

# GEOLOGY OF THE CLAY DEPOSITS IN PARTS OF WASHINGTON AND IDAHO<sup>1</sup>

*by*

JOHN W. HOSTERMAN

U.S. Geological Survey, Agricultural Research Center, Beltsville, Maryland

## ABSTRACT

The clay deposits of eastern Washington and northern Idaho are along the eastern edge of the Columbia River Plateau physiographic province. Three types of clay occur in the area: (a) residual clay derived from the Columbia River basalt of Tertiary age; (b) residual clay derived from the Cretaceous granodiorite and related intrusive rocks of the Idaho batholith; and (c) transported clay. The two types of residual clay were formed during a protracted lull in the outpouring of the Columbia River basalt, when the relief of land surface was low to moderate and the climate was warm and humid. The topography and climate during this interval were probably ideal for leaching and oxidation. The transported clay is chiefly a product of the weathered granodiorite and related intrusive rocks. Most of it accumulated in basins formed by damming of streams by basalt flows.

Kaolinite and halloysite are the principal clay minerals found in the area. The residual clay derived from basalt is chiefly composed of halloysite. Most of this clay is colored blue, gray or grayish black by finely disseminated ilmenite and locally it is stained brown by limonite; most of it has a relict basaltic texture.

The residual clay derived from granodiorite and related intrusive rocks contains both kaolinite and halloysite, and the transported clay is predominantly kaolinite. Both of these clays are white and contain abundant quartz grains and mica flakes. The residual clay has a relict granitic texture, and the transported clay has a well-developed bedding and is interbedded with clastic material.

## INTRODUCTION

The clay deposits of eastern Washington and northern Idaho are on the eastern edge of the Columbia River Plateau physiographic province in an area known as the Palouse Hills, the topography of which is characterized by broad gently rounded hills and fairly broad even-floored valleys. The area is bounded on the east by the Bitterroot Mountains, on the south by the Snake River, and on the west and north by the Spokane River (Fig. 1). The areas most intensely studied were in Latah County, Idaho and Spokane County, Washington. In these two counties there are many deposits of low- to high-grade refractory clay and extensive deposits of high alumina clay that are potential sources for aluminum. Many as yet undiscovered clay deposits probably exist in the 60 mile belt along the western edge of the plateau between Latah County and Spokane County.

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## GEOLOGIC HISTORY

The oldest rocks in the region are the argillaceous and arenaceous sediments of the Precambrian Belt series, which locally are overlain unconformably by volcanic flow rocks of questionable Permian age. In Cretaceous time,

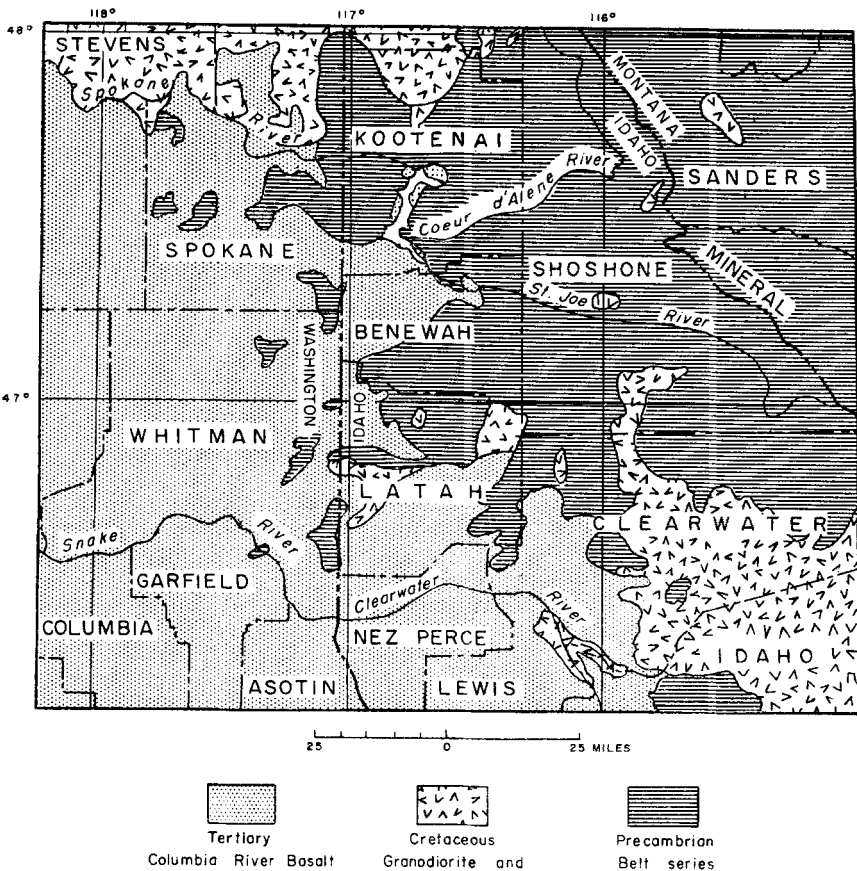


FIGURE 1.—Geologic map of eastern Washington and northern Idaho showing the eastern edge of the Columbia River plateau where many of the clay deposits occur.

these rocks were intruded by large masses of granodiorite and related intrusive rocks that are considered to be part of the Idaho batholith.

The Columbia River basalt was extruded in Miocene time as many separate flows. The length of time between flows was in many places so short that each succeeding flow spread out on a relatively fresh basalt surface. Streams flowing from the east were dammed by the flood of basalt from the west to form lakes in which sediments of the Latah formation were deposited (Pardee

and Bryan, 1926, pp. 8-12). The Latah formation is interbedded with and contemporaneous with the Columbia River basalt. During a protracted but local lull in the extrusion of the basalt, the Excelsior interval (Scheid, 1947), along the eastern margin of the Columbia River Plateau, weathering took place and residual clay as thick as 124 ft was formed. This weathered zone developed while the climate was warm and humid (Berry, 1929, p. 233) on a well-drained surface of low to moderate relief, with conditions that permitted complete oxidation of the parent material. Drilling has disclosed that the zone extends along a nearly plane surface beneath the present hills, and the valleys have cut only a few feet below it. Its lateral extent is not known because it is buried beneath later basalt flows to the west, and in the mountainous area to the east it has been removed by erosion, except on the lower western slopes where it is covered by a thin layer of basalt flows. Other intraflow weathering zones are present at several places in the Plateau region, but none have residual clays that approach the dimensions of deposits formed during this long interval of weathering. None of these smaller clay deposits will be discussed in this paper.

Renewed extrusion of basalt brought the protracted weathering period to an end; first by damming streams and forming lakes that became the depositional basins for material eroded from the mountainous area to the east; and second by covering both the residual clay and the lake sediments with additional basalt flows. The lake sediment represents the upper part of the Latah formation and contains the principal transported clay deposits (Kirkham and Johnson, 1929). When the extrusion of the basalt flows ceased, erosion once more became the dominant activity of the area.

Toward the end of the Pliocene, the central portion of the Columbia River Plateau was downwarped and the northern part of the Bitterroot range to the west was uplifted. This diastrophism produced a surface that sloped gently to the southwest and initiated the present drainage system in the Palouse Hills. Early during the Pleistocene, the aeolian material of the Palouse formation was deposited as a blanket over most of the Columbia River Plateau. Subsequently glaciers developed in the mountainous areas to the north and east, and much of the Palouse formation was removed from the valleys by glacial melt-water.

### TYPES OF CLAY DEPOSITS

The deposits of eastern Washington and northern Idaho contain three types of clay: residual clay derived from basalt; residual clay derived from granodiorite and related intrusive rocks; and transported clay of the Latah formation.

#### *Residual Clay Derived from Basalt*

The residual clay derived from basalt is composed chiefly of halloysite with minor amounts of kaolinite and the nonclay minerals ilmenite and quartz. Most of this clay has an indistinct relict basaltic texture accented by grains of blue-black ilmenite against the light-colored clay. The halloysite

is apparently the principal alteration product of plagioclase and the glassy groundmass, the major constituents of the basalt. The kaolinite occurs as crack fillings and is probably clay that has been transported and redeposited by ground water. The halloysite is hydrated, as shown in x-ray diffractometer traces by the broad 001 basal spacing at 10.1 Å (Fig. 2) which collapses to 7.2 Å when the clay is allowed to dry. Differential thermal analysis curves (Fig. 2) also indicate hydration of the halloysite by a large endothermic peak between 150° and 250°C. The electron micrograph of this clay (Fig. 3) shows that the halloysite occurs as tubes and irregular blobs.

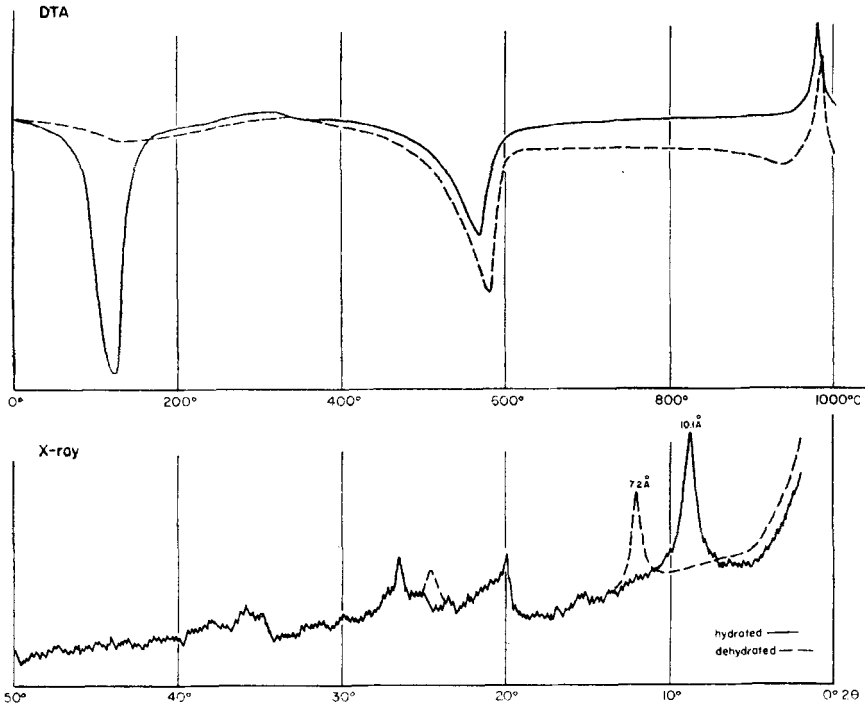


FIGURE 2.—X-Ray diffraction trace (CuK $\alpha$  radiation) and DTA curves of halloysite from residual clay derived from basalt.

Alteration of the Columbia River basalt appears to have been controlled largely by subsurface drainage. Most of the basalts are vesicular, and all are cut by numerous joints; water entered these joints but could not move freely at first. As the basalts weathered, the permeability and porosity increased, and the internal drainage improved, permitting the complete oxidation and leaching that produced halloysite. Had the poor drainage conditions and lack of oxidation persisted, montmorillonite and nontronite probably would have formed instead. In fact, in places where there was poor drainage, and where alkalis were present, the basaltic glass of the tuffs and breccias was altered to palagonite that in turn altered to nontronite. In

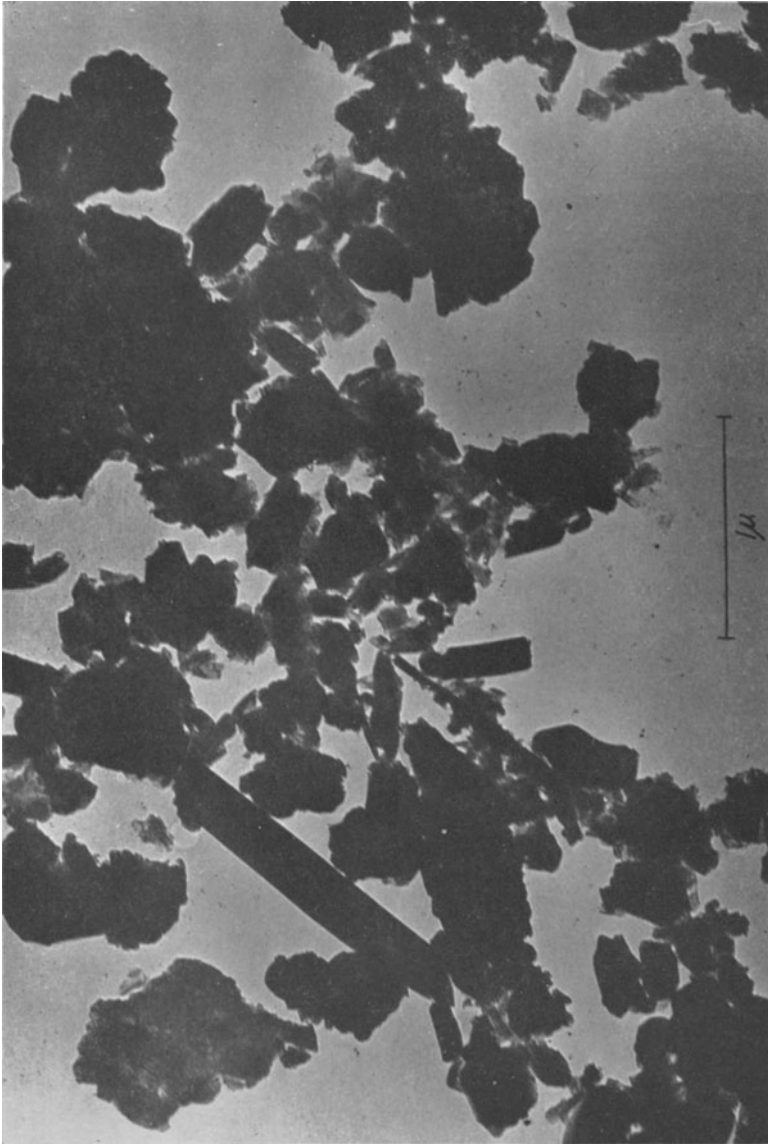


FIGURE 3.—Electron micrograph of halloysite from residual clay derived from basalt.

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areas where the drainage improved as the weathering progressed, the early-formed nontronite was removed by solutions and redeposited in cracks and vesicles in the fresh basalt lower down. Near the surface, the glass pumice fragments, feldspars and groundmass of the basalt altered directly to halloysite. Ilmenite and a very small amount of fine-grained quartz remain essentially unaltered and are somewhat concentrated by the weathering processes.

Five gradational zones can be recognized in a typical weathered profile of residual clay derived from basalt. The first zone, which is quite plastic, is composed almost entirely of halloysite and unaltered ilmenite. The clay is colored blue and bluish black by ilmenite, except where weathering of the ilmenite has produced yellow, limonitic spots and streaks. If there are any cracks, they are filled with kaolinite that was transported from the overlying Latah formation and redeposited through ground-water movement. The second zone is composed of halloysite, unaltered ilmenite, and a little nontronite and limonite. The clay in this zone is generally gray or brown from the ilmenite or limonite, and it may have a yellowish-green hue from the nontronite. If the clays have been derived from vesicular basalt, most of the vesicles and openings are filled with transported halloysite, and a few may be filled with transported nontronite. The third zone is composed of halloysite, ilmenite, nontronite and limonite. The clay is gray, blue, green and brown. This zone is distinctly harder than those above it, and the brown color is due to large quantities of limonite. Most of the vesicles and openings are filled with transported nontronite, but a few are filled with transported halloysite. A few grains of residual nontronite can be seen in this same zone. The fourth zone changes abruptly into the underlying semidecomposed basalt, which contains unaltered original minerals, grains of residual nontronite, and sparse specks of residual halloysite. Transported nontronite fills some of the vesicles and openings while the rest remain unfilled. The last zone is the fresh, hard basalt, unaltered except for a few specks of nontronite formed by the alteration of ferromagnesian minerals. The openings in the fresh basalt are unfilled.

*Residual Clay Derived from Granodiorite and  
Related Intrusive Rocks*

The second type of residual clay results from weathering of granodiorite and, to a lesser extent, quartz monzonite, tonalite, granite and syenite, that occur along the western fringe of the Idaho batholith. The original granitic, aplitic, pegmatitic and gneissic textures commonly are retained in the residual clay. Only the clay that formed at lower elevations has been preserved, inasmuch as the deposits at higher elevations have been eroded and in part redeposited as transported clay. Most of the residual clays can be zoned downward in a stepwise manner by the increase in proportions of unweathered minerals of the parent rock. Both quartz and muscovite are common in the most thoroughly weathered zones and the feldspars and biotite are present, in varying amounts, in the intermediate and unweathered zones. These deposits are truncated by the present land surface and pre-

sumably the material that was most thoroughly weathered is no longer present. The residual clay deposits differ greatly in depth and lateral extent, and the irregularities are governed by (a) resistance of parent igneous rocks to weathering, (b) local structures controlling permeability, (c) duration of weathering, and (d) amounts of clay removed by erosion.

The mineralogy of the clay derived from granodiorite and related rocks differs from place to place throughout eastern Washington and northern Idaho. One example of the mineralogical relationship can be observed at the Benson pit 3.5 miles northeast of Troy, Latah County, Idaho. Here the

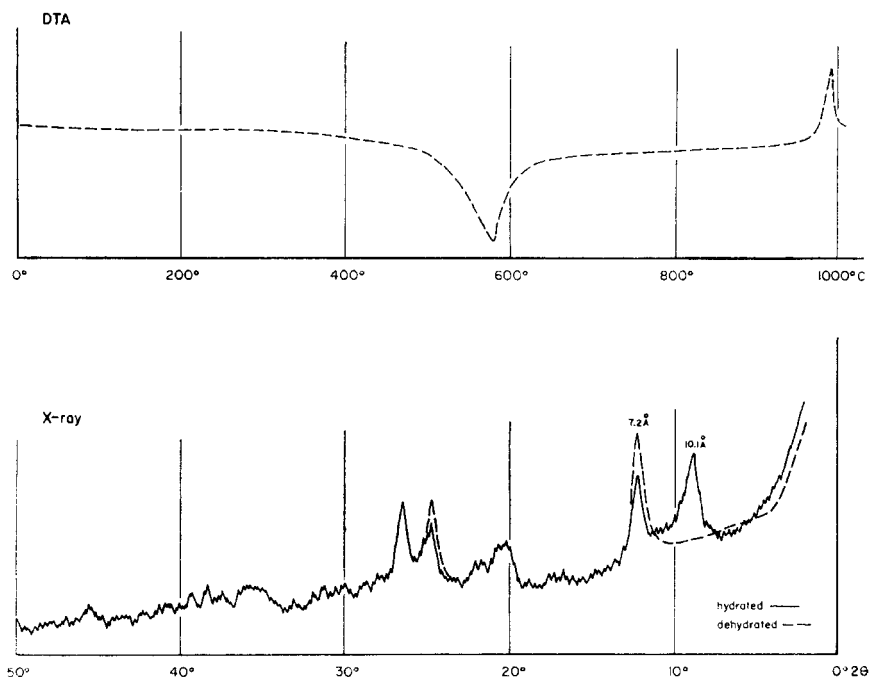


FIGURE 4.—X-Ray diffraction trace (CuK $\alpha$  radiation) and DTA curve of a mixture of halloysite and kaolinite from residual clay derived from granodiorite and related intrusive rocks.

residual clay can be divided into three gradational zones. The clay in the upper zone is composed of hydrated halloysite and kaolinite, as judged from the 7 Å x-ray diffraction peak (Fig. 4) and the hexagonal crystals shown in the upper right-hand corner of the electron micrograph (Fig. 5). This zone also contains a small amount of muscovite and quartz. The second zone differs from the upper one in that it contains less kaolinite, more halloysite, and scattered grains of fresh feldspar, in addition to some quartz and muscovite. The third zone contains muscovite, quartz, feldspar, biotite and some halloysite. The abundance of feldspar and biotite increases rapidly with depth. In general, the ratio of halloysite to kaolinite at the Benson pit

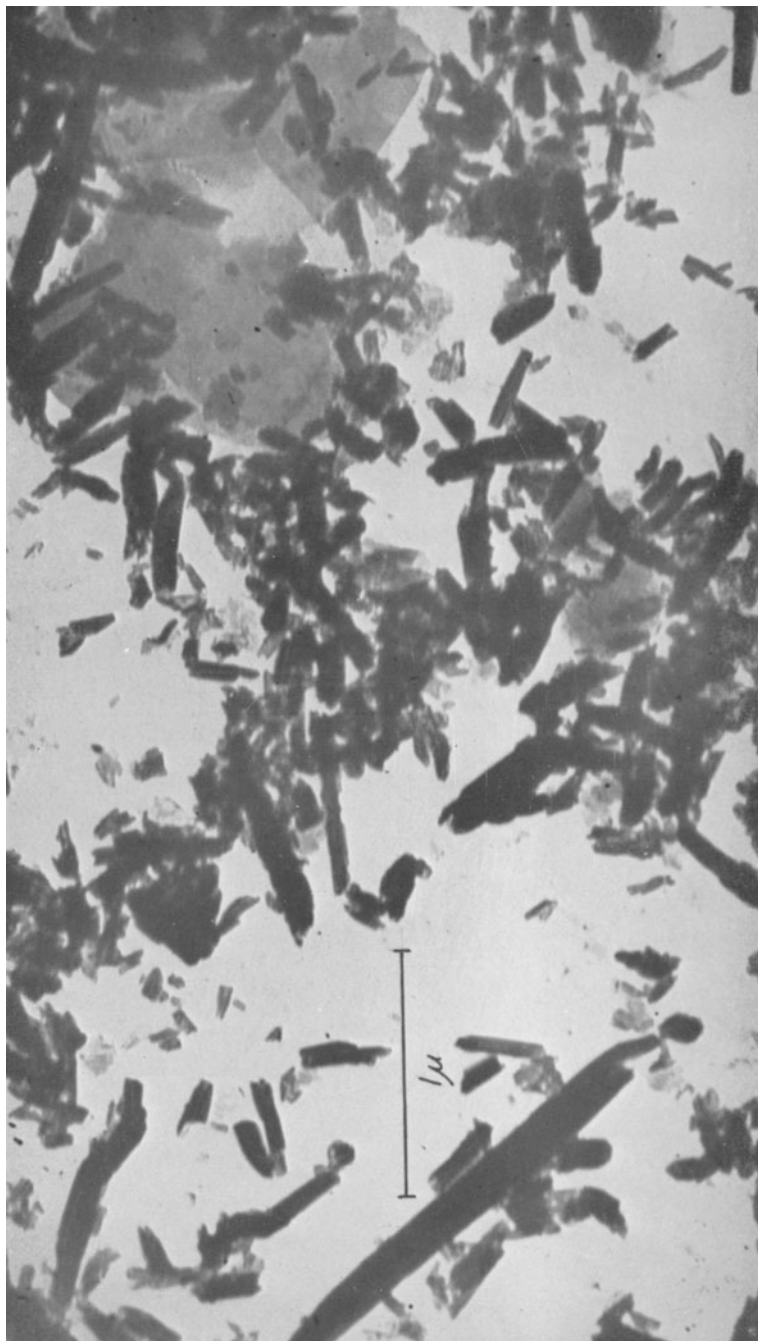


FIGURE 5.—Electron micrograph of a mixture of halloysite and kaolinite from residual clay derived from granodiorite and related intrusive rocks.

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increases downward. This relationship might be explained by the observations of Sand (1956, pp. 38-39) concerning residual kaolins of the southern Appalachian region, where conditions of mineral composition, rock texture, degree of fracturing, topographic expression, vegetation and climate favor the formation of halloysite: a feldspathic rock high in mica content yields a clay high in kaolinite, and conversely a rock low in mica yields a clay high in halloysite. At the Benson pit, the kaolinite in the upper zone is an alteration product of the mica, whereas the mica in the lower zones remain essentially unaltered. The halloysite is an alteration product of the feldspars, which tend to weather much more rapidly than the mica.

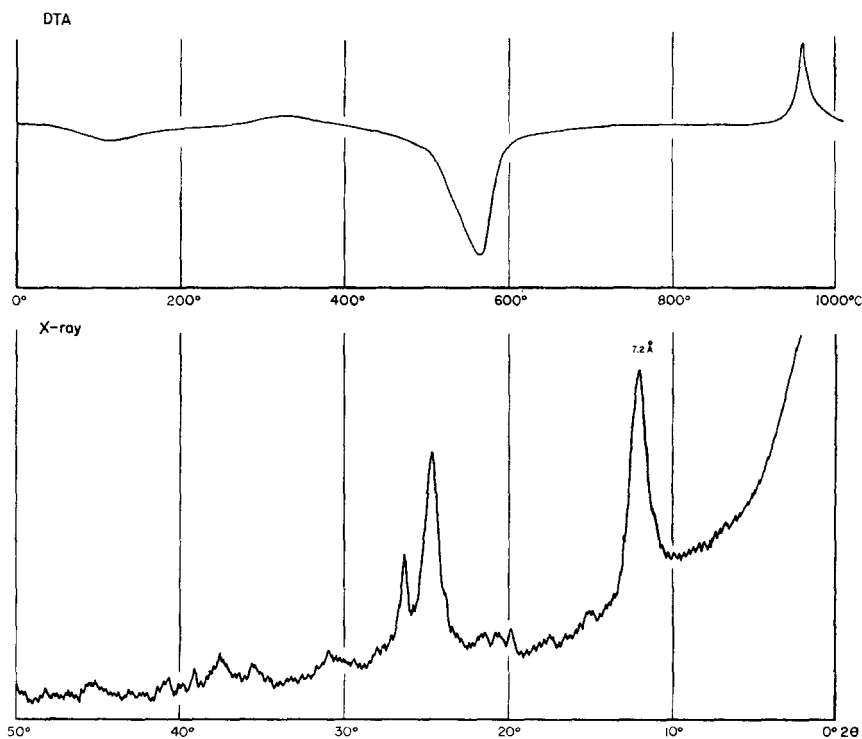


FIGURE 6.—X-Ray diffraction trace (CuK $\alpha$  radiation) and DTA curve of kaolinite from the transported clay of the Latah formation.

#### *Transported Clay*

The transported clay occurs in bedded deposits in the upper part of the Latah formation overlying the residual clay derived from basalt and locally overlying the residual clay derived from granodiorite and related rocks. Zones of sandy clay, sand and pebble beds are locally interbedded with the transported clay. The clay is light gray or pink and commonly is stained or streaked yellow, brown or red by iron oxides. The clay is plastic, and it has a very high content of kaolinite (Figs. 6 and 7). Quartz silt and muscovite

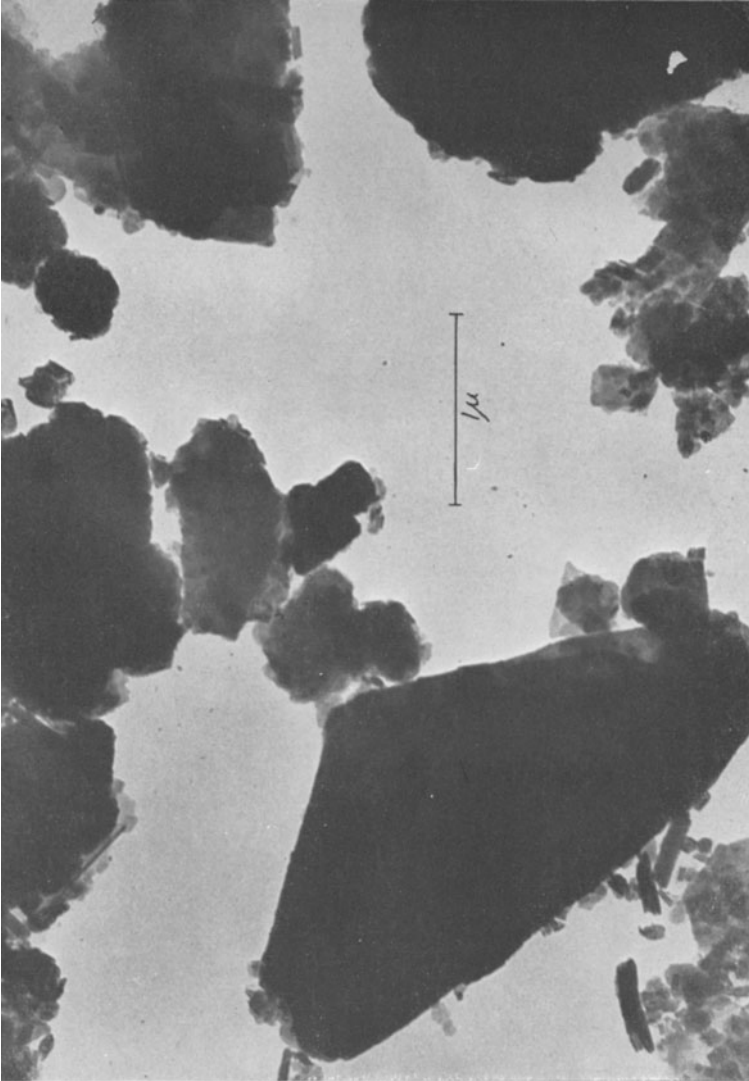


FIGURE 7.—Electron micrograph of kaolinite from the transported clay of the Latah formation.

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flakes are present in different amounts. Kaolinite and mica flakes are not found in the residual clay derived from basalt, and most of the transported clays therefore appear to have been reworked from clays formed by weathering of granodiorite and related rocks.

### CHEMICAL COMPOSITION

The average chemical properties of the residual clay derived from basalt, residual clay derived from granodiorite and related rocks, and transported clay are given in Table 1. The residual clays derived from basalt have the

TABLE 1.—AVERAGE CHEMICAL PROPERTIES OF THE THREE TYPES OF CLAY  
(Analyses from Hosterman *et al.*, in press, Table 5)

	(1)	(2)	(3)
Ignition loss (700°C)	10.6	6.1	8.5
Al <sub>2</sub> O <sub>3</sub>	30.1	21.3	24.8
SiO <sub>2</sub>	42.4	68.7	58.5
Fe <sub>2</sub> O <sub>3</sub>	9.4	4.0	4.9
TiO <sub>2</sub>	6.4	0.4	1.0

- (1) Residual clay derived from basalt.  
 (2) Residual clay derived from granodiorite and related rocks.  
 (3) Transported clay.

highest alumina content. The silica content, which is present in part as quartz grains, is higher in the residual clay derived from granodiorite and transported clay. The high content of titania in the residual clays derived from basalt is quite understandable because the parent rock of this clay is the only one containing ilmenite. The weathered ilmenite also is responsible for the higher iron oxide content in the clay.

The residual clay derived from basalt would make the best source of alumina, and possibly titania could be extracted as a by-product. Both the residual clay derived from granodiorite and the transported clay would make better refractory materials because the iron oxide and titania contents are much lower.

### REFERENCES

- Berry, E. W. (1929) A revision of the flora of the Latah formation: *U.S. Geol. Survey*, Prof. Paper 154H, pp. 225-265.  
 Hosterman, J. W. *et al.* (1960) Investigations of some clay deposits in parts of Washington and Idaho: *U.S. Geol. Survey*, Bull. 1091. In preparation.  
 Kirkham, V. R. and Johnson, M. M. (1929) The Latah formation in Idaho: *J. Geol.*, v. 37, no. 5, pp. 483-504.  
 Pardee, J. T. and Bryan, K. (1926) Geology of the Latah formation in relation to the lavas of the Columbia Plateau near Spokane, Washington: *U.S. Geol. Survey*, Prof. Paper 140-A, pp. 1-16.  
 Sand, L. B. (1956) On the genesis of residual kaolins: *Amer. Min.*, v. 41, no. 1-2, pp. 28-40.  
 Scheid, V. E. (1947) Excelsior surface—an intra-Columbia River basalt weathering surface: *Bull. Geol. Soc. Amer.*, v. 58, no. 12, pp. 1224-1225. (Abstract.)