnesium ions in the altering system is favorable for the formation of montmorillonite-type minerals, in many of which it is characteristically present. The formation of montmorillonite-type minerals is favored by alkaline conditions and that of kaolinite by acid conditions. These relations are modified by climatic factors, such as length of time during which weathering continues."2/

According to one source of information 1/ pure Kaolinite is a hydrous aluminum silicate of definite composition; Halloysite is also a hydrous aluminum silicate but having a somewhat higher water content; Illite is a complex hydrous silicate of aluminum, iron, magnesium, and potassium; and Montmorillonite is a complex silicate of aluminum, magnesium, and soda. Actually, natural occurrences seldom adhere closely to these definitions but they serve for the purpose of type classification. The natural occurrences usually are a mixture of alteration products and unaltered minerals of the parent rock. The degree of alteration may have been slight or it may have been great, even nearly complete. Naturally, where the parent rock consists mainly of one mineral substance a purer grade of alteration product may be expected; conversely, complex mixtures of several mineral substances may be expected to yield a mixed product. As an example of the extremes to be found in the Wichita Mountains, in one location a relatively pure anorthosite lies adjacent to a complex gabbro, both altered presumably by the same natural forces and at the same time. The alteration of the anorthosite produced a high quality white mass whereas the gabbro produced a dirty brown mixed mess of complex composition.

When the products of rock alteration remain "in place" except for the water-soluble portion, that is, when the products have not been transported from the original location the material is known as "primary" or "residual". When the altered material has been moved by natural processes from its place of origin in whole or in part and the transported material redeposited such deposits are known as "secondary" or sedimentary. Obviously, in the course of being transported the material may have been classified fractionated, or sorted through differences in gravity or of particle size of the several constituents to yield improved material. However, since the transported material may have been subjected to contact with extraneous matter the purity may have been lowered by accumulation of objectionable substances. Occurrences of altered rock in the Wichita Mountains that have been observed all appear to be residual. Petrographic and chemical examinations indicate wide variations in the nature of the "clay minerals" that have been produced.

A map of that portion of the Wichita Mountains in the two counties, Kiowa and Comanche, is shown here on which are located roughly the occurrences of altered rock which have been investigated by members of the staff of the Oklahoma Geological Survey and also areas which within the past ten years was examined by the U. S. Bureau of Mines. A discussion of these occurrences follows. The areas of exposed granite, anorthosite, and gabbro are designated by different shading (see Map Legend). The locations of exposed, altered rock that have been examined are shown as black blotches and designated as I, II, and III. Oklahoma Geological

Survey test holes are numbered 1, 2, 3, 4, and 5, whereas U. S. B. M. holes are unnumbered or have the prefix P. A.

Location No. I

Small areas of altered rock are found throughout the Wichita Mountains but in only a few places are the occurrences of sufficient extent to be of any significance. One of the largest exposures of altered gabbro-anorthosite is in NE¼, Sec. 36, T. 4 N., R. 14 W., which is approximately 2 miles due west of Meers Post Office. This area is covered with variable thickness of soil and only where stream erosion has removed this cover can the altered zone be seen. The best exposure is near the center of the section where a small stream has cut its channel to a depth of 15 feet in the altered rock. Altered gabbro in the stream bank is dirty greyish-brown in color whereas the altered anorthosite is light grey to white in color. The line of demarkation between the two is sharp and distinct, suggesting that the two parent rocks were faulted against each other and that later solutions moving along the fault plane and into the fractures has drastically changed or altered the composition of the rocks.

The exposure of altered anorthosite is 185 feet in length and 44 feet in width. The depth has not been determined but a thickness of 12 feet is exposed by the stream erosion. Nor has the overall extent been determined. Test holes will have to be drilled to determine both the extent and the thickness. Test hole No. 5 was put down in the SE¼ of Sec. 25, T. 4 N., R. 14 W., and found 30 feet of altered anorthosite covered by 6 feet of soil. It is thought that this hole penetrates the same altered zone that is exposed in Section 36. If so, it indicates the altered area to be of considerable extent.

A petrographic examination of the altered anorthosite from the center of Section 36 shows the original rock to have been 91 percent lime-soda feldspars, with 72 percent of the feldspar being lime spar and 28 percent soda spar. In addition to the feldspars the original rock contained 5 percent augite and 3 percent magnetite. The examination further shows that 25 percent of the feldspars has been altered to kaolin-type clay mineral. Chemical analyses made on elutrated (water fractionated) material confirm the nature of the original rock and the alteration product.

A representative sample of the altered anorthosite was soaked in water, then diluted and thoroughly agitated. After being allowed to stand for a short time to settle out the heavier and coarser material, the water together with such matter as remained in suspension was syphoned off. The suspended matter was removed by filtration, dried, and analyzed.

Suspended material	SiO_2	Al_2O_3	Fe_2O_3	CaO
Lightest fraction 11.2%	46.15	36.43	1.83	1.23
Second fraction 5.4%	46.83	34.47	1.90	6.17
Unaltered anorthosite	49.39	28.95	2.05	15.31

(continued)

Suspended material	MgO	K_2O	Na_2O	$+H_2O$	$-H_2O$
Lightest fraction 11.2%	.21	.31	.99	12.18	1.43
Second fraction 5.4%	.14	.26	1.42	8.17	1.22
Unaltered anorthosite	1.27	.24	2.91	.17	.04

These analyses show the changes brought about by the alteration; decrease in silica, lime, and alkalies and increase in alumina and water. The lightest fraction appears to be a relatively pure kaolin whereas the second fraction appears to contain a larger portion of unaltered anorthosite. Since residual beds in the clay-producing states are often worked to recover as little as 6 percent clay substance this material shows promise for commercial exploitation. Ceramic tests describe the lightest fraction as non-plastic, slight drying and firing shrinkage, that fires to nearly white color, suggesting commercial possibilities.

Location No. II

A similar zone of altered anorthosite as that described above is located in Sec. 23, T. 4 N., R. 17 W. No. I test hole a half mile north of the exposure, drilled in the road ditch in the middle of a small valley, revealed 29 feet of altered material with 6 feet of soil as cover. A petrographic examination of this altered material shows that the original rock contained 96 percent lime-soda feldspars and that the feldspars consisted of 68 percent lime spar and 32 percent soda spar. Other minerals present were 2 percent augite and 2 percent magnetite. In this case it appears that 20 to 25 percent of the feldspars are altered to kaolin. Beneficiated by elutration, 14 percent kaolinite-type clay was recovered, which fires to clear white. Test hole No. 2 found 11 feet of cover and only 3 feet of altered anorthosite, whereas Hole No. 3, on the exposure, found 14 feet altered anorthosite above 10 feet of altered gabbro.

Location No. III

A third altered zone of anorthosite was examined in the SE, NE, Sec. 7, T. 4 N., R. 17 W., south of Roosevelt, where the exposure covers a very small area on the west side of the section line road. The anorthosite is impregnated by numerous small granite dikes and is, therefore, a mixed rock. The anorthosite has not been as intensely altered as in the two previously mentioned locations. Numerous rounded boulders of unaltered rock were noted as being in place in the altered rock. A petrographic examination of this altered material shows the original rock to have contained 16 percent potash-soda feldspar and 77 percent lime-soda feldspar together with 5 percent augite and 2 percent magnetite. Chemical analyses of the two fractions obtained by elutration follows:

Dried at 110° C.	SiO_2	Al_2O_3	Fe_2O_3	CaO
Suspended fraction, 7%	45.52	34.62	1.78	5.75
Settled fraction, 93%	46.10	35.95	1.68	13.25

(continued)

Dried at 110° C.	MgO	K_2O-Na_2O	$+H_2O$
Suspended fraction, 7%	0.67	n.d.	10.24
Settled fraction, 93%	0.34	2.13	1.28

The analysis indicates that the altered material consists of kaolin-type clay with considerable unaltered but silt size minerals. Ceramic tests describe it as a non-plastic clay, only slight drying and firing shrinkage, that fires to light buff color, suggesting that it may have commercial possibilities for ceramics if color is not objectionable.

Other Locations

During 1944 and 1945 the United States Bureau of Mines, in a search for high-alumina clays suitable for extraction by the lime-soda sinter method, drilled a number of test holes in Kiowa County. The location of these holes are indicated on the map by solid black spots. More recently one of us (Chase) has re-examined this area and drilled further holes, which are shown on the map by small circles and which are numbered: holes 1, 2, 3, and 5 having already been referred to. Hole No. 4 was drilled in the SW, SW¼, Sec. 24, T. 4 N., R. 17 W., and found 3 feet of cover over 38 feet of altered gabbro and bottomed still in same material.

This hole is approximately $\frac{1}{4}$ mile north of a U. S. B. M. hole marked as P.A. 2 in which was found "soft, soapy, white, red, and brown varicolored" clay and some calcite from the surface to a depth of 64 feet. The average chemical analysis calculated from analyses reported by the U. S. B. M. on the several sections of core follows:

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Ignition loss
46.06	22.21	6.47	1.28	13.67

Evidently the parent rock was a gabbro, as indicated by the high iron and titania. Also, it is doubtful that the clay mineral in the altered material is kaolinite or that the clay can be classed as kaolin because of the low alumina.

A perusal of the analytical results from other P.A. holes show much similarity, indicating that the rock drilled by the Bureau was all more or less gabbroic, and that the clay minerals resulting from the alteration might contain only minor quantities of kaolinite, if any. For example, hole P.A. 10 which was drilled in the SW, SE$\frac{1}{4}$, Sec. 34, T. 4 N., R. 16 W., found 87 feet of altered material. Chemical analyses on the core made by the U. S. B. M., together with analysis made in the O. G. S. laboratory by Dr. A. C. Shead on a "carefully selected white and soap-like sample" removed from a portion of the core at about 85 foot depth is given herein:

Depth(ft.)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Ign.loss
3 to 10	60.54	13.06	2.68	0.80	10.88
10 to 40	52.54	22.59	4.56	1.23	14.81
40 to 65	42.96	22.39	4.56	0.79	20.64
65 to 87	45.86	22.55	4.02	0.76	18.94
87 to 97	46.47	24.80	4.49	0.63	11.21

Analysis of selected specimen: SiO_2, 53.79; Al_2O_3,19.36; Fe_2O_3,0.81; TiO_2,0.00; CaO,1.24; MgO, 4.31; K_2O,0.30; Na_2O,1.91; $+H_2O$,11.15;and $-H_2O$,7.28.

Examination of the portion of the P.A. 10 core from which the selected specimen was removed was made by Dr. W. E. Ham of the O.G.S. staff who reported in part as follows: "Drop-bucket core, 3 inches in diameter and 2 inches thick, which preserves structure and texture of rock in place. Estimate by eye indicates the core is composed of 80 percent clay material; partly decomposed igneous rock, 12 percent; and calcite, 8 percent.

"Clay mineral (Montmorillonite): compact, very fine grained and homogenous, light blue-grey in color, and translucent. Waxy, unctous feel and greasy luster. Hardness about 2. Under the petrographic microscope the material is a matted aggregate of very small fibers with random orientation. Mean index of refraction of aggregates is 1.490 plus or minus .005. Fibers have moderate birefrigence. Optical properties indicate the mineral to be montmorillonite. Although clay material makes up the bulk of the core, there are small areas of partly decomposed igneous rock which are cut by small stringers of montmorillonite....."

In summarizing their work on Kiowa County clays the U. S. B. M. state "The clays are not amenable to beneficiation by sedimentation processes, as is the case with some clays, and it appears that there is no simple way to decrease the amount of impurities in the clay before treatment for alumina extraction" and have very little prospective value for either acid or lime-soda sinter extraction of alumina. As a clay material for well drilling purposes they found them to have "fair wall-building properties but their ability to promote viscosity is low." They state further that the clays may have some value as a binder for foundry sands when mixed with other commercial binders. Their tests on selected specimens show that the clays are not refractory and also on firing have tendency to bloat "which precludes their use in the ceramic industry." This last observation might not hold if the material could serve as a raw material for light-weight aggregate production for concrete.

Summary

There are numerous altered zones in the igneous rock of Comanche and Kiowa Counties, some small and probably several that are quite extensive. Evidently, alteration in several zones has produced kaolin of sufficient purity and quantity to encourage further work looking toward commercial production. This kaolin is relatively non-plastic and light firing. Also, it is evident that in other zones the alteration has yielded clay of the montmorillonite type, possibly in combination in certain parts with kaolin. The U. S. B. M. was unfortunate in the selection of drilling sites when looking for high-alumina clay because most of their holes were made in more or less gabbroic material rather than the high-quality anorthosite which the O. G. S. found. The clay substance found by the U. S. B. M. contained from 20 to 26 percent alumina whereas the kaolinic material located by the O.G.S. contained 34 to 36 percent, thereby changing very materially the potentialities of the area as a source of high-alumina clays for both alumina extraction and ceramic purposes.

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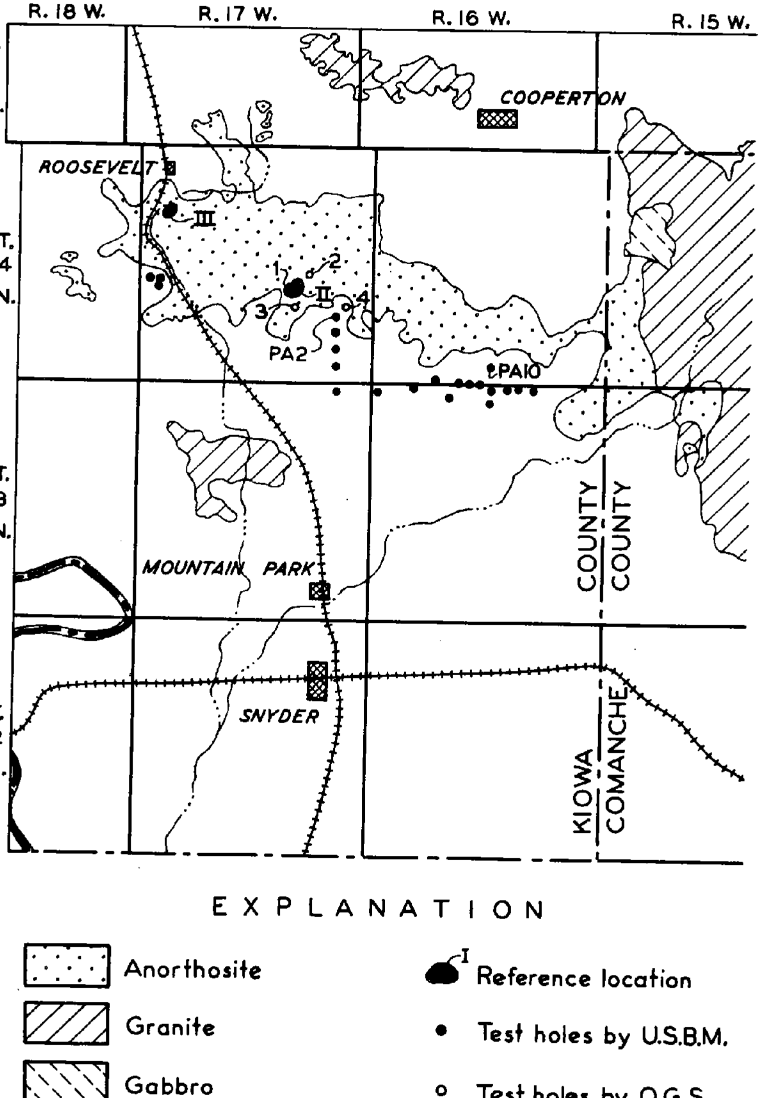
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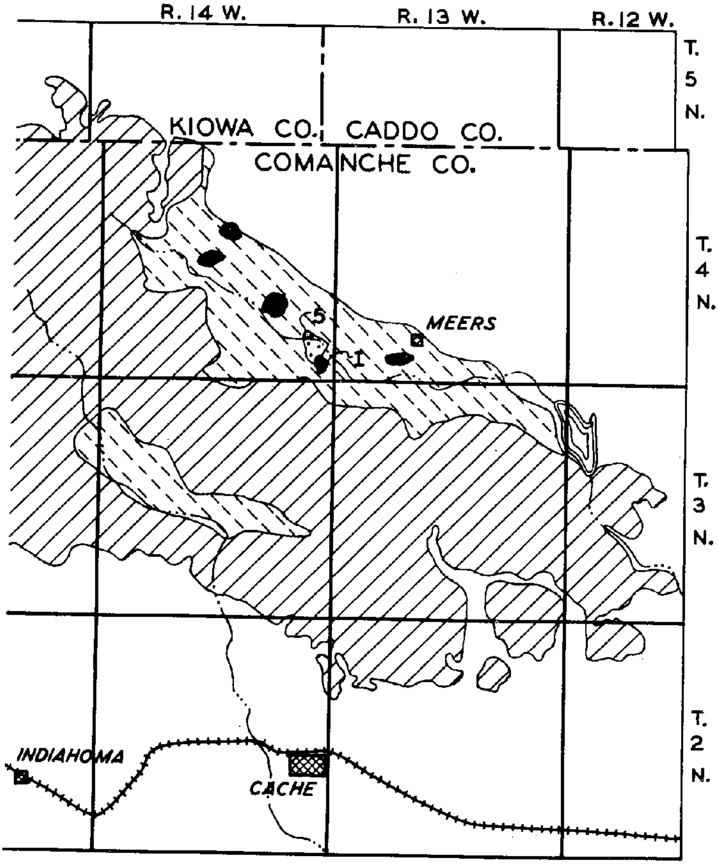
R. 17 W.
R. 16 W.
R. 15 W.
T. 5 N.
T. 4 N.
T. 3 N.
T. 2 N.
COOPERTON
ROOSEVELT
III
1
2
3
4
II
PA2
PA10
MOUNTAIN PARK
SNYDER
KIOWA COUNTY
COMANCHE COUNTY
EXPLANATION
Anorthosite
Granite
Gabbro
I
Reference location
Test holes by U.S.B.M.
Test holes by O.G.S.



MAP SHOWING REFERENCE LOCATIONS
IN ALTERED IGNEOUS ROCKS
KIOWA AND COMANCHE COUNTIES, OKLAHOMA

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