UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

EXCELSIOR HIGH-ALUMINA CLAY DEPOSIT

SPOKANE COUNTY, WASHINGTON

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ILLUSTRATIONS

ABSTRACT

The Excelsior high-alumina clay deposit is about 11 miles southeast of Spokane, Wash. During World War II, the area was studied by the U. S. Geological Survey in cooperation with the U. S. Bureau of Mines. The Bureau of Mines hand-augered and machine-drilled 139 holes and analyzed the samples for ignition loss, available alumina, and availabe ferric oxide.

The deposit contains two types of clay: basaltic residual clay derived from the weathering of Tertiary Columbia River basalt in place, and transported clays of the Latah formation derived from the weathered debris of the older igneous and metamorphic rocks. Basaltic residual clay comprises about 94 percent of the deposit.

The Excelsior high-alumina clay deposit averages about 28.7 percent available alumina, 5.6 percent available ferric oxide, and 7.1 percent total titania. The deposit could serve as a source of low-grade high-alumina clay with titanium as a byproduct.

The deposit is in a part of the Columbia River Plateau physiographic province that is characterized by broad, gently-rounded hills and fairly broad, even-floored valleys. Altitudes range from 2,450 to 2,600 feet; however, local relief seldom exceeds more than 50 feet. The southern half of the area is drained by the tributaries of California Creek, a tributary of Latah Creek which empties into the Spokane River at Spokane. The northern part of the area is drained by a stream flowing northward to the Spokane River through a glacial col transecting the Selkirk Mountains. All streams in the Excelsior area are seasonal.

INTRODUCTION

Purpose and Location

During World War II, the U. S. Geological Survey, in cooperation with the U. S. Bureau of Mines, made an appraisal of the national alumina resources in an attempt to guarantee an adequate domestic supply of aluminum. This report is part of a study of high-alumina clay resources in the Pacific Northwest region, and describes the results of the investigation of a deposit of high-alumina clay in Spokane County, Wash.

The Excelsior clay deposit is in secs. 20, 21, 22, 23, 28, and 29, T. 24 N., R. 44 E., Willamette Meridian, Spokane County, Wash. (pl. 1 and fig. 1) approximately 11 miles southeast of Spokane. State highway 3-H, the Palouse Highway, and many gravel roads traverse the area. The small village of Mica is at the eastern edge of the deposit, and it is a station for two railroads, the Union Pacific and the Chicago, Milwaukee, St. Paul, and Pacific. Valleyford, a small farming community, is at the southern edge of the area, and it is a station of the Great Northern Railroad.

Field Work and Acknowledgments

During the fall of 1943, the U. S. Bureau of Mines, under the supervision of P. E. Oscarson, District Engineer, and R. H. Storch, Project Engineer, drilled 32 preliminary hand auger holes. The results from these drill holes were so promising that a second program of machine and hand auger drilling was carried on during the winter of 1944-45. Eighty-three hand auger holes and 56 machine drilled holes were drilled totaling 3,613.5 feet, and chemical assays were made on 392 samples. In the fall and winter of 1943 the writer logged the drill holes and plotted the geology on areal photographs enlarged to a scale of 500 feet to the inch.

The author is indebted to Mr. Oscarson and Mr. Storch, U. S. Bureau of Mines, for the many courtesies extended and for the chemical data they made available. Mr. V. T. Allen assisted the author with his helpful suggestions and mineralogic and petrographic studies. The authors wish to thank Mr. I. G. Sohn for assistance in the field and his helpfulness in preparing the report. The writer is indebted to the University of Idaho for the use of office space while preparing portions of the report.

GEOLOGY

General Features

An understanding of the clay deposit is best obtained by a brief summary of the regional geology. Eastern Washington and northern Idaho were originally underlain by argillaceous and arenaceous sediments of pre-Cambrian Belt series. In late Jurassic or early Cretaceous time, these older rocks were cut by large masses of granodiorite and related igneous rocks that are considered to be part of the Nelson and Idaho batholiths. Post-intrusion erosion exposed the granitic rocks, and a mature topography developed.

Beginning in Miocene time, the Columbia River basalts were extruded (Pardee and Bryan, 1926, p. 11-12). These basalts are composed of plagioclase and augite with minor amounts of ilmenite and olivine in a glassy groundmass. Streams dammed by the lavas formed lakes in which the Latah formation was deposited (Pardee and Bryan, 1926, p. 8). Thus, the Latah formation is interbedded with and contemporaneous with the basalt. During a protracted lull in the extrusion of basalt, a weathering surface developed in eastern Washington and northwestern Idaho. This weathering surface, which divides the upper basalts from the lower basalts, was given the name Excelsior surface (Scheid, 1947). During the Excelsior interval, the climate was very warm and humid, with conditions that permitted complete oxidation and the formation of residual clays. Renewed extrusion of basalt brought the Excelsior weathering interval to an end. The upper member of the Latah formation was deposited upon the residual clay in lakes that were formed by streams dammed by the post-Excelsior basalt flows. This member contains the principal transported clay deposits, and it is thickest beneath the hills. The Latah formation is composed of lacustrine and stream deposits of interbedded clays and some sands and gravels that are derived from the weathered debris of granitic and metamorphic rocks. With the cessation of the basalt extrusion, erosion again became dominant in the region.

Toward the end of Pliocene time, diastrophism resulted in the downwarp of the central portion of the basalt plateau and uplift of the Cascade range. This diastrophism produced a basalt surface that slopes gently to the southwest and initiated the present period of canyon-cutting. It is suggested by Flint (1938, p. 226) that the uplift of the Horse Heaven Hills dammed the Columbia River and a great lake was formed. Into this lake Pleistocene sediments of the Ringold formation of central Washington and the Palouse formation of eastern Washington and northwestern Idaho were deposited. In time, the Horse Heaven Hills dam was breached and erosion began throughout the area. During Pleistocene time, glaciers developed in the mountains to the north released melt-water that removed some of the Palouse formation from the valley. As the glaciers retreated, canyon cutting continued and Recent alluvium is now found in many of the stream valleys.

Pre-basalt granite gneiss.--The mountainous portion of the region near Excelsior, as shown on figure 1, is underlain chiefly by crystalline and metamorphic rocks, such as granitoid gneiss, schist, coarse-grained igneous rocks, and small masses of pre-Cambrian quartzite. The predominant type is a gneissic rock of granitic composition formed by metamorphism of the pre-Cambrian Belt quartzite. The metamorphism is spatially related to the Nelson batholith. The granite gneiss is traversed by ramifying pegmatitic dikes of varying sizes. The gneiss forms the sides of the Valleyford Embayment and outcrops in the higher northwest and northeast portions of the mapped area (pl. 1). Drill holes Ex 1, Ex 53, Mi 9, and Mi 58 penetrate the weathered and semi-decomposed surficial portion of the gneiss. From this the granite gneiss is believed to extend beneath the Columbia River Plateau as a basement upon which the basalts and sediments rest.

In the mountainous area, the granite gneiss has only a small amount of weathered debris at the surface, but at the base of the hills where the basalt laps onto the gneiss, the gneiss is weathered to great depths. This weathered material is mined for structural clayware at Mica and Freeman and was prospected one mile northeast of Mica by the Anaconda Copper Mining Co. in 1920 as a possible source of high-alumina clay. The weathered debris of the granite gneiss supplied most of the material of the Tertiary Latah sediments.

Columbia River basalts.--Although the basalts may range in age from Miocene or even Eocene to Pliocene, they are considered as the product of closely related eruptive activity and as one formation. In the mapped area, a thick weathering profile exists within the basalt series and serves as a convenient marker to subdivide the formation into upper basalt flows and lower basalt flows. Where the weathering profile is not exposed, it is not possible to separate the lower from the upper basalts. The lower Columbia River basalts are exposed at the following places: (1) road cut near the north end of Section X-X'; (2) road cut opposite drill hole Ex 40; (3) road cut east of drill hole Mi 31; (4) road cut near south end of Section X-X'; and (5) the walls of the railroad siding cut east of drill hole Mi 47. At all of these artificial exposures, the lower basalt occurs as blue-gray and gray, basaltic residual clay. Drill holes have revealed that the lower basalts, like the upper basalts, consist of pillow lava, tuffs, breccias, and solid flows. In the field, the upper and lower basalts appear lithologically similar, but under the microscope the lower basalts are decomposed and the upper basalts are fresh.

The upper basalts consist of solid blocky or massive flows, vesicular lava, volcanic breccias, and pillow lavas. The typical lithology is fine-grained, dense, gray or blue-gray or black basalt. Plagioclase, augite, and glass have been identified as the major constituents, and olivine as a minor constituent. Generally, the vesicles in the vesicular lava are quite small and are partly filled or lined with carbonate or iron hydroxide minerals. The rounded masses of the pillow lava are from 1 to 6 feet in diameter, and they have a one-half inch glassy coating with a dense or vesicular interior. The interior of the pillows is gray or black and the plagioclase phenocrysts are often arranged in a sub-triangular texture. The exterior of the pillows is buff to yellow, and sedimentary material often fills the space between the pillows.

Latah formation.--The Latah formation comprises all the sedimentary material that was deposited from the time of the earliest basalt flows until just prior to the deposition of the Palouse formation (Pardee and Bryan, 1926, p. 8). The bulk of the Latah formation was deposited during the lull between the lower and upper basalts (Excelsior interval). The time of the last deposition is indeterminate, but certain drill logs indicate that the first Palouse sediments were deposited as a mixture with the Latah sediments. Locally, the Latah sediments are separated from the Palouse formation by an erosional surface with at least 10 feet of relief, and elsewhere bog iron deposits occur between the Palouse and Latah formations.

The few natural exposures are as follows: (1) 300 feet west of drill hole Mi 48; (2) at drill hole Mi 40; (3) 800 feet north of drill hole Ex 49; and (4) 1,200 feet northwest of drill hole Mi 11B. All other exposures are either roadcuts or clay pits. The Latah sediments consist of unconsolidated lacustrine and stream deposits of weathered debris derived from the gneissic and granitic rocks of the mountainous areas. The sediments are generally light gray, occasionally white or yellow, and rarely red. They are composed of quartz gravel, quartz and feldspar sand, muscovite flakes, and kaolinite clay. The greatest thickness penetrated by drilling was 31 feet at drill hole Ex 7; however, a thickness of 41 feet was noted in the pit at drill hole Mi 47. Although most of the Latah formation is clay, commonly sandy and gravelly zones 13 to 15 feet thick occur at the base. The pure clay beds are economically useful for ceramic purposes, and are being mined from the large pit at drill hole Mi 47 and from the pits east of Mica.

Quaternary sediments.--All sedimentary rocks younger than the Latah formation have been grouped together as Quaternary sediments. This group includes the Palouse formation, glacial deposits of Pleistocene age, and alluvium of Recent age.

The Palouse formation corresponds to what Bryan (1927, p. 44) calls the "inner core" of the Palouse Hills. At places in the region, the formation is more than 100 feet thick, but the greatest thickness at the Excelsior deposit is 59 feet at drill hole Ex 46 (appendix). The formation is composed of massive, sometimes stratified, brown and reddish-brown silt. At many places, the base of the formation consists of granitic sands and gravels up to 10 feet thick, and at other places basaltic gravel is mixed with silt. The Palouse formation antedates all glacial activity in the area, and the major part of the formation has long been considered to be deposited by wind which obtained the material from the west. The author, however, believes, that although the material was windborne, it was deposited in a lake or series of lakes. No other method explains the stratification or the presence of gravel and occasional boulders found at widely spaced places. Subsequent erosion has removed more of the silt from the valleys than from the hills, so that this formation is now thicker on the hills than in the valleys. The specific gravity of the Palouse formation ranged from 1.78 to 2.06 and the average is 1.90. The moisture content ranged from 12.3 to 19.1 percent with an average of 16.8 percent.

The remainder of the Quaternary sediments are composed of glacial deposits and alluvium. Glacial gravels probably filled the valleys of the mapped area at one time, but have been removed except in certain protected tributary valleys. The glacial gravels are composed of quartz, granite, and basalt sands, gravels, and boulders. Remnants of the gravel filling exist as a small terrace on the north side of California Creek, north of Valleyford, and along the east side of the central valley (pl. 1). Glacial gravel and sand deposits, mostly basaltic, occur along the highway and railroad south of drill hole Mi 33 where they have been used for road material. Erratic boulders of granite gneiss, basalt, and some schist, quartzite, diorite, and pegmatite are found throughout the mapped area.

Geomorphology

The drainage pattern of the pre-lower basalt erosion surface developed upon the granite gneiss rocks has been the geomorphic control of all subsequent formations. Its characteristics, with slight modifications, have been periodically inherited. Figure 1 and plates 1 to 4 show that in pre-lower basalt time the California Creek valley and the central north-south valley had courses very much as they are today. These valleys were flooded by the lower basalts, forming the Valleyford embayment. Since no dikes which might have been feeders for the basalt flows were found in the granite gneiss areas, it is assumed that the flows came from the south or west. The lower basalts did not completely fill the old valleys so that the post-lower basalt streams were confined to some extent to the old valley walls that rose above the lava surface. Thus, the drainage courses were above the old buried courses. The farthest advancement of the lower basalts into the Valleyford embayment left a narrow, sharply defined, peripheral valley formed by the steep front of a flow and the sloping surface of the embayed valley. This peripheral valley developed in both directions from the points where California Creek and the central valley crossed the granite gneiss-basalt contact. The major set of contact valleys ran north and south from California Creek along the east and west sides of the embayment, and a minor set ran east and west from the central valley at the head of the embayment. The two sets of contact valleys developed headwardly toward each other until a low gap was produced.

The Latah formation was deposited in lakes formed behind dams of upper basalt. At one time the formation probably completely covered the lower basalt surface, but unconsolidated beds offered little resistance to erosion when the streams reestablished themselves in the old channels. Thus, the Latah formation was removed from the valleys, but left on the hill tops (pl. 2 to 4).

The advancing upper basalts almost completely buried the old topography in the southern portion of the area, but flooded only the valleys in the central and northern portions of the mapped area. Thus, the upper basalts rest upon lower basalt throughout most of the area, upon granite gneiss along the northern margin of the embayment, and upon small areas of the Latah formation along the sides of the buried valleys. At every place where the lower contact of the upper basalt was noted, the base of the flow is a series of pillow basalts. This indicates that the first extrusion of upper basalt was into water.

With the pre-upper basalt valleys only partially filled, the streams were again confined within the walls of the old valleys. Thus, the streams began to cut channels in the upper basalt that are above the older channels.

Erosion of the upper basalts had not progressed far enough to cut very deep valleys before the area was covered by the Palouse formation. The unconsolidated materials did not change the drainage pattern. The melt-water from the Pleistocene glaciers removed the Palouse formation from the valleys and left small terraces.

Therefore, the major drainage of the area has been successively inherited from the pre-lower basalt land surface. During each succeeding geologic epoch down to the present, the general configuration of the land surface has been inherited and maintained with little modification since the production of the Excelsior surface in post-basalt time. The Excelsior surface and the many minor erosion surfaces produced during inter-basalt times are evidence that the Columbia River basalts are not a series of parallel flows. Likewise, the inheritance of topographic features is contrary to the belief that the Palouse formation was deposited upon a level surface.

The Excelsior Surface

The length of time between successive flows of the Columbia River basalt varied, but in general, it must have been short, since most flow tops are composed of fresh lava or lava weathered to only a minor degree. However, at one time an inter-basalt interval occurred that was longer than any that preceded or followed it. During this inter-basalt interval lavas probably were being extruded at other places throughout the Columbia River Plateau, but in eastern Washington and northern Idaho, the outpouring of basalt gave way to a protracted period of weathering. During this weathering interval the great thickness of basaltic residual clay of the Excelsior and other clay deposits was formed. The full thickness of the weathered zone is not everywhere known, but the 46 feet of basaltic residual clay encountered in drill hole Mi 42 testifies to a long and intense weathering interval. Because the Excelsior deposit is the most completely drilled and studied area, the author has named the surface developed during this intense weathering interval the Excelsior surface.

The Excelsior surface, within the mapped area, has a relief of about 100 feet, but from any one hilltop to its adjacent valley, the relief does not exceed 50 feet. The surface slopes gently to the southwest, and toward the mountains to the east and west, it rises gently for a mile beyond the end of the basalt. The deep weathering of the granitic rocks in the adjacent mountainous areas probably occurred during the same weathering interval.

The full areal extent of the Excelsior surface is not known, but very likely its western extension is buried beneath a great thickness of later basalt flows. The eastern extension is preserved near the mountains because the surface was thinly covered by later basalt flows and was not destroyed by erosion.

CLAY DEPOSIT

General Features

The Excelsior high-alumina clay deposit is in the Valleyford embayment, and it is dominantly composed of basaltic residual clay, the product of the weathering of basalt in place. It also contains a minor amount of transported clay derived primarily from the weathered debris of the granitic rocks that has been transported and deposited in water. The deposit is divisible into five blocks (pl. 1) by drainage and topographic conditions. The central north-south drainage divides the embayment into two almost equal parts: Area I on the west side has three blocks and Area II on the east side has two blocks.

The base of the clay deposit is determined in most cases by chemical assays, but part of the deposit rests on granite gneiss. The lateral extent of the deposit is limited mainly by the upper flows of the Columbia River basalt, and to some extent the iron content and erosion of the upper portion of the basaltic residual clay.

The overburden averages 21.4 feet thick. It is composed mostly of the Palouse formation and partly low-grade clay beds of the Latah formation. The ratio of overburden to clay reserves ranges from 0.50:1 to 2.48:1.

The grade of the clay is only vaguely related to depth of clay. Local lithologic conditions apparently controlled variation of the grade, and over a large part of the deposit the clay actually increased in grade for a depth of several feet below the surface (fig. 2). Local conditions, particularly porosity, may have permitted greater movement of ground water which produced the abnormally thick basaltic residual clay.

The cross sections (pls. 2 to 4) show that basaltic residual clay is thickest along the flanks of the ridges and thinner on the ridge-tops and in adjacent valleys. This distribution of clay may have been caused in several ways--(1) soil creep, (2) the position of the ground-water table, and (3) the different soil profiles on the same hill. If the last cause was the most effective, a variation in the thickness of the basaltic residual clay may not exist.

The U. S. Bureau of Mines drilled 139 holes for a total of 4,633.5 feet in the vicinity of the Excelsior deposit. Eighty-three holes were drilled by hand, using 3-inch post-hole augers of the Iwan type. Fifty-six holes were machine-drilled by the drive pipe method using a 71 Speed Star churn drill mounted on a Chevrolet truck chassis. Logs of the drill holes are in the appendix. Samples were taken at 5-foot intervals or where the material showed a marked change. The samples were prepared at Spokane, Wash., and were sent to the U. S. Bureau of Mines, Northwest Experiment Station, Seattle, Wash., to be assayed. About 1,500 samples were assayed for ignition loss, available alumina, and available ferric oxide.

The samples were calcined for one hour at 700° C., and the loss in weight, due to the escape of the hydroxyl ion, organic matter, and small amount of CO_2, is reported as ignition loss.

Available alumina (Al_2O_3), as defined by Skinner and Kelly (1949, p. 6), is the amount of alumina extracted from the clay that has been dried at 130° C. overnight, weighed, calcined at 700° C. for one hour, and boiled in a 20 percent solution of sulfuric acid for one hour.

The available ferric oxide (Fe_2O_3) is defined as the percentage by weight of ferric oxide in the calcined clay that is soluble in 20 percent solution of sulfuric acid under the same conditions as above. Because ilmenite is not appreciably soluble in sulfuric acid, its iron content, for the most part, is not available.

Area I, West Block.--The West Block of Area I (pl. 1) lies along the western margin of the Valleyford embayment. It is approximately 6,000 feet long and 900 feet wide and has an average clay thickness of 14.7 feet. The north end terminates against granite gneiss and the eastern boundary is a buried valley in the lower basalt. The western and southern limits are determined by low-grade clay.

Area I, Middle Block.--The Middle Block of Area I (pl. 1) is approximately 4,600 feet long and 1,500 feet wide and has an average high-alumina clay thickness of 16.8 feet. On the east and west sides the clay has been largely removed or greatly thinned by erosion. The north boundary is partly determined by the lower basalt and partly by erosion. The southern boundary is arbitrarily placed because the clay increases in iron content.

Area I, East Block.--The East Block of Area I (pl. 1) is roughly 3,200 feet long and 1,200 feet wide and has an average high-alumina clay thickness of 14.1 feet. The south and west sides are determined by the lower basalt. The increase in iron content arbitrarily determines the northern boundary. To the east, the clay has been almost entirely removed by erosion.

Area II, West Block.--The West Block of Area II (pl. 1) is the largest of the five blocks. It is approximately 4,400 feet long and 2,000 feet wide, and averages 21.9 feet in thickness. The north and south boundaries are arbitrarily determined by the increasing content of iron. The west boundary is formed by the glacial debris cover, and lower basalt. On the east side, the clay has been thinned by erosion.

Area II, East Block.--The East Block of Area II (pl. 1) is approximately 2,700 feet long, and 1,200 feet wide. The average thickness is 15.6 feet. The northeast boundary terminates against granite gneiss, and the southeast boundary is determined by an excessive overburden of lower basalt. On the west, north, and south sides, the clay is thinned by erosion and has an increasing iron content.

Basaltic Residual Clay

Mineralogy.--Mr. V. T. Allen made examinations of the minerals found in the basaltic residual clay. Of the minerals identified, only a few are of any economic importance.

Kaolinite ($Al_2O_3 \cdot 2\ SiO_2 \cdot 2H_2O$) is the chief mineral of the basaltic residual clay and the only one of importance for its alumina content. It is usually white or gray, but often stained yellow or tan by iron oxide. It occurs as a weathered product of plagioclase and to a minor degree of augite. Also, glassy pumice fragments and the groundmass of the basalt are altered to kaolinite under favorable conditions of good drainage. Some X-ray patterns of the basaltic residual clay indicate that a certain amount of halloysite is present with the kaolinite.

Nontronite ($Fe_2O_3 \cdot 3SiO_2 \cdot nH_2O$), normally a rare mineral, forms an isomorphous series with beidellite. The nontronite is a weathered product, under conditions of poor drainage, of the basalt glassy groundmass and, to a minor extent, of augite (Allen, 1946, p. 309). Two types of nontronite have been found in the basaltic residual clay: the first type is residual and occurs as grains that are dark olive green, yellowish green, or brown in color; the second type is transported and occurs in veins that are yellowish green to dark grass green in color. Both types of nontronite are massive, waxy, and sectile. A sample of transported nontronite gave the following analysis.

SiO_2	41.63 percent	Na_2O	0.22 percent
Al_2O_3	8.69 percent	K_2O	0.32 percent
Fe_2O_3	25.99 percent	LiO_2	trace
MgO	0.33 percent	H_2O-	10.67 percent
CaO	1.78 percent	H_2O+	9.91 percent
		Total	99.54 percent

Beidellite ($Al_2O_3 \cdot 3SiO_2 \cdot nH_2O$) is present as a waxy, brown material filling some of the cracks a few feet from the top of the basaltic residual clay. The beidellite is believed to have been derived from the overlying Palouse formation.

Ilmenite ($FeO \cdot TiO_2$) is found in all of the basaltic residual clay, and is apparently unaffected by weathering. The ilmenite occurs as abundant, small, uniformly disseminated flakes that are blue-black in color.

Limonite ($2Fe_2O_3 \cdot 3H_2O$) fills very small cracks in the basaltic residual clay, and also stained the clay tan or yellow.

Lithology.--The basaltic residual clays are the result of the weathering of the lower Columbia River basalts during the Excelsior interval. The residual clay retains the original basaltic texture to some degree. The fine- and even-grained texture is sharply defined by the uniformly disseminated grains of ilmenite. Thus, the texture in the residual clay is more sharply defined than in the fresh basalt, in which the texture is often indistinct when examined with a hand lens.

From the top of the basaltic residual clay to fresh basalt, five subparallel, gradational zones can be distinguished. They are: (1) high-grade alumina clays, (2) intermediate-grade alumina clays, (3) poor grade alumina clays, (4) semi-decomposed basalt, and (5) fresh basalt.

The high-grade alumina clays are composed almost entirely of kaolinite and unaltered ilmenite, and are plastic. These clays are blue and bluish-gray from the metallic blue-black ilmenite. The upper part of this zone is often stained yellow in spots and streaks by the alteration products derived from ilmenite. The basaltic residual clay in this zone averages about 31 percent available alumina and three percent available ferric oxide.

The intermediate-grade alumina clays are composed of kaolinite, unaltered ilmenite, and some nontronite. These clays are generally gray or brown, but may have tones of green or blue. The brown color is from the limonite. Where these clays have been derived from vesicular basalts, most of the vesicles and openings are filled with transported kaolinite, but a few are filled with transported nontronite. The basaltic residual clays in this zone average about 28 percent available alumina and 5 percent available ferric oxide.

The low-grade alumina clays are composed of kaolinite, ilmenite, nontronite, and limonite. The clays are dark shades of 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 in this zone are filled with transported nontronite, but a few are filled with transported kaolinite. Grains of residual nontronite were noted in this zone. The basaltic residual clay in this zone averages about 23 percent available alumina and 13 percent available ferric oxide.

The low-grade clay zone changes abruptly into the underlying semi-decomposed basalt which is composed of rock with unaltered original minerals, grains of residual nontronite, and sparse residual kaolinite. Transported nontronite fills some of the vesicles and openings, the rest being unfilled. This zone averages about 13 percent available alumina and 7 percent available ferric oxide.

The fresh rock is hard unaltered basalt. A small amount of residual nontronite grains may be seen and the openings are unfilled.

Determinations of specific gravity and moisture content of the basaltic residual clay were made on 12 drill holes totaling 235 feet. The specific gravity ranged from 1.51 to 1.84 with an average 1.64. The moisture content ranged from 22.4 to 39.6 percent and averaged 33.7 percent.

Origin.--Intense weathering of the basalt flows and their associated pillow lavas and breccias formed the basaltic residual clays upon a land surface of low to moderate relief and under conditions that permitted complete oxidation (Scheid, 1947). The climate (Berry, 1929, p.233) was humid and relatively warm.

Most of the basalts are vesicular, and all of them are trisected by joints. At first such joints and vesicles would allow groundwater to enter, but would not permit free groundwater movement. Later, the permeability and porosity increased to allow good internal drainage and complete oxidation producing kaolinite (Allen and Scheid, 1946, p. 309). The observations of Hoskins' (1940, p. 206) indicate that had poor drainage and no oxidation persisted montmorillonite or beidellite and nontronite would have formed instead of kaolinite. Under poor conditions of drainage and in the presence of alkalies the basaltic glass of the tuffs and breccias probably was altered to palagonite, which in turn altered to nontronite. As the drainage increased, the nontronite was moved and deposited in the cracks and vesicles of the fresh and semi-decomposed rock. The plagioclase began to alter directly to kaolinite and the iron oxides were reduced to the ferrous state by neutral or slightly acid solutions. The openings left by the nontronite are filled either with kaolinite transported from above or by compaction of the basaltic residual clay. Residual ilmenite is somewhat concentrated by the weathering process and remains essentially unaltered. Thus, the best grade clays are composed of residual kaolinite and transported kaolinite with scattered ilmenite.

The chemical changes that have occurred in the alteration of basalt to basaltic residual clay are shown by a comparison of the assays listed below (table 1).

Table 1. Chemical analyses to show changes.

Table 1. Chemical analyses to show changes produced by alteration of basalt to basaltic residual clay.

	A	B	C
SiO_2	54.50	40.3	41.2
Al_2O_3	14.43	30.8	31.1
Fe_2O_3	2.17	9.1	8.2
FeO	8.80	--	--
MgO	4.24	0.0[a]	0.0[a]
CaO	8.01	1.0	1.0
Na_2O	3.05	0.5	0.4
K_2O	1.29	0.4	0.3
TiO_2	1.69	7.5	7.3
P_2O_5	0.21	--	--
V_2O_5	--	0.05	<0.05
MnO	0.10	--	--
SrO	0.09	--	--
BaO	0.06	--	--
SO_3	0.11	--	--
H_2O-	0.29	--	--
H_2O+	1.09	10.9[a]	11.1[a]
Total	100.13	100.5	100.6

a/ Total ignition loss.

A. Yakima basalt, Clealum Ridge, Kittitas County, Wash. (Smith, G. O., 1904, Mount Stuart folio: U. S. Geol. Survey Geol. Atlas, no. 106, p. 8).

B. Basaltic residual clay (Weighted composite sample of Area I, except northern lobe of West Block).

C. Basaltic residual clay (Weighted composite sample of Area II).

Chemistry.--Table II shows representative assays of the Excelsior high-alumina clay deposit. The maximum, minimum, and average assay values are discussed below.

The quantity of silica depends upon the degree of weathering of the source rock. In general, more complete weathering produces a higher content of clay minerals and a lower content of silica. For the composite samples, the silica content ranges from 47.1 to 36.9 percent and averages about 40 percent.

The loss on ignition depends primarily upon the quantity of clay. A direct ratio exists between the ignition loss and available alumina as shown on table II. For the composite samples, the ignition loss ranges from 7.9 to 11.9 percent and averages about 10.8 percent.

The quantity of total and available alumina has been shown to depend upon the degree of weathering, and thus, on the kind and amount of clay minerals. In general, the more complete the weathering, the higher the available alumina content. For the composite samples, the total alumina ranges from 22.8 to 34.4 percent and averages about 30.6 percent, and the available alumina ranges from 21.9 to 33.1 percent and averages about 29.3 percent. The ratio of available alumina to total alumina or percent recovery ranges from 89.2 to 103.0 percent and averages about 96 percent.

The quantity of total ferric oxide is dependent upon ilmenite, limonite, and nontronite content. Because ilmenite is not appreciably soluble in a 20 percent solution of sulfuric acid, its iron content is not available; therefore, the quantity of available ferric oxide is dependent on limonite and to a minor degree nontronite. For the composite samples, the total ferric oxide ranges from 5.3 to 14.7 percent and averages about 9.3 percent, and the available ferric oxide ranges from 1.0 to 9.9 percent and averages about 5 percent. The ratio of available ferric oxide to total ferric oxide ranges from 17.2 to 78.0 percent and averages about 54 percent.

The quantity of total titania is dependent upon the amount of ilmenite and whatever amounts of leucoxene and rutile may be associated with it. Because the titania minerals are not appreciably soluble in a 20 percent solution of sulfuric acid, most of the titania is unavailable. For the composite samples, the total titania ranges from 5.0 to 8.4 percent and averages about 7.1 percent and the available titania ranges from 0.35 to 0.72 percent and averages about 0.5 percent. The percentage of recovery ranges from 5.83 to 12.63 percent and averages about 8 percent.

One sample from the railroad siding at the Washington Brick and Lime pit in the East Block of Area I assayed 0.005 percent gallium.

Transported Clay

The transported clays of the upper Latah formation comprise about 6 percent of the Excelsior high-alumina clay deposit. The Latah formation is composed of weathered debris from the granite gneiss and related rocks. It was deposited upon the granitic and basaltic residual clays in lakes that were formed by streams dammed by post-Excelsior interval flows of basalt. The transported clays average about 5 feet in thickness, and they are light gray to white, plastic, slick, and fine-grained. They are composed of kaolinite, with quartz sand and gravel and muscovite flakes. About 30 assays were made on the transported clays and the average values are 24.30 percent for available alumina and 9.59 percent for available ferric oxide.

Determinations of specific gravity and moisture content of the transported clay were made on samples from four drill holes totaling 64 feet. The specific gravity ranged from 1.77 to 1.98 with an average of 1.89. The moisture content ranged from 12.3 to 20.7 percent and averaged 15.7 percent.

CONCLUSION

Under emergency conditions, the Excelsior clay deposit could serve as a source of aluminum and some titanium. The aluminum plant at Mead, near Spokane, Wash., is within a very short distance of the Excelsior deposit.

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APPENDIX: REPRESENTATIVE LOGS WITH ASSAYS

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-1: Coord. 25,010N, 14,035E.				
Qp	0.0-8.0	Soil and Palouse formation.				
Tlu	8.0-11.0	Gravel, transported, gneiss pebbles, poorly sorted.				
Kgn	11.0-16.0	Clay, residual gneissic, poor quality.				
	16.0-37.0	Gneiss medium-grained, quartzitic, biotite clusters, slightly weathered.				
	37.0	Gneiss.				
		Drill Hole Ex-2: Coord. 25,000N, 15,020E.				
Qp	0.0-27.0	Soil and Palouse formation.				
Tlu	27.0-42.0	Clay, transported, gray, sandy and micaceous, plastic.				
	42.0-57.0	Gravel, transported, gray plastic clay 48.0 feet to 53.0 feet.				
Tcrl	57.0-65.0	Clay, residual, basaltic, blue, white kaolin amygdules and streaks, some iron staining.	58.0-65.0	11.1	3.1	31.3
	65.0-69.0	Clay, residual, basaltic, brown and dark gray.	65.0-73.0	9.9	16.4	23.2
	69.0-76.0	Clay, residual, basaltic, blue and blue-gray.				
	76.0-78.5	Clay, residual, basaltic, greenish gray, iron-stained.				
	78.5-80.0	Clay, residual, basaltic, blue, white kaolin amygdules.	73.0-80.0	10.2	8.7	26.7
	80.0-87.0	Semi-decomposed basalt, brownish gray, iron-stained.	80.0-87.0	9.4	16.6	22.2
	87.0	Basalt.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-3: Coord. 24,475N, 16,130E.				
Qp	0.0-3.0	Soil and Palouse formation.				
Tlu	3.0-29.0	Clay, transported, light gray, some sand and mica. Last 0.5 foot iron-cemented sand.	28.0-31.0	10.4	5.8	27.2
	29.0-31.0	Clay, transported, white, plastic, dense.				
Tcrl	31.0-35.0	Clay, residual, basaltic, blue-gray, white kaolin amygdules.	31.0-35.0	3.0	2.9	8.9
	35.0-36.0	Semi-decomposed basalt, brown.				
	36.0	Basalt.				
		Drill Hole Ex-4: Coord. 24,550N, 16,680E.				
Qp	0.0-30.0	Soil and Palouse formation.				
Tlu	30.0-45.0	Sand and clay, transported, gray, micaceous, plastic.				
	45.0-50.5	Clay, transported, limonitic.	47.0-50.0	9.2	16.1	21.9
Tcrl	50.5-51.5	Clay, residual, basaltic, white and tan-gray.	50.0-57.0	11.1	2.0	32.9
	51.5-58.0	Clay, residual, basaltic, blue and blue-gray, white kaolin amygdules.	57.0-60.5	9.3	3.8	27.2
	58.0-63.0	Clay, residual, basaltic, blue, plastic.				
	63.0-65.0	Semi-decomposed basalt, brown-black.				
	65.0	Basalt.				
		Drill Hole Ex-5: Coord. 24,890N, 18,320E.				
Qp	0.0-14.0	Soil and Palouse formation.				
Tcrl	14.0-21.0	Clay, residual, basaltic, blue-gray and brown, white kaolin amygdules.	17.0-21.0	5.6	14.1	15.0
	21.0-26.0	Basalt, black, amygdaloidal.				

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Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-6: Coord. 24,520N, 18,805E.				
Qp	0.0-19.0	Soil and Palouse formation.				
	19.0-24.0	Gravel, gneiss pebbles.				
Tcru	24.0-36.0	Clay, residual, basaltic, blue, white kaolin amygdules, upper 3 feet waxy. 6-inch seam of tan, iron-stained palagonite at 27 feet.	24.0-30.0	8.7	20.0	19.4
			30.0-36.0	9.0	15.4	21.3
	36.0-41.5	Clay, residual, basaltic, tan, palagonitic, mixed with micaceous clayey sand.	36.0-42.0	7.5	14.4	17.0
			42.0-48.0	7.9	13.7	17.9
	41.5-59.5	Clay, residual, basaltic, tan, palagonitic. About 1/3 blue and blue-gray clay.	48.0-54.0	7.2	12.6	15.6
			54.0-59.0	6.8	12.5	16.6
	59.5-63.5	Clay, residual, basaltic, blue, waxy, vesicular.	59.0-65.0	7.5	9.7	19.4
	63.5-66.0	Clay, residual, basaltic, tan, palagonitic.	65.0-71.0	8.4	3.7	24.6
	66.0-68.0	Clay, residual, basaltic, blue.				
Tlu	68.0-74.5	Sand, transported, clayey, micaceous.	71.0-74.5	5.9	4.2	17.2
	74.5-81.0	Sand, transported, brown, micaceous, iron-stained.				
		Drill Hole Ex-7: Coord. 24,030N, 13,525E.				
Qp	0.0-48.0	Soil and Palouse formation.				
Tlu	48.0-64.0	Sand and gravel, transported, gneiss, some white clay.	65.0-71.0	5.8	2.3	15.4
	64.0-77.0	Sand, transported, yellow and yellowish gray, clayey and micaceous.	71.0-77.0	6.9	13.2	14.6
	77.0-78.0	Clay, transported, white, powdery kaolin, bottom 2 inches sandy.	77.0-79.0	11.6	3.0	31.1
	78.0-79.0	Clay, transported, gray, powdery kaolin.				
Tcrl	79.0-80.0	Clay, residual, basaltic, blue, white kaolin amygdules.	79.0-85.0	6.6	4.0	19.7
	80.0-82.0	Clay, residual, basaltic, gray, some white streaks.	85.0-88.0	3.0	6.8	9.3
	82.0-88.0	Semi-decomposed basalt, gray and brown.				
	88.0	Basalt.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-8: Coord. 23,890N, 14,515E.				
Qp	0.0-31.0	Soil and Palouse formation. Some granite gravel.				
Tcrl	31.0-33.0	Clay, residual, basaltic, dark blue. Completely decomposed vesicular basalt; vesicles filled with white and yellow transported kaolinite.	31.0-33.0	10.1	2.5	29.9
	33.0-35.0	Clay, residual, basaltic, tannish- and bluish-gray. Narrow seams and amygdules of transported, white kaolinite. Disseminated minute specks of ilmenite.	33.0-36.0	10.2	3.1	29.3
	35.0-37.5	Lost core (Probably similar to 33-35 feet).				
	37.5-38.0	Semi-decomposed basalt, yellow-green, hard.	36.0-41.5	3.6	8.5	9.0
	38.0-40.5	Clay, residual, basaltic, light blue-gray, dense. Scattered hard spots.				
	40.5-47.0	Slightly altered basalt, brown-black, even-grained, hard. Spots and zones of gray-blue clay along joints. At 46.5 feet hard, blue basalt. At 47 feet, 6-inch iron streak.	41.5-45.5	2.6	7.0	5.8
	47.0-48.0	Clay, residual, basaltic, dark-blue, vesicular. Vesicles filled with tan and white kaolinite.	45.5-48.5	4.0	13.2	9.0
	48.0-49.5	Semi-decomposed basalt, light yellowish-green, even-grained. Green nontronite specks and black ilmenite specks.				
	49.5-51.0	Lost core. (Probably similar to 48.0-54.0 feet).	48.5-53.0	4.1	13.0	8.5
	51.0-54.0	Semi-decomposed basalt, grayish-green, some blue; 1/2 is hard. Waxy, green nontronite spots and streaks. At 53 feet, a 6-inch limonite seam.				
	54.0-67.0	Clay, residual, basaltic, yellow, palagonitic, plastic, mixed with white transported kaolinite and some diatoms.	53.0-55.0 55.0-59.0 59.0-63.0	5.8 9.3 9.3	13.7 5.1 6.9	13.5 24.4 25.3

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-8: (continued)				
		Scattered spots (up to 6 inches) of blue basalt clay, some of which has centers of unaltered vesicular basalt. Probably a pillow basalt.	63.0-67.0	9.2	7.9	25.3
	67.0-69.0	Slightly decomposed basalt, black-brown.				
Tcrl	69.0-76.0	Clay, residual, basaltic, yellow, and green zones, palagonitic, waxy. Brown waxy clay scattered through the green zones. At 71 feet, one foot of black-brown, semi-decomposed basalt similar to 67.0-69.0 feet. At 74 feet, one foot of mixed yellow-green palagonitic clay, and brown, semi-decomposed, fine-grained basalt.	67.0-71.0	6.8	15.8	15.8
			71.0-77.0	6.6	21.3	14.7
	71.0-82.0	Partially decomposed basalt, dark-brown, fine-grained. Last 3 or 4 feet mixed with 1/3 to 1/2 yellow and green palagonitic clay.	77.0-82.0	7.4	23.6	15.2
	82.0	Basalt.				
		Drill Hole Ex-9: Coord. 24,000N, 15,505E.				
Qp	0.0-5.0	Soil and Palouse formation.				
	5.0-23.0	Palouse formation and gravel.				
Tcrl	23.0-27.0	Partially altered basalt, slightly vesicular, ilmenite specks, olive green montronite spots.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-10: Coord. 23,960N, 16,500 E.				
Qp	0.0-42.0	Soil and Palouse formation.				
Tlu	42.0-47.5	Clay, transported, gray-white, plastic.	42.0-48.0	7.5	1.3	21.2
Tcrl	47.5-57.0	Clay, residual, basaltic, blue and blue-gray. Some white kaolinite amygdules.	48.0-53.0	11.0	1.3	31.8
			53.0-57.0	9.7	6.6	26.8
	57.0-64.0	Semi-decomposed basalt, gray. Much iron stain and green nontronite.	57.0-63.0	7.7	20.8	16.7
	64.0-70.0	Partially decomposed basalt, gray-black. Abundant green nontronite. Hard spots.	63.0-69.0	6.0	14.9	14.5
	70.0	Basalt.				
		Drill Hole Ex-11: Coord. 23,960N, 17,500E.				
Qp	0.0-7.0	Soil and Palouse formation.				
Tcrl	7.0-8.0	Basalt, green nontronite.				
	8.0	Basalt.				
		Drill Hole Ex-12: Coord. 23,940N, 18,500E.				
Qp	0.0-16.5	Soil and Palouse formation.				
Tcrl	16.5-24.0	Clay, residual, basaltic, dark blue and brown.	17.0-23.0	9.5	19.8	22.7
	24.0-38.0	Clay, residual, basaltic, blue and some brown, green nontronite streaks, some amygdules.	23.0-28.0	8.6	19.3	20.0
			28.0-31.0	9.4	14.6	22.4
	38.0-42.0	Clay, residual, basaltic, brown, tan amygdules.	31.0-37.0	9.6	13.1	24.0
	42.0-47.0	Clay, residual, basaltic, blue and blue-gray and brown, iron streaks.	37.0-43.0	8.5	17.7	20.6
	47.0-50.0	Clay, residual, basaltic, blue.	43.0-49.0	8.4	18.8	20.3
	50.0	Basalt.				

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Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-13: Coord. 23,000N, 13,010E.				
Qp	0.0-34.0	Soil and Palouse formation, granitic sand at base.				
Tlu	34.0-41.0	Clay, transported, gray and white, plastic.	33.5-42.0	10.4	1.7	28.5
Tcrl	41.0-45.0	Clay, residual, basaltic, amygdaloidal.	42.0-45.0	4.2	7.9	11.1
	45.0-46.0	Partially altered basalt, brown.				
	46.0-53.0	Basalt, black, vesicles filled with tan clay.				
	53.0-58.0	Semi-decomposed basalt, black, iron streaks near top.	53.0-57.0	3.4	12.4	7.4
	58.0	Basalt.				
		Drill Hole Ex-14: Coord. 23,015N, 14,015E.				
Qp	0.0-43.5	Soil and Palouse formation. Granite sand and occasional pebbles of green nontronite and decomposed basalt.				
Tcrl	43.5-54.0	Clay, residual, basaltic, blue. Amygdules and streaks of white kaolinite. From 48 feet on it is very fine- and even-grained.	43.5-50.0 50.0-53.5 53.5-55.0	11.4 11.8 9.5	0.9 1.0 17.8	32.5 32.6 21.8
	54.0-59.0	Clay, residual, basaltic, bands of gray, green, and brown. High iron. Some only semi-decomposed. Small spot of semi-decomposed palagonite.	55.0-56.0 56.0-57.0 57.0-59.0	9.8 9.6 9.8	13.9 22.8 10.7	20.5 20.0 25.5
	59.0-66.0	Semi-decomposed basalt, brown and gray-green, waxy, limonite crusts, Montronite spots and vesicle linings. Hard spots near bottom.	59.0-66.0	8.2	38.7	13.3
	66.0-69.0	Clay, residual, basaltic, blue. Middle part strongly streaked and spotted by hard, waxy, green nontronite.	66.0-69.0	5.0	16.1	10.9
	69.0-74.0	Partially decomposed basalt, black-blue, vesicular, hard. Montronite spots.	71.0-74.0	2.7	12.8	6.4
	74.0-77.0	Basalt, similar to 59.0-66.0 feet.	74.0-76.0 76.0-77.0	7.1 7.6	32.3 33.8	11.1 11.6

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-14: (continued)				
	77.0-80.0	Semi-decomposed basalt. Upper 6 inches blue, rest green from nontronite.	77.0-82.0	7.0	39.0	8.8
	80.0-82.0	Basalt, abundant limonite.				
	82.0	Basalt.				
		Drill Hole Ex-15: Coord. 22,975N, 15,090E.				
Qp	0.0-25.0	Soil and Palouse formation.				
Tcrl	25.0-27.0	Clay, residual, basaltic, blue, vesicular.	24.5-27.0	5.2	4.1	13.5
	27.0-32.0	Clay, residual, basaltic, tan and bluish gray, some hard spots.	27.5-29.0	8.0	4.8	23.0
	32.0-32.5	Clay, residual, basaltic, blue, vesicular.	27.0-32.0	5.2	2.4	15.4
	32.5-35.0	Basalt, black and dark gray, vesicular. 4-inch of yellow clay.	32.0-35.0	3.6	3.4	9.7
	35.0-48.0	Slightly decomposed pillow basalt and associated tuff. Some vesicles filled with tan clay. Streaks and spots of green-yellow nontronite at 35 feet. 6-inch iron streak at 38 feet.	35.0-40.0	4.6	4.8	12.2
			40.0-48.0	5.4	7.9	13.9
		Drill Hole Ex-16: Coord. 22,990N, 16,000E.				
Qp	0.0-30.0	Soil and Palouse formation.				
	30.0-39.0	Sand, gray, micaceous and clayey.				
Tlu	39.0-47.0	Clay, transported, gray, plastic.	41.0-43.0	5.6	0.9	14.7
	47.0-49.5	Limonite.	47.0-49.5	10.2	22.4	21.2
Tcrl	49.5-63.0	Clay, residual, basaltic, blue, vesicles and cracks filled with white kaolin. 4-inch band of yellow clay at 61 feet.	49.5-53.0	11.4	3.2	31.6
			53.0-58.0	12.0	1.1	32.9
			58.0-63.0	11.5	1.8	32.8
	63.0-67.5	Clay, residual, basaltic, blue-gray and green-brown; hard spots begin at 65 feet. Yellow-green nontronite fills cracks and vesicles.	63.0-65.0	9.4	5.8	26.2
			65.0-67.5	5.9	6.3	16.5
	67.5	Basalt.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-17: Coord. 22,970N, 16,985E.				
Qp	0.0-3.0	Soil and Palouse formation.				
	3.0-11.0	Pebbles of green montronite and white quartz.				
Tcru	11.0-25.0	Basalt, black, hard.				
	25.0	Basalt.				
		Drill Hole Ex-18: Coord. 22,950N, 17,920E.				
Qp	0.0-38.5	Soil and Palouse formation. Some gravel at bottom.				
Tcrl	38.5-41.0	Clay, residual, basaltic, light blue-gray.	35.0-41.0	9.0	17.1	19.5
	41.0-42.5	Semi-decomposed basalt, brown.	41.0-43.0	9.0	15.7	19.7
	42.5-52.5	Clay, residual, basaltic, light blue, most vesicles filled with white kaolin, others filled with green montronite.	43.0-48.0 48.0-53.0	9.0 9.8	14.8 13.1	21.6 25.1
	52.5-53.5	Semi-decomposed basalt, black-brown.	53.0-58.0	9.5	15.3	24.1
	53.5-61.0	Clay, residual, basaltic, gray, light blue, and brown.	58.0-61.0	7.8	15.2	20.2
	61.0	Basalt.				
		Drill Hole Ex-19: Coord. 22,960N, 18,985E.				
Qp	0.0-4.0	Soil and Palouse formation, gravel at base.				
Tcrl	4.0-6.0	Semi-decomposed basalt, light brownish, grayish.	5.0-11.0	9.6	17.6	22.4
	6.0-8.0	Semi-decomposed basalt, light gray.				
	8.0-10.0	Semi-decomposed basalt, iron-brown.				
	10.0-16.0	Semi-decomposed basalt, bluish-gray. Few amygdules of white kaolinite. Green nontronite spots.	11.0-17.0	9.0	16.5	21.5
	16.0-22.0	Similar to above. Less decomposed, brownish. Occasional hard spots.	17.0-22.0	6.9	17.3	16.9
	22.0-22.5	Basalt, black, hard. Montronite streaks and spots.				
	22.5-26.0	Slightly decomposed basalt, gray black.				
	26.0-32.0	Basalt, black, hard. Green montronite in cracks and vesicles.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-19: (continued)				
	32.0-35.0	Basalt, brown and black, iron-stain.				
	35.0-37.0	Partially decomposed basalt, gray.	35.0-37.0	4.4	12.5	10.7
	37.0-45.0	Semi-decomposed basalt, tannish- and greenish-gray. Nontronite specks uniformly distributed. Hard spots. 37-40 feet, strong limonite streaks. At 44 feet, several small nontronite streaks.	37.0-40.0 40.0-45.0	8.2 3.8	24.3 11.5	17.1 10.3
	45.0-49.5	Clay, residual, basaltic, blue, scattered small amygdules of white kaolinite.	45.0-50.0	5.0	16.1	12.1
	49.5-51.5	Limonite, red-brown.				
	51.5-52.0	Clay, residual, basaltic, blue.	50.0-55.0	8.4	24.8	18.2
	52.0-54.0	Semi-decomposed basalt, green-brown, hard spots.				
	54.0-63.0	Clay, residual, basaltic, mottled, brown with disseminated black spots; top 6 inches is blue. Many cracks and cavities filled or lined with yellow, palagonitic clay. Bordering the cracks for 1/2 inch is blue clay grading into less altered black and brown clay.	55.0-59.0 59.0-63.0	9.8 9.6	18.0 18.8	23.2 15.7
		Drill Hole Ex-21: Coord. 22,025N, 13,500E.				
Qp	0.0-26.5	Soil and Palouse formation, few quartz pebbles at base.				
Tcrl	26.5-31.0	Semi-decomposed basalt, green, vesicular.				
	31.0-35.0	Semi-decomposed basalt, black, streaks and amygdules of green nontronite.				
		Drill Hole Ex-23: Coord. 22,000N, 15,485E.				
Qp	0.0-35.0	Soil and Palouse formation, granitic sand near base.				
Tlu	35.0-38.0	Clay, transported, gray, slick, plastic.	35.0-38.0	9.4	0.9	23.7
	38.0-49.0	Clay, transported, yellow, plastic, some sandy. One foot white, plastic clay at base.	43.0-49.0	10.8	14.3	26.3

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-21: (continued)				
Tcrl	49.0-72.0	Clay, residual, basaltic, blue, plastic. Amygdules of white and tannish kaolinite. At 57 feet the color becomes darker blue and vesicles are more abundant. The clay grades downward to lighter blue and less vesicular. At 68 and 71 feet, limonite streaks. 65-72 feet, occasional green stain.	49.0-54.0	9.8	1.8	28.7
			54.0-60.0	9.8	2.1	28.4
			60.0-65.0	10.0	2.2	28.9
			65.0-71.0	10.1	8.9	27.0
	72.0-75.0	Clay, residual, basaltic, brown and blue.				
	75.0-82.0	Clay, residual, basaltic, mottled brown; top foot has yellow palagonitic clay mixed with it.	71.0-77.0	10.5	12.4	26.7
			77.0-83.0	10.5	16.3	25.5
	82.0-102.0	Decomposed pillow basalt and associated breccia. Mixture of mottled brown basaltic clay, blue basaltic clay, limonite, and yellow palagonitic clay. About 1/2 to 3/4 is decomposed. Yellow palagonitic clay at 93-97 feet; unweathered basalt and basalt glass at 97 feet to bottom.	83.0-90.0	10.0	23.0	22.5
			90.0-97.0	9.9	21.7	22.1
			97.0-102.0	6.2	10.9	15.8
	102.0	Basalt.				
		Drill Hole Ex-24: Coord. 21,960N, 16,480E.				
Qp	0.0-23.0	Soil and Palouse formation, some gravel.	19.0-22.0	3.5	12.0	8.8
	23.0-26.0	Gravel.	22.0-26.0	5.4	5.8	15.8
Tcru	26.0-28.0	Clay, residual, basaltic, brown, limonitic.	26.0-32.0	10.5	25.0	21.6
	28.0-29.0	Clay, residual, basaltic, yellow, tuffaceous.				
	29.0-33.0	Clay, residual, basaltic, brown, limonitic.				
	33.0-40.0	Clay, residual, basaltic, yellow.				
	40.0-43.0	Semi-decomposed basalt, black and brown.				
	43.0-46.0	Tuff, basaltic glass, and ash.				
	46.0	Basalt.				

Forma-tion	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-25: Coord. 21,940N, 17,470E.				
Qp	0.0-32.0	Soil and Palouse formation.				
Tlu	32.0-36.0	Clay, transported, yellow, limonitic; lower 6 inches white.	32.0-35.0	10.5	19.6	23.2
Terl	36.0-39.0	Clay, residual, basaltic, dark, blue-white kaolinite amygdules. Light tan and white clay seams.	35.0-41.0	11.2	3.4	31.8
	39.0-46.0	Clay, residual, basaltic, light blue-gray.	41.0-47.0	10.8	2.4	32.1
	46.0-50.0	Clay, residual, basaltic, dark-blue.	47.0-50.5	11.0	3.4	32.0
	50.0-52.5	Clay, residual, basaltic, brown.	50.5-52.5	8.4	20.9	18.6
	52.5-55.0	Basalt, brown and black.				
		Drill Hole Ex-26: Coord. 21,925N, 18,475E.				
Qp	0.0-22.5	Soil and Palouse formation, some granitic gravel.				
Teru	22.5-32.5	Semi-decomposed basalt, brownish-black, dark gray at bottom. Joints filled with reddish brown, waxy beidellite.	21.0-32.5	6.6	18.0	14.2
	32.5	Basalt.				
		Drill Hole Ex-27: Coord. 21,015N, 12,980E.				
Qp	0.0-23.5	Soil and Palouse formation.				
Terl	23.5-24.0	Semi-decomposed basalt.				
	24.0	Basalt.				
		Drill Hole Ex-28: Coord. 21,015N, 13,980E.				
Qp	0.0-13.0	Soil and Palouse formation.				

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Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-28: (continued)				
Tcrl	13.0-15.0	Clay, residual, basaltic, blue-gray, mottled, white amygdules.	12.0-14.0	10.0	2.7	29.0
	15.0-16.0	Clay, residual, basaltic, blue, white amygdules.	14.0-18.0	11.0	1.5	31.7
	16.0-21.0	Clay, residual, basaltic, light blue-gray, white amygdules, vesicular.	18.0-22.0	11.1	1.6	32.3
	21.0-25.0	Clay, residual, basaltic, brown, tuffaceous.	22.0-26.0	9.2	8.0	25.6
	25.0-29.5	Semi-decomposed basalt, brown, hard near base.				
	29.5	Basalt.				
		Drill Hole Ex-29: Coord. 21,000N, 14,965E.				
Qp	0.0-14.0	Soil and Palouse formation.				
Tcrl	14.0-20.0	Clay, residual, basaltic, blue-gray.	13.5-17.5	10.1	7.2	28.2
	20.0-30.0	Semi-decomposed basalt, dark blue, vesicular, iron-streaked.	17.5-20.0	8.7	13.5	22.0
			20.0-24.0	5.1	9.6	14.7
	30.0-36.0	Clay, residual, basaltic, greenish yellow, tuffaceous. Some round pieces of vesicular basalt.	31.0-36.0	8.0	13.0	21.4
	36.0-44.0	Partially decomposed basalt.				
	44.0	Basalt.				
		Drill Hole Ex-30: Coord. 20,985N, 15,955E.				
Qp	0.0-25.0	Gravel, granitic, and basaltic.				
	25.0-40.0	Palouse formation.				
Tcru	40.0	Basalt.				
		Drill Hole Ex-31: Coord. 20,970N, 16,960E.				
Qp	0.0-25.0	Soil and Palouse formation.				
Tcru	25.0-28.0	Semi-decomposed, black.				
	28.0-32.0	Basalt.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-32: Coord. 20,950N, 17,955E.				
Qp	0.0-23.0	Soil and Palouse formation.				
Tcru	23.0-25.0	Semi-decomposed basalt, vesicular, iron-stained.				
	25.0-27.0	Semi-decomposed basalt, gray, iron-stained kaolin amygdules.	25.0-30.0	9.6	12.6	23.2
	27.0-30.0	Semi-decomposed basalt, black and dark gray, yellow and olive green nontronite amygdules. Seams of brown beidellite. Iron-stained near top.				
	30.0-35.0	Partially altered basalt, gray, vesicular.	30.0-36.0	4.3	11.9	10.1
	35.0-40.0	Semi-decomposed basalt, black and dark gray, yellow and olive green nontronite amygdules. Seams of brown beidellite. Iron-stained near top.	36.0-39.0	6.5	14.8	16.6
	40.0	Basalt.				
		Drill Hole Ex-34: Coord. 20,380N, 13,470E.				
Qp	0.0-13.5	Soil and Palouse formation.				
Tcrl	13.5-15.0	Clay, residual, basaltic, blue-gray.	13.0-20.0	11.7	2.2	32.2
	15.0-18.5	Clay, residual, basaltic, dark blue.	20.0-28.0	11.1	8.6	28.9
	18.5-24.0	Clay, residual, basaltic, light gray, iron-stained.	28.0-35.0	11.1	8.3	29.6
	24.0-43.0	Clay, residual, basaltic, blue and tan, tuffaceous.	35.0-41.0	10.3	11.7	26.6
	43.0-63.0	Semi-decomposed basalt, mottled brown, tan tuffaceous clay.	41.0-50.0	10.4	13.5	25.5
			50.0-56.0	10.1	11.3	26.1
	63.0	Basalt.	56.0-63.0	8.2	17.9	19.2
		Drill Hole Ex-35: Coord. 20,385N, 14,440E.				
Qp	0.0-19.0	Soil and Palouse formation.				
Tlu	19.0-27.0	Clay, transported, gray and purplish, gray clayey sand and quartz gravel at base.	21.0-24.0	6.3	3.1	16.2

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-35: (continued)				
Tcrl	27.0-30.0	Clay, residual, basaltic, blue-gray, vesicular.				
	30.0-31.0	Semi-decomposed, brown-black.				
	31.0	Basalt.				
		Drill Hole Ex-36: Coord. 20,075N, 15,450E.				
Qp	0.0-9.0	Soil and Palouse formation, some sand and gravel.				
Tcru	9.0-11.0	Semi-decomposed basalt, black and gray.	10.0-16.0	7.2	18.3	16.5
	11.0-20.0	Semi-decomposed basalt, brown tuff and volcanic breccia, olive nontronite filling vesicles.	16.0-20.0	7.5	16.9	18.3
	20.0-30.0	Basalt, nontronite spots.				
	30.0	Basalt.				
		Drill Hole Ex-37: Coord. 20,000N, 16,450E.				
Qp	0.0-16.0	Soil and Palouse formation.				
Tcru	16.0-17.0	Semi-decomposed basalt, gray, green nontronite spots.				
	17.0	Basalt.				
		Drill Hole Ex-40: Coord. 22,970N, 17,490E.				
Qp	0.0-2.0	Soil and Palouse formation.				
Tcrl	2.0-7.0	Clay, residual, basaltic, blue gray, mottled with white kaolinite spots on blue background. Limonite streak at base.	1.0-7.0	11.4	3.2	31.6
	7.0-28.0	Clay, residual, basaltic, light tan and blue-gray, limonite streaks and stains. 17-26 feet, iron is very strong.	7.0-12.0	11.2	6.7	30.9
			12.0-17.0	11.4	7.2	30.8
			17.0-22.0	10.6	22.6	23.8
			22.0-28.0	10.4	18.0	23.6
	28.8-39.0	Clay, residual, basaltic, dark blue, white kaolinite amygdules. Several limonite bands and stains. Light blue from 37 feet on.	28.0-35.0	10.2	17.9	23.7
			35.0-40.0	9.6	21.0	21.0

Formation	Interval (feet)	Description	Interval feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-40: (continued)				
	39.0-49.0	Clay, residual, basaltic, tannish and greenish gray, occasional hard spots.	40.0-45.0	9.2	15.4	21.2
			45.0-50.0	5.9	12.9	14.3
	49.0-56.0	Semi-decomposed basalt, blue-black. A few yellow kaolin amygdules. Scattered hard spots. Limonite. 6-inch beds of semi-decomposed palagonite at 51 and 54 feet.	50.0-56.0	6.5	16.3	14.1
	56.0-63.0	Palagonite and vesicular ash, mostly semi-decomposed. Many ash blocks are glassy. At 58 feet, hard, brown, basalt. At 61 feet, semi-decomposed, brown basalt.	56.0-63.0	7.5	17.9	17.3
	63.0-64.5	Basalt, brown and black, hard. Green nontronite particles.				
	64.5-66.5	Semi-hard basalt, black and gray. White kaolinite and green nontronite particles.				
	66.5-71.0	Semi-decomposed basalt, gray and brown, amygdaloidal. Most amygdules are white kaolinite but some are green nontronite. Some hard black basalt and some palagonite.				
	71.0-74.0	Much like 66.5-71.0 feet, but less decomposed and more black basalt.				
		Drill Hole Ex-41: Coord. 19,010N, 13,950E.				
Qp	0.0-4.5	Soil and Palouse formation.				
Tcru	4.5-5.0	Slightly altered pillow basalt.				
	5.0-6.0	Pillow basalt, hard black glass with tan palagonite.				
	6.0	Basalt.				
		Drill Hole Ex-42: Coord. 19,000N, 14,925E.				
Qp	0.0-5.5	Soil and Palouse formation.				
Tcru	5.5-19.0	Volcanic tuff, ash, and bombs, tan, black glass blocks with yellow palagonite.				
	19.0-29.0	Basalt, black.				
	29.0	Basalt.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-43: Coord. 18,975N, 15,985E.				
Qp	0.0-18.0	Soil and Palouse formation.				
Tcru	18.0-25.0	Semi-decomposed basalt, mottled brown and black vesicular basalt and dark-gray basalt with some palagonite, limonite streaks.	19.0-25.0	9.9	17.9	23.2
Tcrl	25.0-29.0	Clay, residual, basaltic, blue-gray with tan kaolinite amygdules. Dark gray clay in cracks.	25.0-29.0	10.0	6.6	27.5
	29.0-40.0	Semi-decomposed basalt, mostly brown and gray, some dark-blue and black, a few vesicles filled with tan kaolinite, most vesicles unfilled.	29.0-35.0 35.0-40.0	6.8 3.6	10.2 14.3	17.4 7.6
		Drill Hole Ex-45: Coord. 17,960N, 16,170E.				
Qp	0.0-7.0	Soil and Palouse formation.				
Tcru	7.0-10.0	Semi-decomposed basalt, brown and blue-black, amygdaloidal.				
	10.0-13.0	Semi-decomposed tuff, brown iron stains.				
	13.0-18.0	Semi-decomposed basalt, mottled brown and dark blue vesicles.				
	18.0-22.5	Semi-decomposed tuff and volcanic ash, tan.				
	22.5-25.0	Semi-decomposed basalt, dark brown, blue and yellow clay stringers.				
	25.0-34.0	Semi-decomposed tuff and volcanic ash, brown.				
	34.0-36.0	Semi-decomposed basalt, brown and blue, olive green nontronite stringers.				
	36.0-40.0	Semi-decomposed tuff and volcanic ash, red-brown.				
	40.0	Basalt.				
		Drill Hole Ex-46: Coord. 25,045N, 13,045E.				
Qp	0.0-59.0	Soil and Palouse formation. Quartz gravel in last 3 feet.				
Tlu	59.0-78.0	Clay, transported, gray, gravel and silt.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-47: Coord. 18,190N, 14,040E.				
Qp	0.0-22.0	Soil and Palouse formation.				
Tcrl	22.0-41.0	Clay, residual, basaltic, blue and gray, white amygdules.	21.0-30.0	10.0	10.9	25.9
	41.0-45.0	Clay, residual, basaltic, tan, tuffaceous.	30.0-36.0	9.6	14.3	24.4
	45.0-54.0	Semi-decomposed basalt, gray and brown.	36.0-42.0	7.7	10.9	19.3
			42.0-46.0	9.4	17.7	21.7
	54.0	Basalt.	46.0-50.0	4.1	8.9	11.3
		Drill Hole Ex-48: Coord. 23,935N, 19,500E.				
Qp	0.0-5.0	Soil and Palouse formation.				
Tcru	5.0-21.0	Clay, residual, basaltic, brown and gray, tuffaceous, a few hard spots.	4.0-10.0	6.6	18.0	15.0
			10.0-16.0	8.3	25.2	16.6
	21.0-37.0	Clay, residual, basaltic, tan and some blue, tuffaceous.	16.0-21.0	8.0	17.9	16.6
	37.0-47.0	Clay, residual, basaltic, tan, and tuffaceous.	21.0-31.0	6.6	12.8	13.1
			31.0-40.0	6.8	6.5	18.1
Tcrl	47.0-52.0	Basalt, black, hard.	40.0-46.0	6.8	6.3	12.2
		Drill Hole Ex-49: Coord. 24,700N, 20,110E.				
Qp	0.0-2.0	Soil and Palouse formation, some gravel.				
Tcrl	2.0-7.0	Clay, residual, basaltic, green, blue, gray-green, iron-stained near base.	2.0-8.0	10.6	8.3	28.5
			8.0-12.0	4.6	11.7	11.9
	7.0-14.0	Semi-decomposed basalt, green and gray, amygdaloidal.				
	14.0	Basalt.				
		Drill Hole Ex-50: Coord. 17,290N, 25,425E.				
Qp	0.0-33.5	Soil and Palouse formation.				
Tcru	33.5-35.0	Basalt, dark green-gray, hard.				
	35.0	Basalt.				

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Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-51:				
Qp	0.0-34.5	Soil and Palouse formation.				
Tcrl	34.5-41.0	Clay, residual, basaltic, blue-gray and brown, amygdaloidal.				
	41.0-43.5	Clay, residual, basaltic, green-gray, amygdaloidal.				
	43.5-45.0	Basalt, green-gray, hard.				
		Drill Hole Ex-52:				
Qp	0.0-57.0	Soil and Palouse formation.				
Tcr	57.0-59.0	Basalt, dark gray, hard, vesicular.				
		Drill Hole Ex-53:				
Qp	0.0-7.0	Soil and Palouse formation.				
Kg	7.0-49.0	Schist, pink and brownish pink, medium-grained, contains quartz, some feldspar, and muscovite. At 44 feet a 3-inch pegmatite dike.				
		Drill Hole Ex-54:				
Qp	0.0-18.0	Soil and Palouse formation.				
Tcrl	18.0-19.0	Clay, residual, basaltic, green montronite.	18.0-23.0	9.9	12.5	23.8
	19.0-27.0	Clay, residual, basaltic, blue and blue-gray, powdery, amygdaloidal.	23.0-27.0	8.7	15.9	20.2
	27.0-31.0	Tuff, brown, green montronite spots.	27.0-32.0	7.1	25.5	13.7
	31.0-34.0	Basalt, dark gray, hard, amygdaloidal. Top 6 inches is weathered to blue clay.				
	34.0	Basalt.				

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-55:				
Qp	0.0-33.0	Soil and Palouse formation.				
Tcr	33.0-36.5	Basalt, black, hard.				
		Drill Hole Ex-56:				
Qp	0.0-21.5	Soil and Palouse formation.				
Tcr	21.5-25.0	Clay, residual, basaltic, blue-gray, dry powdery, amygdaloidal.	21.5-25.0	10.8	3.5	30.9
	25.0-38.5	Clay, residual, basaltic, blue-gray and brown, few amygdules, iron-stained.	25.0-28.0	11.0	10.5	29.4
			28.0-34.0	10.6	17.3	26.1
	38.5-41.0	Clay, residual, basaltic, green.	34.0-40.0	9.4	21.0	21.6
	41.0-43.0	Clay, residual, basaltic, black.	40.0-46.0	9.3	19.6	23.0
	43.0-47.0	Clay, residual, basaltic, blue-gray and yellow.	46.0-52.0	8.8	19.8	21.7
	47.0-50.5	Clay, residual, basaltic, green.	52.0-56.0	8.9	20.5	21.5
	50.5-55.0	Clay, residual, basaltic, black, iron-streaked, amygdaloidal.	56.0-62.0	8.6	17.7	20.3
	55.0-66.0	Clay, residual, basaltic, green. A few inches of hard clay with green amygdules at 64 feet.	62.0-68.0	8.9	17.5	21.0
			68.0-74.0	9.2	19.6	21.7
	66.0-79.5	Clay, residual, basaltic, black, dark blue, and brown, white amygdules. 2-inch layers of brown tuffaceous clay.	74.0-80.0	8.6	17.2	21.8
			80.0-86.0	7.6	15.3	19.8
	79.5-94.0	Clay, residual, basaltic, green-gray, some amygdules, powdery. Top foot has nontronite filling cracks and vesicles.	86.0-89.0	6.2	13.4	14.7
	94.0	Semi-decomposed basalt.				
		Drill Hole Ex-57:				
Qp	0.0-38.0	Soil and Palouse formation.				
Tcr	38.0-44.0	Clay, residual, basaltic, brown, white and green amygdules.	39.0-44.0	8.3	24.3	19.2
			44.0-50.0	7.9	21.6	18.6
	44.0-47.0	Clay, residual, basaltic, gray-green and blue-green, some nontronite filling cracks.	50.0-59.0	7.6	21.2	18.4

Formation	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-57: (continued)				
	47.0-53.0	Clay, residual, basaltic, brown and black, amygdaloidal and vesicular, a little tuffaceous near top.				
	53.0-69.0	Clay, residual, basaltic, green and gray-green, slightly amygdaloidal, iron-streaked.				
	69.0-71.0	Basalt, black, hard, vesicular.				
		Drill Hole Ex-58:				
Qp	0.0-50.0	Soil and Palouse formation.				
Tcr	50.0-53.0	Clay, residual, basaltic, green, amygdaloidal.	51.0-59.0	8.5	15.6	21.5
	53.0-61.5	Clay, residual, basaltic, black, dark blue, and some brown, tan and green nontronite amygdules.	59.0-62.0	8.8	16.0	21.0
			62.0-68.0	8.9	16.7	19.4
	61.5-71.5	Clay, residual, basaltic, green, slightly amygdaloidal, some hard spots.				
	71.5	Semi-decomposed basalt.				
		Drill Hole Ex-59:				
Qp	0.0-33.0	Soil and Palouse formation, 2-inch limonite band at base.				
Tcrl	33.0-38.0	Clay, residual, basaltic, green-gray. Green nontronite filling interstices. 6-inch limonite at base.	33.0-39.0	8.7	20.6	19.3
	38.0-46.0	Clay, residual, basaltic, brown, Interstices filled with green nontronite. Some hard spots.	39.0-45.0	9.5	14.9	22.2
	46.0-52.0	Semi-decomposed basalt, green. At top 3-4 inch crack filled by green nontronite.	45.0-51.0	7.6	20.2	16.9
	52.0-56.0	Clay, basaltic, gray-blue, dry, powdery. At top 3 inches green nontronite. At 55 feet, darker blue, harder, and nontronite spots. Last 6 inches green nontronite mixed with brown nontronite.	51.0-55.0	7.9	13.7	19.4
	56.0-62.0	Clay, residual, basaltic, blue and blue-gray; white and some green amygdules. 6 inches of massive nontronite at 59 feet.	55.0-61.0	8.4	16.0	20.6

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Forma-tion	Interval (feet)	Description	Interval (feet)	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Ex-59: (continued)				
	62.0-67.0	Clay, residual, basaltic, green. Montronite amygdules and spots throughout. Bottom in semi-decomposed basalt.				
		Drill Hole Ex-60:				
Qp	0.0-5.0	Soil and Palouse formation.				
Tcru	5.0-25.0	Gravel and sands, transported gneissic. Last 4 feet mixed with gray clay.				
	25.0-31.0	Clay, transported, gray, plastic, quartz silt. Last 2 feet tan and micaceous.	25.0-30.0	7.8	1.5	22.1
	31.0-36.5	Gravel, transported, gneissic; and limonitic, micaceous, and clayey sand.				
	36.5-49.0	Clay, residual, basaltic, blue. White and some tan kaolinite amygdules. Thin metallic flecks bring out texture.	36.0-42.0	11.0	3.1	30.4
			42.0-49.0	9.0	3.5	24.5
	49.0-58.0	Silt, transported, brown, micaceous, sandy; and quartz and basalt gravel. Some basalt gravel pieces are basaltic clay.	49.0-54.0	7.1	8.2	18.6
			54.0-58.0	7.7	14.5	17.1
	58.0-60.0	Semi-decomposed basalt, green-gray and blue-gray.				
	60.0-60.5	Basalt, black and green (nontronite), hard.				
		Drill Hole Ex-61:				
Qp	0.0-26.0	Soil and Palouse formation.				
Tcr	26.0-37.0	Clay, residual, basaltic, mottled brown, slightly amygdaloidal. At 35 feet crack filled with yellow nontronite and bordered by blue clay.				
	37.0-38.0	Clay, residual, basaltic, blue-gray, yellow nontronite filling cracks.				
	38.0-46.0	Clay, residual, basaltic, brown, mottled.				
	46.0-50.0	Semi-decomposed basalt, green-black, vesicular, hard.				

Forma-tion	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-8: Coord. 25,900N, 15,850E.			
Tlu	0.0-5.0	Clay, transported, gray and yellow, silty.	6.2	2.0	17.4
	5.0-10.0	Clay, transported, gray and yellow, silty.	7.0	1.6	19.8
	10.0-25.0	Clay, transported, yellow, sandy.	6.3	3.1	15.9
	25.0-35.0	Clay, transported, yellow, sandy.	6.6	3.6	17.3
		Drill Hole Mi-9: Coord. 25,870N, 15,955E.			
Qp	0.0-3.0	Soil and Palouse formation.			
Tcrl	3.0-13.0	Clay, residual, basaltic, brown and gray.	9.7	21.6	22.3
	13.0-30.0	Clay, residual, basaltic, brown.	10.2	23.1	22.8
		Drill Hole Mi-10: Coord. 24,035N, 15,480E.			
Qp	0.0-3.0	Soil and Palouse formation.			
Tlu	3.0-8.0	Clay, transported, yellow.	9.9	9.7	23.5
Tcrl	8.0-13.0	Clay, residual, basaltic, blue-gray.	9.0	2.0	26.4
		Drill Hole Mi-11A: Coord. 25,910N, 15,725E.			
Qp	0.0-10.0	Soil and Palouse formation.	3.6	4.8	7.5
	10.0-15.0	Soil and Palouse formation.	3.5	4.1	9.2
	15.0-16.0	Gravel.			
		Drill Hole Mi-11B: Coord. 26,075N, 15,460E.			
Qp	0.0-10.0	Soil and Palouse formation.			
		Gravel.			
		Drill Hole Mi-12: Coord. 22,985N, 15,410E.			
Qp	0.0-6.0	Soil and Palouse formation.			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-12: (continued)			
Tlu	6.0-9.0	Clay, transported, yellow.	10.2	11.7	24.1
Tcrl	9.0-19.0	Clay, residual, basaltic, blue-gray.	11.4	2.3	31.7
	19.0-32.0	Clay, residual, basaltic, blue-gray.	10.0	2.0	32.0
		Drill Hole Mi-13: Coord. 24,140N, 17,045E.			
Qp	0.0-2.5	Soil and Palouse formation.			
	2.5-7.5	Gravel.	3.7	5.4	7.8
Tcru	7.5-12.5	Clay, residual, basaltic, yellow, pink, and gray. Some unweathered basalt gravel.	3.6	6.9	8.5
Tcrl	12.5-17.5	Clay, residual, basaltic, blue-gray.	10.2	3.4	28.2
	17.5-22.5	Clay, residual, basaltic, blue-gray.	7.2	5.3	19.7
	22.5-24.5	Clay, residual, basaltic, blue-gray.	5.3	6.9	14.5
		Drill Hole Mi-14: 22,970N, 16,675E.			
Qp	0.0-7.5	Soil and Palouse formation.			
Tcrl	7.5-17.5	Clay, residual, basaltic, blue-gray.	11.0	2.0	31.0
	17.5-24.5	Clay, residual, basaltic, blue-gray, mottled white with kaolinite amygdules. Hole blocked by wrench.	9.7	5.9	25.3
		Drill Hole Mi-15A: Coord. 20,575N, 16,305E.			
Qp	0.0-10.0	Soil and Palouse formation.			
	10.0	Gravel.			
		Drill Hole Mi-15B: Coord. 20,700N, 16,330E.			
Qp	0.0-10.0	Soil and Palouse formation.			
	10.0	Gravel.			

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Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-15C: Coord. 21,330N, 16,070E.			
Qp	0.0-5.0	Soil and Palouse formation.			
	5.0	Gravel, coarse.			
		Drill Hole Mi-15D: Coord. 21,840N, 16,030E.			
Qp	0.0-1.0	Soil.			
	1.0-5.5	Palouse formation.	5.7	6.1	14.5
	5.5-10.0	Palouse formation.	3.6	4.9	8.3
	10.0-16.0	Palouse formation.			
		Drill Hole Mi-16: Coord. 23,580N, 17,875E.			
Qp	0.0-3.5	Soil and Palouse formation.			
Tcrl	3.5-8.5	Clay, residual, basaltic, blue and yellow.	10.3	5.9	27.5
	8.5-13.5	Clay, residual, basaltic, blue and yellow.	10.6	8.5	28.1
	13.5-17.0	Clay, residual, basaltic, brown and blue-gray.	8.7	17.2	20.2
		Drill Hole Mi-17: Coord. 22,530N, 17,330E.			
Qp	0.0-12.0	Soil and Palouse formation.			
Tcrl	12.0-15.0	Clay, residual, basaltic, blue-gray and tan.	9.9	10.0	25.9
	15.0-18.5	Clay, residual, basaltic, blue-gray and tan.	9.5	13.8	23.6
	18.5-22.0	Clay, residual, basaltic, brown and tan.	8.6	20.5	17.5
	22.0-27.0	Clay, residual, basaltic, brown, tan, and blue.	8.9	20.4	19.1
		Drill Hole Mi-18: Coord. 25,055N, 18,205E.			
Qp	0.0-5.0	Soil and Palouse formation.			
Tcrl	5.0-10.0	Clay, residual, basaltic, blue-gray and yellow.	8.6	14.9	20.4
	10.0-19.0	Clay, residual, basaltic, brown and blue-gray.	7.9	20.7	17.2
	19.0-21.0	Clay, residual, basaltic, greenish brown.	6.4	23.6	12.2

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-19: Coord. 22,950N, 18,250E.			
Qp	0.0-13.0	Soil and Palouse formation.			
		Drill Hole Mi-20: Coord. 21,650N, 16,660E.			
Qp	0.0-2.0	Soil and Palouse formation.			
Tcrl	2.0-5.5	Clay, residual, basaltic, blue-gray.	10.4	5.1	27.5
	5.5-13.0	Clay, residual, basaltic, blue-gray.	11.4	5.1	29.6
	13.0-23.0	Clay, residual, basaltic, greenish brown.	8.1	9.7	21.1
		Drill Hole Mi-21: Coord. 23,950N, 18,490E.			
Qp	0.0-16.0	Soil and Palouse formation.			
		Drill Hole Mi-22: Coord. 24,330N, 17,760E.			
Qp	0.0-7.0	Soil and Palouse formation.			
Tcrl	7.0-12.0	Clay, residual, basaltic, brownish black.			
	12.0-19.0	Clay, residual, basaltic, brownish black.	6.1	12.0	14.5
		Drill Hole Mi-23: Coord. 25,825N, 16,970E.			
Qp	0.0-7.0	Soil and Palouse formation.			
	7.0-17.0	Palouse formation; mixed basaltic and granitic clay.	6.3	11.3	15.0
Kg	17.0-22.0	Clay, residual, granitic, yellowish gray and white.	4.7	4.1	11.4
		Drill Hole Mi-24: Coord. 24,795N, 14,795E.			
Qp	0.0-5.0	Soil and Palouse formation.			
Tcrl	5.0-10.5	Clay, residual, basaltic, blue and brown.	9.8	12.8	25.1
	10.5-20.5	Clay, residual, basaltic, brownish black, spotted green and blue-gray.	9.6	18.2	18.4
	20.5-28.0	Clay, residual, basaltic, brown, greenish yellow amygdules.	8.4	16.4	21.6

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-25: Coord. 21,655N, 14,930E.			
Qp	0.0-6.0	Soil and Palouse formation.			
	6.0-17.0	Palouse formation.	3.9	4.3	8.0
		Drill Hole Mi-26A: Coord. 20,190N, 15,085E.			
Qp	0.0-9.0	Soil and Palouse formation.			
		Drill Hole Mi-26B: Coord. 20,345N, 15,870E.			
Qp	0.0-9.0	Soil and Palouse formation.			
Tcrl	9.0-18.0	Clay, residual, basaltic, blue-gray and brown.	11.5	5.4	24.0
		Drill Hole Mi-27: Coord. 17,960N, 14,585E.			
Qp	0.0-14.0	Soil and Palouse formation.			
	14.0-19.0	Palouse formation and weathered basalt.	8.0	10.8	11.3
	19.0-22.0	Palouse formation and weathered basalt.	9.0	4.9	15.4
Tcru	22.0-23.5	Clay, residual, basaltic, blue-gray.	7.2	4.9	18.2
	23.5-28.5	Clay, residual, basaltic, blue-gray.	5.1	3.9	15.4
		Drill Hole Mi-28: Coord. 19,710N, 15,740E.			
Qp	0.0-3.0	Soil and Palouse formation.			
Tcru	3.0-7.0	Clay, residual, basaltic, tan and blue.	11.9	4.8	31.3
	7.0-12.0	Clay, residual, basaltic, yellow and brown, some basalt glass.	11.3	22.5	25.1
	12.0-19.0	Clay, residual, basaltic, tan.	11.3	17.1	25.6
Tcrl	19.0-20.0	Clay, residual, basaltic, blue-gray.			
	20.0-31.0	Clay, residual, basaltic, blue-gray.	11.0	11.5	29.0
	31.0-37.0	Clay, residual, basaltic, blue-green, and tan.	9.0	15.1	21.8

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-29: Coord. 25,620N, 16,290E.			
Qp	0.0-4.0	Soil and Palouse formation.			
Tcru	4.0-12.0	Clay, residual, basaltic, brown and tan.	8.9	19.9	18.7
		Drill Hole Mi-30			
Qp	0.0-13.0	Soil and Palouse formation.			
Tcrl	13.0-18.0	Clay, residual, basaltic, blue-gray.	10.3	3.1	28.6
	18.0-28.0	Clay, residual, basaltic, blue-gray and some yellow. Drilling stopped because of hardness.	7.6	9.0	19.2
		Drill Hole Mi-31: Coord. 16,550N, 14,140E.			
Qp	0.0-27.0	Soil and Palouse formation.			
	27.0-29.0	Palouse formation.	6.8	11.5	15.5
Tcru	29.0-31.0	Clay, residual, basaltic, blue-gray and green.	7.9	12.3	18.4
	31.0-34.0	Clay, residual, basaltic, blue-gray and green.	7.0	13.3	17.1
	34.0-36.0	Clay, residual, basaltic, blue-gray.	8.4	10.3	21.4
	36.0-37.0	Clay, residual, basaltic, iron-stained.	7.9	21.3	18.0
		Drill Hole MI-32: Coord. 19,715N, 13,830E.			
Qp	0.0-9.5	Soil and Palouse formation.			
Tcrl	9.5-14.5	Clay, residual, basaltic, iron-stained.	10.5	15.9	25.7
	14.5-18.5	Clay, residual, basaltic, brown and blue-gray.	10.8	16.3	25.9
	18.5-22.5	Clay, residual, basaltic, yellow and blue.	10.5	13.5	25.3
		Drill Hole Mi-33: Coord. 17,495N, 16,490E.			
Qp	0.0-6.0	Soil and Palouse formation.			
Tcru	6.0-11.0	Clay, residual, basaltic, brown and some yellow.	9.3	15.1	22.1

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-34: Coord. 20,375N, 14,240E.			
Qp	0.0-8.0	Soil and Palouse formation.			
		Drill Hole Mi-35: Coord. 22,975N, 23,250E.			
Qp	0.0-1.0	Soil and Palouse formation.			
Tcrl	1.0-6.0	Clay, residual, basaltic, gray, some iron staining.	9.3	16.1	21.0
	6.0-11.0	Clay, residual, basaltic, gray, some iron staining.	9.3	20.3	19.6
	11.0	Semi-decomposed basalt.			
		Drill Hole Mi-36: Coord. 22,905N, 23,800E.			
Qp	0.0-13.0	Soil and Palouse formation.			
Tcrl	13.0	Semi-decomposed basalt.			
		Drill Hole Mi-37: Coord. 22,925N, 24,880E.			
Tlu	0.0-12.0	Sand, transported. Drilling stopped because of water.			
		Drill Hole Mi-38			
Tcrl	0.0-5.0	Clay, residual, basaltic, blue and gray, some iron staining.	9.6	9.4	26.0
	5.0-10.0	Clay, residual, basaltic, blue and gray.	10.2	7.5	27.6
	10.0-13.0	Clay, residual, basaltic, blue and gray.	9.1	13.5	23.5
	13.0	Basalt.			
		Drill Hole Mi-39: Coord. 23,665N, 23,755 E.			
Qp	0.0-5.0	Soil and Palouse formation.			
Tcrl	5.0-10.0	Clay, residual, basaltic, blue-gray, some iron.	12.0	6.3	31.5
	10.0-15.0	Clay, residual, basaltic, blue-gray.	11.1	4.2	30.2
	15.0-20.0	Clay, residual, basaltic, light gray.	11.2	2.7	32.1
	20.0-24.0	Clay, residual, basaltic, light gray.	11.2	3.4	31.4

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-39: (continued)			
	24.0-26.0	Clay, residual, basaltic, light gray, heavily iron-stained.	11.0	5.4	29.6
	26.0-31.0	Clay, residual, basaltic, gray, iron-stained.	10.0	4.8	29.8
	31.0-36.0	Clay, residual, basaltic, gray, iron-stained.	10.6	7.1	28.6
	36.0-38.0	Semi-decomposed basalt, heavily iron-stained.			
		Drill Hole Mi-40: Coord. 24,925N, 23,100E.			
Tcrl	0.0-5.0	Clay, residual, basaltic, blue-gray.	9.8	3.6	26.2
	5.0-8.0	Clay, residual, basaltic, blue-gray.	10.8	2.1	31.1
	8.0-11.0	Clay, residual, basaltic, blue-gray, some iron staining.	11.2	3.1	32.0
	11.0-14.0	Clay, residual, basaltic, blue, heavily iron-stained.	11.6	16.6	27.2
	14.0	Semi-decomposed basalt.			
		Drill Hole Mi-41: Coord. 25,480N, 23,220E.			
Qp	0.0-12.0	Soil and Palouse formation.			
Tlu	12.0-14.0	Gravel and clay, transported.			
Tcrl	14.0-17.0	Clay, residual, basaltic, blue, iron-stained.	10.8	10.8	27.0
	17.0-21.0	Clay, residual, basaltic, blue, some iron staining.	11.0	4.0	30.4
	21.0-26.0	Clay, residual, basaltic, light gray, little iron staining.	11.0	2.2	32.2
	26.0-31.0	Clay, residual, basaltic, blue, yellow tuffaceous clay.	10.7	7.8	27.5
	31.0-36.0	Clay, residual, basaltic, blue, yellow tuffaceous clay.	11.7	1.2	32.8
	36.0-41.0	Clay, residual, basaltic, blue, yellow tuffaceous clay.	10.4	1.7	30.0
	41.0-46.0	Clay, residual, basaltic, blue, yellow tuffaceous clay.	10.2	1.3	29.3
	46.0-51.0	Clay, residual, basaltic, blue, yellow tuffaceous clay.	9.8	2.4	28.8
		Drill Hole Mi-42: Coord. 26,410N, 23,145E.			
Qp	0.0-2.0	Soil and Palouse formation.			
	2.0-3.0	Gravel.			
Tcrl	3.0-8.0	Clay, residual, basaltic, blue-gray.	11.7	3.3	31.7
	8.0-12.0	Clay, residual, basaltic, blue-gray.	10.5	5.3	29.7
	12.0-16.0	Clay, residual, basaltic, light brown. May have some transported clay mixed in.	10.2	5.0	28.2

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Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-42: (continued)			
	16.0-21.0	Clay, residual, basaltic, dark blue.	11.4	1.6	31.8
	21.0-26.0	Clay, residual, basaltic, blue.	11.2	1.4	31.6
	26.0-31.0	Clay, residual, basaltic, blue.	10.5	2.5	30.3
	31.0-36.0	Clay, residual, basaltic, blue, yellow tuffaceous clay. May have some transported clay mixed in.	10.5	2.5	31.1
	36.0-41.0	Clay, residual, basaltic, blue, yellow tuffaceous clay. May have some transported clay mixed in.	10.9	2.0	31.6
	41.0-46.0	Clay, residual, basaltic, blue, yellow tuffaceous clay. May have some transported clay mixed in.	10.6	2.8	29.9
	46.0-49.0	Clay, residual, basaltic, blue, yellow tuffaceous clay. May have some transported clay mixed in.	9.6	4.5	26.9
		Drill Hole Mi-43: Coord. 25,290N, 23,855E.			
Qp	0.0-1.0	Soil and Palouse formation.			
	1.0-6.0	Palouse formation and gravel.			
Tlu	6.0-10.0	Clay, transported, sandy, micaceous.			
	10.0-14.0	Clay, transported, sandy, micaceous.			
	14.0-15.0	Clay, transported.	(		
			(12.1	2.2	34.0
Tcrl	15.0-17.0	Clay, residual, basaltic, blue.	(		
	17.0-21.0	Clay, residual, basaltic, blue, some iron.	10.8	4.7	30.5
	21.0-26.0	Clay, residual, basaltic, blue, little iron.	10.8	3.4	30.9
	26.0-31.0	Clay, residual, basaltic, blue, little iron.	11.0	2.2	31.8
		Drill Hole Mi-44: Coord. 26,775N, 24,470E.			
Qp	0.0-1.0	Soil and Palouse formation.			
Tlu	1.0-6.0	Clay, transported, white, micaceous.			
	6.0-12.0	Clay, transported, white, sandy layers.			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-44: (continued)			
Tcrl	12.0-17.0	Clay, residual, basaltic, blue, iron-stained, some transported clay at top.	11.2	4.8	30.4
	17.0-22.0	Clay, residual, basaltic, light gray.	11.4	2.5	31.7
	22.0-27.0	Clay, residual, basaltic, blue and white.	11.2	1.9	31.9
	27.0-32.0	Clay, residual, basaltic, blue and white.	11.0	2.7	31.7
	32.0-36.0	Clay, residual, basaltic, white and blue, some iron-staining.	11.3	3.6	32.2
	36.0-41.0	Clay, residual, basaltic, blue.	10.8	2.0	31.6
	41.0-44.0	Clay, residual, basaltic, blue.	10.8	6.1	28.5
	44.0-47.0	Clay, residual, basaltic, blue and brown, iron-stained.	8.8	12.4	22.8
	47.0	Semi-decomposed basalt.			
		Drill Hole Mi-45: Coord. 25,870N, 24,575E.			
Qp	0.0-13.0	Soil and Palouse formation.			
Tcrl	13.0	Semi-decomposed basalt.			
		Drill Hole Mi-46: Coord. 25,755N, 24,925E.			
Qp	0.0-16.0	Soil and Palouse formation.			
Tcrl	16.0-21.0	Clay, residual, basaltic, gray, iron-stained.	8.4	11.8	21.1
	21.0				
		Drill Hole Mi-47: Coord. 25,880N, 25,910E.			
Tlu	0.0-11.0	Clay, transported, white, micaceous layers.			
Tcrl	11.0-17.0	Clay, residual, basaltic, blue.	11.0	3.2	30.4
	17.0-22.0	Clay, residual, basaltic, blue.	11.3	2.2	32.5
	22.0-27.0	Clay, residual, basaltic, blue.	10.6	1.6	32.1
	27.0-30.0	Clay, residual, basaltic, gray, semi-decomposed basalt.	7.0	2.2	21.8
	30.0	Semi-decomposed basalt.			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-48: Coord. 26,140N, 25,550 E.			
Qp	0.0-5.0	Soil and Palouse formation.			
Tlu	5.0-17.0	Clay, transported, heavily iron-stained.			
Tcrl	17.0	Semi-decomposed basalt.			
		Drill Hole Mi-49: Coord. 24,610N, 23,725E.			
Qp	0.0-11.0	Soil and Palouse formation.			
Tcrl	11.0-16.0	Clay, residual, basaltic, blue-gray, some iron staining.	10.6	6.8	27.8
	16.0-21.0	Clay, residual, basaltic, gray, iron-stained.	10.7	6.1	22.0
	21.0-26.0	Clay, residual, basaltic, gray-blue.	10.8	2.9	31.7
	26.0-31.0	Clay, residual, basaltic, gray-blue, some iron-staining.	10.2	4.5	29.9
	31.0-36.0	Clay, residual, basaltic, gray-blue, some iron-staining.	10.2	4.6	29.5
	36.0-42.0	Clay, residual, basaltic, gray-blue, iron-stained.	9.4	9.2	26.6
	42.0-43.0	Clay, residual, basaltic, heavily iron-stained. Semi-decomposed basalt.			
		Drill Hole Mi-50: Coord. 24,170N, 24,120E.			
Qp	0.0-2.0	Soil and Palouse formation.			
Tcrl	2.0-6.0	Clay, residual, basaltic, gray, heavily iron-stained.	10.8	6.0	29.8
	6.0-9.0	Clay, residual, basaltic, gray, some iron staining.	11.2	6.8	30.2
	9.0-15.0	Clay, residual, basaltic, gray, iron-stained.	10.0	22.3	23.4
	15.0-21.0	Clay, residual, basaltic, green-blue, some iron staining.	9.5	10.4	24.6
	21.0-26.0	Clay, residual, basaltic, green-gray. Semi-decomposed basalt.	7.6	11.5	18.8
		Drill Hole Mi-51: Coord. 23,590N, 22,840E.			
Qp	0.0-2.0	Soil and Palouse formation.			
Tcrl	2.0-7.0	Clay, residual, basaltic, blue, tuffaceous clay, iron-stained.	7.7	8.3	20.5
	7.0-12.0	Clay, residual, basaltic, blue, tuffaceous clay, iron-stained.	9.1	13.6	22.6

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-51: (continued)			
	12.0-17.0	Clay, residual, basaltic, blue.	9.0	10.4	23.8
	17.0-22.0	Clay, residual, basaltic, blue. Semi-decomposed basalt, iron-stained. Water at 21 feet.	8.6	23.7	17.8
	22.0-27.0	Semi-decomposed basalt, iron-stained.	7.3	30.2	13.8
	27.0-32.0	Semi-decomposed basalt, iron-stained, spots of green nontronite.	6.8	26.0	13.8
	32.0-36.0	Semi-decomposed basalt, iron-stained, spots of green nontronite.	5.8	14.9	15.1
		Drill Hole Mi-52: Coord. 23,545N, 24,190E.			
Qp	0.0-2.0	Soil and Palouse formation.			
Tcrl	2.0-15.0	Clay, residual, basaltic, blue, heavily iron-stained.			
	15.0-21.0	Clay, residual, basaltic, blue, brown, and gray, some tuffaceous clay, heavily iron-stained.	10.5	11.0	28.2
	21.0-25.0	Clay, residual, basaltic, green-brown and purple, amygdaloidal, heavily iron-stained.	10.4	9.9	27.5
	25.0-30.0	Clay, residual, basaltic, blue-gray. Some semi-decomposed basalt.	9.8	13.0	25.6
		Drill Hole Mi-53: Coord. 23,510N, 24,760E.			
Qp	0.0-11.0	Soil and Palouse formation.			
Tlu	11.0-20.0	Sand, transported, micaceous.			
	20.0-28.0	Sand, transported, white clay layers.			
	28.0	Sand, transported.			
		Drill Hole Mi-54: Coord. 24,350N, 25,645E.			
Qp	0.0-10.0	Soil and Palouse formation.			
	10.0-11.0	Gravel.			
Tcru	11.0	Basalt?			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-55: Coord. 23,535N, 25,790E.			
Qp	0.0-7.0	Soil and Palouse formation.			
Tcru	7.0	Basalt?			
		Drill Hole Mi-56: Coord. 24,270N, 25,120E.			
Qp	0.0-14.0	Soil and Palouse formation.			
Tlu	14.0-26.0	Clay and gravel, transported, micaceous. Drilling stopped because of caving.			
		Drill Hole Mi-57: Coord. 24,340N, 22,590E.			
Qp	0.0-2.0	Soil and Palouse formation.			
Tcru	2.0-5.0	Clay, residual, basaltic, gray.	(		
	5.0-6.0	Clay, residual, basaltic, blue.	(5.4	5.7	13.7
Tlu	6.0-9.0	Clay, transported, tan and brown, sandy.	(		
	9.0-14.0	Sand, transported, tan and gray, clayey, some gravel, iron-stained.	4.9	5.0	12.4
	14.0-20.0	Clay, transported, gray, heavily iron-stained.			
Tcrl?	20.0	Basalt.			
		Drill Hole Mi-58: Coord. 27,840N, 24,940E.			
Qp	0.0-2.0	Soil and Palouse formation.			
Tcrl	2.0-7.0	Clay, residual, basaltic, gray-blue, iron-stained.	9.0	17.4	21.6
	7.0-12.0	Clay, residual, basaltic, gray, limonite.	9.6	19.8	22.6
	12.0-17.0	Clay, residual, basaltic, gray, heavily iron-stained.			
	17.0-22.0	Clay, residual, basaltic, brown, iron-stained.			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-58: (continued)			
Tll	22.0-27.0	Clay, transported, purplish white and reddish brown, sandy seams.			
Kg	27.0-33.0	Semi-decomposed granite.			
		Drill Hole Mi-59: Coord. 27,970N, 24,540E.			
Qp	0.0-2.0	Soil and Palouse formation.			
Tcrl	2.0-5.0	Decomposed basalt, green nontronite.	7.6	16.2	16.5
	5.0-10.5	Clay, residual, basaltic, green and bluish green.	7.1	16.9	17.6
	10.5	Semi-decomposed basalt.			
		Drill Hole Mi-60: Coord. 27,475N, 24,610E.			
Qp	0.0-3.0	Soil and Palouse formation.			
Tcrl	3.0-8.0	Clay, residual, basaltic, gray and tan.	10.7	7.4	28.8
	8.0-13.0	Clay, residual, basaltic, tan, blue, and brown; white amygdules.	10.3	11.8	28.4
	13.0-18.0	Clay, residual, basaltic, tan, blue, and brown; white amygdules, heavily iron-stained.	9.7	18.4	23.4
	18.0-24.0	Clay, residual, basaltic, tan, tuffaceous, iron-stained.	8.3	17.4	20.6
	24.0	Semi-decomposed basalt.			
		Drill Hole Mi-61: Coord. 26,825N, 24,985E.			
Qp	0.0-28.0	Soil and Palouse formation.			
Tlu	28.0-32.0	Gravel, transported.			
		Drill Hole Mi-62: Coord. 26,790N, 25,570E.			
Tlu	0.0-20.0	Sand, transported, white, yellow, gray; micaceous, clayey.			
	20.0-23.0	Clay, transported, gray.			
	32.0-35.0	Sand, transported, micaceous, slightly clayey.			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-63: Coord. 27,460N, 24,840E.			
Qp	0.0-1.0	Soil and Palouse formation.			
Tcrl	1.0-6.0	Clay, tuffaceous, yellow. Semi-decomposed vesicular basalt ash fragments.	6.9	11.0	17.6
	6.0-10.0	Semi-decomposed yellow tuff.	6.2	13.2	14.0
	10.0	Decomposed basalt.			
		Drill Hole Mi-64: Coord. 27,735N, 23,800E.			
Qp	0.0-5.0	Soil and Palouse formation.			
	5.0-10.0	Palouse formation; mixed blue basaltic clay and mica.	5.2	13.3	12.5
	10.0-12.0	Palouse formation; blue basaltic clay. At bottom brown, micaceous sand.	4.7	13.1	10.1
		Drill Hole Mi-65: Coord. 24,810N, 25,655E.			
Qp	0.0-12.0	Soil and Palouse formation.			
Tlu	12.0-14.0	Clay, transported, red.			
Tcrl	17.0-22.0	Clay, residual, basaltic, blue.	10.0	4.0	28.7
	22.0-27.0	Clay, residual, basaltic, blue. Tan, tuffaceous clay.	10.7	6.5	29.6
	27.0-32.0	Clay, residual, basaltic, blue, amygdaloidal.	10.7	5.2	30.6
	32.0-37.0	Clay, residual, basaltic, blue, iron-stained.	10.4	11.5	26.9
	37.0-41.0	Clay, residual, basaltic, blue.	8.4	7.4	23.7
	41.0	Semi-decomposed blue basalt.			
		Drill Hole Mi-66: Coord. 26,340N, 23,820E.			
Qp	0.0-6.0	Soil and glacial drift.			
		Drill Hole Mi-67: Coord. 22,425N, 23,810E.			
Qp	0.0-7.0	Soil and Palouse formation.			
Tcrl	7.0-12.0	Clay, residual, basaltic, tan and gray, iron-stained.	5.0	16.7	20.0

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-67: (continued)			
	12.0-17.0	Clay, residual, basaltic, brownish gray, iron-stained, amygdaloidal.	9.0	14.2	21.6
	17.0-21.0	Clay, residual, basaltic, gray.	8.5	15.8	19.5
	21.0	Semi-decomposed brownish gray basalt.			
		Drill Hole Mi-68: Coord. 23,405N, 24,320E.			
Qp	0.0-20.0	Soil and Palouse formation. Caved because of water.			
		Drill Hole Mi-69: Coord. 22,030N, 23,810E.			
Qp	0.0-12.0	Soil and Palouse formation.			
Tcrl	12.0-14.0	Clay, residual, basaltic, gray-green, amygdaloidal, iron-stained.			
	14.0	Semi-decomposed basalt.			
		Drill Hole Mi-70: Coord. 22,375N, 23,295E.			
Qp	0.0-2.5	Soil and Palouse formation.			
Tcrl	2.5-6.0	Clay, residual, basaltic, green-gray.	6.9	14.8	15.5
	6.0	Semi-decomposed basalt.			
		Drill Hole Mi-71: Coord. 21,855N, 23,250E.			
Qp	0.0-3.0	Soil and Palouse formation.			
Tcrl	3.0-8.5	Clay, residual, basaltic, gray-green.	6.3	15.3	14.5
	8.5	Semi-decomposed basalt.			
		Drill Hole Mi-72: Coord. 22,375N, 22,800E.			
Qp	0.0-1.0	Soil and Palouse formation.			
Tcrl	1.0-6.0	Clay, residual, basaltic, brown and dark gray, iron-stained.	9.5	19.3	20.5
	6.0-9.0	Clay, residual, basaltic, dark blue and brown, hard at base.	8.4	15.9	19.4
	9.0	Semi-decomposed green basalt.			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-73: Coord. 24,735N, 24,315E.			
Qp	0.0-18.0	Soil and Palouse formation.			
Tcrl	18.0-23.0	Clay, residual, basaltic, blue, iron-stained. Water at 20 feet.	8.2	6.6	23.5
	23.0	Basalt.			
		Drill Hole Mi-74: Coord. 25,285N, 24,305E.			
Qp	0.0-10.0	Soil and Palouse formation.			
Tlu	10.0-11.5	Clay, transported, heavily iron-stained.			
	11.5-13.0	Sand and clay, transported, white.			
Tcrl	13.0-18.0	Clay, residual, basaltic, blue, iron-stained.	11.2	7.4	29.4
	18.0-23.0	Clay, residual, basaltic, blue, iron-stained.	9.2	5.4	27.6
	23.0-25.0	Clay, residual, basaltic, blue, iron-stained.	6.8	3.4	15.7
	25.0	Semi-decomposed basalt.			
		Drill Hole Mi-75: Coord. 25,885N, 24,245E.			
Qp	0.0-15.0	Soil and Palouse formation.			
Tlu	15.0-17.0	Bog iron.			
Tcrl	17.0-22.0	Clay, residual, basaltic, blue.	10.7	3.7	30.4
	22.0-27.0	Clay, residual, basaltic, gray.	11.1	2.0	32.8
	27.0-32.0	Clay, residual, basaltic, gray.	11.1	1.9	33.2
	32.0-38.0	Clay, residual, basaltic, light gray, iron-stained.	10.9	5.2	31.4
	38.0-40.0	Clay, residual, basaltic, brown and white, iron-stained.	8.8	5.0	23.6
	40.0-45.0	Clay, residual, basaltic, gray, iron-stained.	10.5	4.0	32.1
	45.0-49.0	Clay, residual, basaltic, gray, iron-stained.	9.8	10.4	26.4
	49.0	Semi-decomposed basalt.			
		Drill Hole Mi-76: Coord. 26,890N, 22,880E.			
Qp	0.0-12.0	Soil and Palouse formation.			
	12.0-17.0	Palouse formation.			
	17.0	Gravel.			

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-77: Coord. 26,390N, 22,720E.			
Qp	0.0-1.0	Soil and Palouse formation.			
	1.0-5.0	Sand and gravel.			
Tcrl	5.0-10.0	Clay, residual, basaltic, blue; yellow tuffaceous clay.	8.1	10.0	20.8
	10.0-15.0	Clay, residual, basaltic, blue; yellow tuffaceous clay.	8.2	9.9	22.7
	15.0-18.0	Clay, residual, basaltic, blue.	8.0	9.1	23.1
		Drill Hole Mi-78: Coord. 22,980N, 14,460E.			
Qp	0.0-18.0	Soil and Palouse formation.			
Tlu	18.0-21.0	Sand, transported.			
	21.0-23.0	Clay, transported, white, iron-stained.			
	23.0-24.0	Clay, transported, white, heavily iron-stained.			
Tcrl	24.0-29.0	Clay, residual, basaltic, blue.	10.9	2.4	30.2
	29.0-34.0	Clay, residual, basaltic, blue.	11.1	1.8	31.5
	34.0-42.0	Clay, residual, basaltic, blue.	10.6	2.2	29.9
		Drill Hole Mi-79: Coord. 24,075N, 14,955E.			
Qp	0.0-7.0	Soil and Palouse formation.			
	7.0-13.0	Palouse formation and gravel.			
Tcrl	13.0-19.0	Clay, residual, basaltic, blue.	5.4	3.5	16.7
	19.0-20.0	Semi-decomposed brown basalt.			
		Drill Hole Mi-80: Coord. 23,475N, 15,500E.			
Qp	0.0-12.0	Soil and Palouse formation.			
Tcrl	12.0-15.0	Clay, residual, basaltic, green-gray.			
	15.0-17.0	Clay, residual, basaltic, blue.	10.6	2.7	29.9
	17.0-22.0	Clay, residual, basaltic, blue.	10.8	2.6	31.8
	22.0-31.0	Clay, residual, basaltic, blue.	10.1	2.2	30.2

Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-81: Coord. 22,490N, 15,155E.			
Qp	0.0-5.0	Soil and Palouse formation.			
Tlu	5.0-9.0	Sand, transported, micaceous.			
Tcrl	9.0-15.0	Clay, residual, basaltic, blue.	11.0	2.4	31.2
	14.0-17.0	Clay, residual, basaltic, gray. Some semi-decomposed basalt.	5.0	11.6	11.6
	17.0	Basalt.			
		Drill Hole Mi-82: Coord. 22,020N, 14,080E.			
Qp	0.0-10.0	Soil and Palouse formation.			
Tcrl.	10.0-16.0	Clay, residual, basaltic, blue, iron-stained.	10.6	11.2	26.1
	16.0-21.0	Clay, residual, basaltic, blue.	10.8	8.6	28.4
	21.0-26.0	Clay, residual, basaltic, blue.	10.6	8.6	27.1
	26.0-32.0	Clay, residual, basaltic, gray and brown, hard.	9.4	12.6	24.4
	32.0	Clay, residual, basaltic, brown, hard; yellow tuffaceous clay. Water in hole.			
		Drill Hole Mi-83: Coord. 21,605N, 13,860E.			
Qp	0.0-14.0	Soil and Palouse formation.			
	14.0-17.0	Palouse formation and gravel.			
Tcrl	17.0-22.0	Clay, residual, basaltic, speckled gray and blue.	9.8	8.1	25.1
	22.0-25.0	Clay, residual, basaltic, speckled gray and blue.	10.1	9.9	26.7
	25.0-28.0	Clay, residual, basaltic, brown and blue.	9.6	8.5	25.0
	28.0	Semi-decomposed basalt.			
		Drill Hole Mi-84: Coord. 22,630N, 16,295E.			
Qp	0.0-2.0	Soil and Palouse formation.			
	2.0-6.0	Gravel.			
	6.0-12.0	Palouse formation and gravel.			

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Formation	Interval (feet)	Description	Ign. Loss	Avail. Fe_2O_3	Avail. Al_2O_3
		Drill Hole Mi-84: (continued)			
Tlu	12.0-16.0	Sand and clay, transported, white.			
Tcrl	16.0-21.0	Clay, residual, basaltic, blue.	9.2	9.4	23.7
	21.0-25.5	Clay, residual, basaltic, blue. Water at 23 feet.	9.7	0.7	28.3
		Drill Hole Mi-85: Coord.			
Qp	0.0-10.0	Soil and Palouse formation.			
Tcrl	10.0-15.0	Clay, residual, basaltic, blue.	10.7	2.6	32.4
	15.0-20.0	Clay, residual, basaltic, blue.	9.7	13.8	24.4
	20.0-23.0	Clay, residual, basaltic, blue.	6.4	15.4	21.9
	23.0	Basalt.			

6 pieces in pocket.