United States Department of the Interior
U.S. Geological Survey
Strategic Minerals Investigations
[Reports - Open file series]

PRELIMINARY REPORT

ON

THE MOLALLA HIGH-ALUMINA CLAY DEPOSIT

NEAR

MOLALLA, CLACKAMAS COUNTY, OREGON

by

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Prepared at Eugene, Oregon

April 1944

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ABSTRACT

The Molalla High-Alumina Clay Deposit lies along the west side of the Molalla river in the Molalla quadrangle, Oregon, approximately 3 miles southeast of Molalla. Molalla is 30 miles south of Portland and 30 miles northeast of Salem, Oregon. A branch line of the Southern Pacific railroad connects it with Canby, Oregon, which is on the main line between San Francisco and Portland.

The investigation of this deposit was carried out jointly by the U. S. Geological Survey and the U. S. Bureau of Mines between July 1942 and May 1943. Seventy-seven holes having a total footage of 7,964.5 feet were drilled.

The ore consists of clay, breccia, and weathered silt, sand, and gravel. It is found mainly in the Molalla formation, although minor amounts are also present in the No. I Terrace deposit. The Molalla formation, which consists of several hundred feet of gently folded continental sediments, is lower Miocene. Interbedded in these sediments are transported and residual high-alumina clays. The transported clays are probably derived from the erosion of weathering profiles to the east. The development of as many as 3 superimposed profiles in the Molalla sediments during the lower Miocene resulted in the formation of residual high-alumina clays. The transported are probably of greater importance than the residual clays. The breccia was probably deposited as a series of mud flows. It consists of large unaltered blocks of volcanic rock surrounded by a matrix of high-alumina clay. It is not as high-grade, in general, as the residual and transported clays, and the presence of large and small unaltered fragments also make it less desirable as a source of high-alumina clay. The No. I Terrace deposit is probably of Illinoian age. Residual high-alumina clays resulting from surface alteration have been developed on it. The principal ore minerals are kaolinite, montmorillonite, beidellite-nontronite, and halloysite.

The reserves have been calculated by the perpendicular bisector method. There are 31,294,000 dry tons of measured ore with 25.73 percent available Al_2O_3 and 7.75 percent available Fe_2O_3 and 17,298,000 dry tons of indicated ore with 27.52 percent available Al_2O_3 and 8.49 percent available Fe_2O_3. It is thought that there may be 50,000,000 wet tons of inferred ore in the district. The weight of the overburden on the measured ore is 21,322,000 wet tons and that on the indicated ore is 15,571,000 wet tons.

The total Al_2O_3 content of the deposit is approximately 10 percent greater than the available Al_2O_3.

INTRODUCTION

Purpose

Due to the scarcity of domestic bauxite, the danger and difficulty in transporting foreign bauxite to Atlantic and Gulf coast ports, and the great need for aluminum during the present emergency, many high-alumina clay deposits have been investigated as possible sources of alumina by the United States Department of the Interior. The present report concerns itself with the Molalla High-Alumina Clay Deposit, the investigation of which was carried out jointly by the U. S. Bureau of Mines and the U. S. Geological Survey between July 1942 and May 1943.

The general geology and the characteristics of the ore body are briefly considered. The reserves are given, and the method of calculation is outlined.

Location and Accessibility

The Molalla High-Alumina Clay Deposit lies in the Molalla quadrangle, which was mapped by the Corps of Engineers, U. S. Army. The deposit is along the west side of the Molalla river, approximately $2\frac{1}{2}$ miles south and 3 miles southeast of Molalla (fig. 1). It is in Clackamas County, within sections 15, 22, 27, and 28 of T. 5S., R. 2 E., W. M., and between latitudes 45°05' and 45°10' and longitudes 122°30' and 122°35'. It is located close to the contact of the Willamette Valley and Western Cascade provinces. 1/

Molalla is approximately 16 miles south of Oregon City, 30 miles south of Portland, and 30 miles northeast of Salem. Good paved highways link Molalla with Salem, Oregon City, and Portland. A branch line of the Southern Pacific railroad connects Molalla with Canby, Oregon, which is on the main line between San Francisco and Portland (fig. 2).

History

A company organized by a Mr. Daly about 1911 built a pottery near Astoria, Oregon. Molalla clay was used, but the company failed

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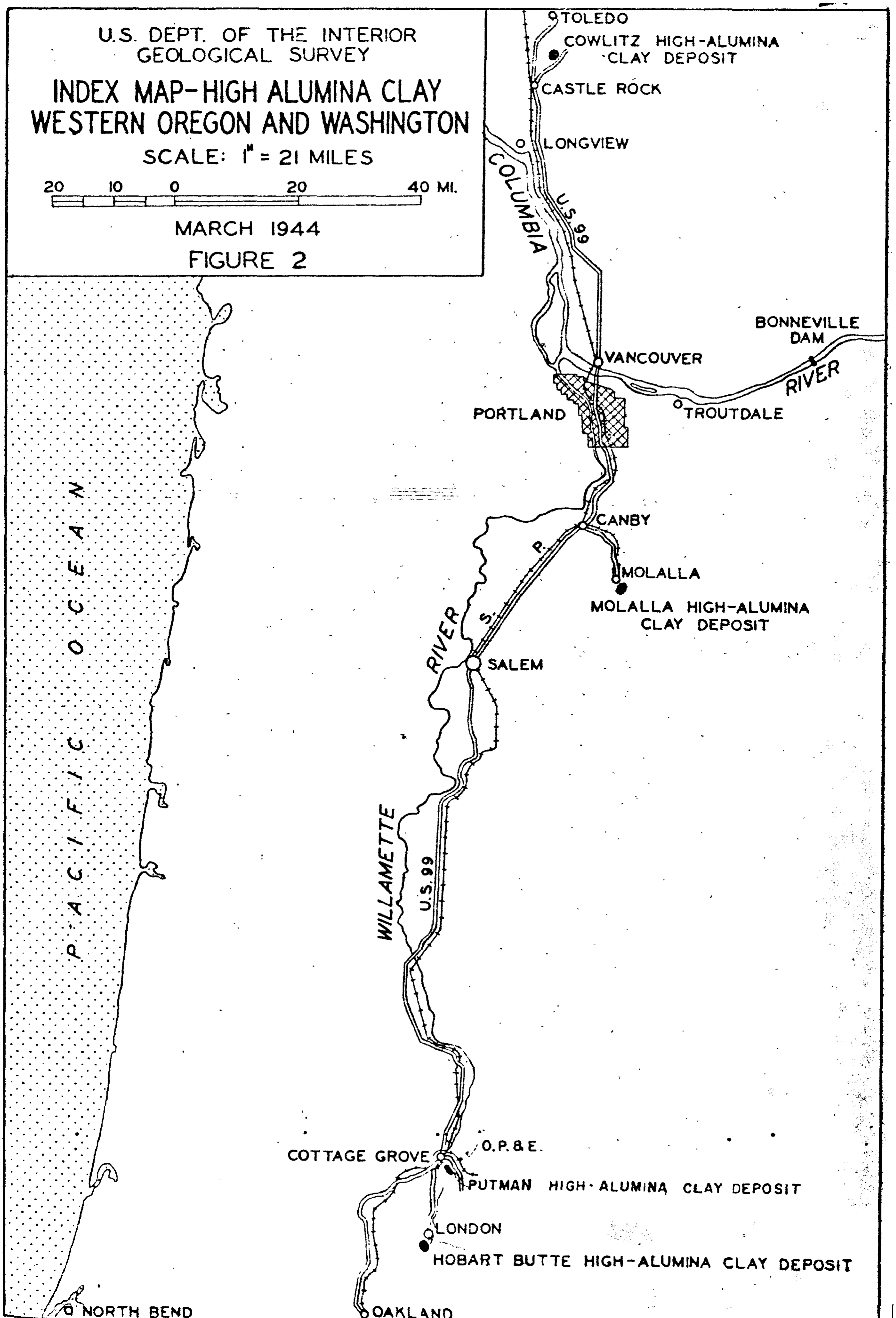
1/ Eugene Callaghan and A. F. Buddington, Metalliferous Mineral Deposits of the Cascade Range in Oregon, U. S. Geol. Survey Bull. 893, pl. 1, 1938.


U.S. DEPT. OF THE INTERIOR
GEOLOGICAL SURVEY
INDEX MAP-HIGH ALUMINA CLAY
WESTERN OREGON AND WASHINGTON
SCALE: 1" = 21 MILES
20 10 0 20 40 MI.
MARCH 1944
FIGURE 2
TOLEDO
COWLITZ HIGH-ALUMINA CLAY DEPOSIT
CASTLE ROCK
LONGVIEW
COLUMBIA
U.S. 99
VANCOUVER
BONNEVILLE DAM
RIVER
PORTLAND
TROUTDALE
CANBY
S. P.
MOLALLA
MOLALLA HIGH-ALUMINA CLAY DEPOSIT
RIVER
SALEM
PACIFIC OCEAN
WILLAMETTE
U.S. 99
COTTAGE GROVE
O. P. & E.
PUTMAN HIGH-ALUMINA CLAY DEPOSIT
LONDON
HOBART BUTTE HIGH-ALUMINA CLAY DEPOSIT
NORTH BEND
OAKLAND

principally because of the excessive shrinkage of the clay. Later the Cascade China Co. built a pottery in Portland and acquired about 40 acres of clay land near Molalla. This company also failed. 2/ Still later small amounts of the Molalla clay were used for experimental purposes by the Willamina Clay Products Co. and by the Denny-Renton Clay and Coal Co.3/ Wilson and Treasher 4/ and Hodge 5/ have briefly described this deposit.

On April 13, 1942 Mr. John E. Allen, geologist, State of Oregon, Dept. of Geology and Mineral Industries, took Mr. C. C. Popoff of the U. S. Bureau of Mines and the writer to the Molalla area. On the basis of this trip and on an analysis of the literature, Mr. Popoff started a prospecting program that consisted of hand-augering, trenching, test pitting, and sampling. More than 250 hand-auger holes were drilled, nearly 100 chemical determinations were made, and an area of approximately $3\frac{1}{2}$ square miles was selected for detailed mechanical drilling. Following the completion of the hand-augering work in August 1942, Mr. H. G. Iverson, District Engineer of Oregon for the U. S. Bureau of Mines, asked the U. S. Geological Survey to check it. The writer had the benefit of a geologic map of the Molalla quadrangle, which was made by Mr. Herbert Harper, a graduate student at Oregon State College, under the direction of Dr. W. D. Wilkinson of the Dept. of Geology at that institution. This map was loaned to him by the State of Oregon, Dept. of Geology and Mineral Industries (fig. 3). Approximately one week was spent in the field during the first part of September, 1942; critical areas were hand drilled; wells, adits, shafts, and outcrops were studied; and the stratigraphy, physiography, structure, and geologic history were considered. It was concluded that the U. S. Bureau of Mines had selected the best area in the quadrangle for drilling.

Scope

Seventy-seven holes were drilled by the U. S. Bureau of Mines between October 24, 1942 and May 17, 1943. The shallowest hole was 37 feet; the deepest, 189.5 feet; and the total footage was 7,964.5 feet (fig. 4). Churn drills equipped for drive-pipe sampling were used and the recovery was practically 100 percent. Most of the cores were $5\frac{1}{4}$ inches in diameter. The U. S. Geological Survey described all the cores, helped with the sampling, and furnished the Bureau engineers with geologic information to guide the prospecting program.

Acknowledgments

All of the assays and moisture and specific gravity determinations used in this report were obtained from the U. S. Bureau of Mines. The topography on the maps is based on surveys by the U. S. Bureau of Mines and the Corps of Engineers, U. S. Army. The geologic map is a simplification and modification of that made by Mr. Herbert Harper of Oregon State College.

2/ W. L. Brown, Unpublished Report to the Denny-Renton Clay and Coal Co., Seattle, Washington, p. 1, Jan. 15, 1926.
3/ Hewitt Wilson and Ray C. Treasher, Preliminary Report of some of the Refractory Clays of Western Oregon, State of Oregon, Dept. of Geology and Mineral Industries, Bull. No. 6, p. 41, 1938.
4/ Op. cit., pp. 39-49.
5/ Edwin T. Hodge, Market for Columbia River Hydroelectric Power Using Northwest Minerals, Section IV-Northwest Clays, Vol. IV, pp. 849-853, 1938.

It is a pleasure to acknowledge the friendliness, helpfulness, and generous cooperation of all of the men of the U. S. Bureau of Mines with whom the writer worked. Special mention should be made of Mr. Arthur M. Evans, Project Engineer, Mr. H. G. Iverson, District Engineer of Oregon, Mr. C. C. Popoff, and Mr. Delbert L. Snyder. Mention has been made that it was with Mr. John E. Allen, State of Oregon, Dept. of Geology and Mineral Industries, that the writer first visited the area. To this it must be added that the writer profited greatly from several long and interesting talks with Mr. Allen on many aspects of the problem. Mr. Victor T. Allen of the U. S. Geological Survey, Commodity Geologist, High-Alumina Clay, is responsible for much of the mineralogical and all of the petrographic data in the report. His constant personal interest in the work has been of much help and is greatly appreciated. Thanks are due to Mr. John J. Collins and Mr. P. J. Shenon of the Northwest Office of the U. S. Geological Survey, for making suggestions and corrections that have been of much value in improving the manuscript and for getting the report ready for distribution. Mr. Wayne Hall was with the writer during the period in which the report was in preparation. He did all of the drafting, took a major share in the calculation of the reserves, and assisted in the work in ways too numerous to mention. For all of this the writer is grateful. It is a pleasure, also, to record the contribution of Mr. John S. Loofbourow, Jr. of the U. S. Geological Survey, who was stationed at Molalla from December 7, 1942 to February 3, 1943. He described approximately one-half the core, helped with the preliminary tonnage calculations and sampling, and did other work that was of value to the project.

GENERAL GEOLOGY

Regional Setting

The prospected area is in the Willamette Valley province, on an Illinoian terrace about 170 feet above the Molalla river. Beneath a thin veneer of terrace deposits lies the Molalla formation. It contains transported and residual high-alumina clays; it has been gently tilted; and it is of lower Miocene age. To the north, east, and south the Molalla formation is buried by the Stayton and Boring lavas.

The formations listed in chronological order are the pre-Molalla(?) lavas, the Butte Creek beds, the Molalla formation, the Stayton lavas, the Boring lavas, and the terrace deposits of various ages.

Pre-Molalla (?) Lavas

Near the base of holes 13, L-9, and perhaps K-4, vesicular and amygdaloidal, basaltic or andesitic lava was encountered. The lava was penetrated for 14 feet in hole L-9 and for $6\frac{1}{2}$ feet in hole 13 (figs. 5 and 6) It appears likely that the lava exposed in all 3 holes belongs either to the same or to nearly contemporaneous flows and it may be scores of feet thick. The lava in hole L-9 is near the bottom of a well-developed weathering profile. It is soft and earthy at the top and progressively increases in hardness with depth. At the same time it changes in color from brown, through yellow and gray, to black slightly weathered lava at the bottom. The weathering is shown not only by the nature of the material, but also by analyses of it for available Al_2O_3. It is not known whether this lava is pre-Molalla or intra-Molalla. If pre-Molalla, it may correlate with the

Mehama volcanics to the south.6/ The weathered portion of this lava was not included in the ore body, and it is likely that it will admirably serve as the mining base.

Butte Creek Beds

The Butte Creek beds, which are marine and lower Miocene, consist of conglomerate, sandstone, and limestone. Their importance lies in the fact that they limit the reserves of the district by cutting off the high-alumina clays of the Molalla formation approximately 4 miles to the south and southwest of the area which was drilled (fig. 3).

Molalla Formation

The Molalla formation, which consists mainly of clay. silt, sand, gravel, tuffaceous sediments, shale, sandstone, conglomerate, mud flow breccias, and coal, is several hundred feet thick. These sediments are mainly of fluvial origin, in part channel, in part flood plain deposits.

Beginning in middle Oligocene and continuing through the lower Miocene, volcanism, mainly of the explosive type, was active along the central belt of the Cascade mountains 7/. These pyroclastics and flows have been assigned to the Eagle Creek (lower Miocene)8/, Mehama (Oligocene)9/ and other formations. A considerable relief was probably developed, and it was possibly streams flowing to the west from these highlands that deposited the Molalla sediments. The presence of coarse gravel indicates that the highlands were not far distant. The Butte Creek shoreline was only a few miles from the prospected area, indicating that deposition took place on a narrow coastal plain (fig. 3).

The Molalla formation is stratigraphically below lavas that Wilkinson and Harper correlate with the Stayton lavas of Thayer (fig. 3). Thayer considers the Stayton to be the equivalent of the Columbia River Basalt formation, which is middle Miocene.10/ The Molalla formation is therefore pre-middle Miocene. Moreover, a study of its flora made by Dr. Beverly Wilder of the University of California indicated that it is early Miocene.11/ Its distribution in the Molalla quadrangle is shown by fig. 3. Treasher,12/ who mapped parts of several quadrangles to the north, found nothing which correlates with it, nor did Thayer 13/ map anything similar to it to the south. The best place to get a general picture of the lithology and stratigraphy is along the unfinished railroad right of way that

6/ T.P. Thayer, Geology of the Salem Hills and the North Santiam River Basin, Ore., State of Ore., Dept. of Geology and Mineral Industries, Bull. No. 15, pp. 5-7, 1939.
7/ Physical and Economic Geography of Oregon, published by Oregon State System of Higher Education, pp. 43-44, 1940.
8/ E. T. Hodge, Geology of the Lower Columbia River, Geol. Soc. Am., Bull., vol. 49, pp. 839-846, 1938.
9/ Op. cit., Bull. No. 15, pp. 5-7, 1939.
10/ Op. cit., pp. 7-8.
11/ Personal communication from Mr. John E. Allen.
12/ Ray C. Treasher, Geologic History of the Portland Area, State of Oregon, Dept. of Geology and Mineral Industries, G.M.I. Short Paper No. 7, 1942.
13/ Op. cit., Fig. 1.

runs along the west side of the Molalla river near the base of the west valley wall, just east of the prospected area. Here cross-bedded sand, mud flow breccias, tuffaceous sediments, and clay can be seen, and it was here that most of the Molalla fossils were collected. It is the most important formation in the area from the economic point of view because most of the ore body is found within it.

Stayton Lavas

The Stayton lavas vary considerably. In many places they are porphyritic with glassy transparent feldspar phenocrysts and a matrix that is black when not weathered. Some of them are vesicular. Well-developed sheeting is common, but columnar jointing is as a rule poorly formed. A weathering profile has been developed on the Stayton lavas in many places, so that the upper 20 feet is commonly soft enough to be cut with a knife. The entire 37 feet of hole F-8 was drilled in this lava. Near the top it was soft and rather completely decomposed, was cut by a series of clay veins, and had 25 percent available Al_2O_3. With increasing depth the degree of weathering decreased and the hardness increased.

The Stayton lavas were extruded upon an erosion surface cut in the Molalla formation with a relief of several hundred feet. The southern part of the quadrangle is largely covered with these lavas (fig. 3) and, because they are often more than 50 feet thick, they probably make strip-mining for the underlying high-alumina clay too costly. The Stayton lavas are thought to be equivalent to the Columbia River Basalt formation, and, if so, they are middle Miocene in age. No Stayton lava was included in the ore body.

Boring Lavas

The Boring lavas are vesicular; columnar jointing is well-developed in them; and they are lighter colored than the Stayton lavas. They are characterized by the presence of olivine and by a porous texture. A weathering profile, similar to that found on the Stayton lavas, has been formed on them, and spheroidal weathering is in places beautifully developed. It is thought that they are either of late Pliocene or early Pleistocene 14/ age and that they are equivalent to the Rhododendron volcanoes of Hodge. 15/ They bury an erosion surface cut in the Molalla formation. Their distribution in the quadrangle is shown on fig. 3. No Boring lava was included in the ore body.

Terrace Deposits

Several terraces have been cut by the Molalla river. The material that veneers Terrace No. I was penetrated by many drill holes. It is of channel and flood plain origin and consists of silt, sand, gravel, and clay. In places it is more than 30 feet thick and is often difficult to differentiate from the Molalla formation. An excellent weathering profile has been developed on it (fig. 6, section 13). In the upper part of this profile

14/ Ray C. Treasher, Geologic History of the Portland Area, State of Oregon, Dept. of Geology and Mineral Industries, G. M. I. Short Paper No. 7, pp. 9-10, 1942.

15/ E. T. Hodge, Geology of the Lower Columbia River, Geol. Soc. Am., Bull., vol. 49, pp. 877-879, 1938.

where the weathering is rather complete, many pebbles and cobbles, up to 5 inches in diameter, can be cut with a knife. With depth the hardness increases, the color commonly changes from yellow to gray, and the degree of weathering and the available Al_2O_3 content decrease. The material that veneers Terrace No. 2, as would be expected, is not as completely weathered (fig. 6, section 9). The relation between the two terraces is shown on fig. 8, section FF'. Terrace deposits cover a large part of the quadrangle (fig. 3) and the prospected area is located mainly on Terrace No. I. Based on the degree of weathering, it is thought that Terrace No. I is either Kansan or Illinoian.16/ The successive terrace deposits and the Recent alluvium along the Molalla river are undifferentiated on fig. 3. Some of the material veneering Terrace No. I is included in the ore body (figs. 6, 7, and 8).

Structure and Geomorphology

The Molalla formation and presumably the Stayton lavas are gently folded. Dips up to 8 degrees are present. In the prospected area there is a regional dip to the northwest (figs. 7 and 8). A few slickensides were observed in the Molalla formation that are probably related to these structures.

The prospected area is located on the flat, extensive surface of Terrace No. I, which is approximately 170 feet above the Molalla river. As seen in fig. 1 there is a great deal of terrace topography in the quadrangle. It makes possible, of course, the existence of great tonnages of high-alumina clay in unprospected areas. The southeast, southwest, and northeast parts of the quadrangle, however, are considerably dissected. In these areas the relief is several hundred feet, and from purely physiographic considerations they are not as favorable for large tonnages as the other parts of the quadrangle.

16/ Ira S. Allison, Pleistocene Alluvial Stages in Northwestern Oregon, Science, vol. 83, n.s., p. 442, 1936.

Geologic History

A simplified, tentative outline of the geologic history of the district follows:

Oligocene ?	1.	Extrusion of pre-Molalla ? lavas
Lower Miocene	2.	Deposition of Butte Creek beds marine sandstone, conglomerate, and limestone.
	3.	Deposition of Molalla formation intermittent deposition; formation of 3 weathering profiles; mainly channel and flood plain deposits; transported and residual clays.
	4.	Erosion relief of a few hundred feet developed.
Middle Miocene	5.	Extrusion of Stayton lavas*
	6.	Diastrophism resulting in gentle dips, open structures.
	7.	Erosion
Pliocene-Pleistocene	8.	Extrusion of Boring lavas*
Pleistocene and Recent	9.	Erosion and successive uplifts formation of several terraces* and deposition of sediments on them; oldest terrace perhaps Illinoian.

* Weathering profiles were formed on the Stayton, Boring, and No. I Terrace deposit; but were better developed on the Stayton and Boring.

ORE DEPOSITS

Mineralogy

Hydrous Aluminum Silicates

Kaolinite ($Al_2O_3.2SiO_2.2H_2O$), montmorillonite (represented by the Irish Creek clay) $(Al_{1.50}Fe_{.14}Mg_{.42})(Al_{.09}Si_{3.91})O_{10}(OH)_2{}^{+}Ca_{.17})$, beidellite-nontronite (represented by Carson district clay)$(Al_{2.00}Fe_{.05}Mg_{.02})(Al_{.52}Si_{3.48})O_{10}(OH)_2{}^{+}Ca_{.16}$ (represented by Sandy Ridge clay) $(Al_{.39}Fe_{1.7})(Al_{.58}Si_{3.42})O_{10}(OH)_2{}^{+}H_{.31})$, and celadonite K (Fe''',Al) (Mg,Fe'')$Si_4O_{10}(OH)_2$ have been identified petrographically by Mr. Victor T. Allen of the U. S. Geological Survey, and X-ray investigation indicates that some halloysite ($Al_2O_3.2SiO_2.2H_2O$) may also be present.17/ Messrs. Joseph A. Pask18/ and Ben Davies of the U. S. Bureau of Mines have identified montmorillonite, a beidellite-like mineral, kaolinite-halloysite, and possibly illite (bravaisite $\frac{K}{2}(Al,Fe,Mg)_2(Al,Si)_4O_{10}(OH)_2$) by thermal analyses.

Aluminum Hydrates

Gibbsite ($Al_2O_3.3H_2O$) has been identified petrographically. It developed from feldspar fragments and from grains of clay.19/ Pask and Davies have also identified it by thermal analyses.20/ Because gibbsite has been found only in minor amounts, the hydrous aluminum silicates are the important ore minerals.

Other Minerals

Siderite ($FeCO_3$) is a common mineral in the deposit (Figs. 5 & 6). It is widely disseminated through the clays, in some places sparsely, in others abundantly. It is found as small concretions less than 1/10 inch in diameter. They are usually spherical, cylindrical, or dumbbell-like in shape. Dumbbell shaped cavities, which apparently resulted from the solution of similarly shaped siderite concretions, are found in the clay.

17/ Personal communication from Mr. Victor T. Allen, U.S. Geol. Survey.
18/ Joseph A. Pask and Ben Davies, Thermal Analysis of Clay Minerals and Acid Extraction of Alumina from Clays, U. S. Dept. Interior, Bureau of Mines, Report of Investigations 3737, pp. 23 and 25, Dec. 1943.
19/ Personal communication from Mr. Victor T. Allen, U. S. Geol. Survey.
20/ Op. cit., pp. 23 and 25.

Occasionally the siderite is in masses several inches across, which greatly increase the specific gravity of the drill cores in which they are found.

Limonite ($2Fe_2O_3.3H_2O$) stains most of the No. I Terrace deposit and many of the lithologic units of the Molalla formation. It is also found as veins cutting the clay (Figs. 1 and 2).

Hematite (Fe_2O_3) stains some of the clay and other sediments, and it is also found as small specks in some of the weathered silts and sands. It is particularly common in hole 3.

Ilmenite ($FeTiO_3$) and magnetite (Fe_3O_4), occurring as beautiful euhedral crystals 1/50 inch across, are very abundant in some of the clay (Figs. 1 and 2). After heavy continuous rains black sand composed of these minerals can be found in the furrows of plowed fields. Similar sand can also be found in the ditches along highways and on washed patches on slopes.

Pyrite (FeS_2) and vivianite ($Fe_3P_2O_8.8H_2O$) are present in minor amounts.

Quartz (SiO_2) grains of irregular shapes and various sizes are scattered through some of the clay and it is very common in some of the unweathered sand. Traces of cristobalite (SiO_2) are revealed by X-ray analysis.

In addition a few grains of zircon ($ZrSiO_4$) have been identified, and some of the beidellite clays contain fragments of fresh feldspar ($NaAlSi_3O_8$). 21/

Chemistry

Several thousand chemical determinations were made of the Molalla High-Alumina Clay by the Seattle laboratory of the U. S. Bureau of Mines. The determinations included total Al_2O_3, Fe_2O_3, TiO_2, SiO_2, MgO, and CaO, loss on ignition, and available Al_2O_3 and Fe_2O_3. The available Al_2O_3 is usually between 84 and 97 percent of the total Al_2O_3. It is the percentage by weight that is obtained in one hour by a 20 percent solution of H_2SO_4 on clay calcined to 700°C or 800°C. The total and available Al_2O_3 and Fe_2O_3 are calculated on the weight of the sample after drying at 130°C.

The following analyses were made on composite samples of the Upper Clay series and the Lower Clay series as defined by the U. S. Bureau of Mines. These clay series are roughly equivalent to the South Ore body and the Lower Ore body considered later.

21/ Personal communication from Mr. Victor T. Allen, U. S. Geological Survey.

Analyzed After Drying at 130°C

	Upper Clay Series	Lower Clay Series
SiO_2	45.5	43.6
Al_2O_3 (total)	27.8	30.2
Fe_2O_3 (total)	11.5	10.3
TiO_2	1.8	1.8
ZrO_2	0.0x	0.0
P_2O_5	0.13	0.19
V_2O_5	0.0	0.0
CaO	0.3	0.3
MgO	0.4	0.3
K_2O	0.0	0.0
Na_2O	0.4	0.1
SO_3	0.0	0.0
Ignition loss 950°C	11.8	12.6
Total	99.63	99.39
Organic carbon, C	0.43	0.33
Carbon dioxide, CO_2	1.43	1.32

x Note: 0.0 indicates less than 0.05 percent.

The loss on ignition (L.O.I.) for the material in the drill cores that were analyzed varied from 0.8 percent to 42 percent. It depends mainly on the abundance of the hydrated aluminum silicates, aluminum hydrates, siderite, and organic material. Of these, the abundance of the clay minerals is usually the most important. The excellent correlation between L.O.I. and the percentage of clay minerals present can be seen in figs. 5 and 6. The relation between L.O.I. and wood is shown in fig. 5, section 5, and in fig. 6, section 9. The correlation between L.O.I. and the presence of siderite is shown in fig. 6, section 10.

Total iron is dependent upon the presence of siderite, limonite, hematite, pyrite, ilmenite, magnetite, and beidellite-nontronite. Because ilmenite and magnetite are not appreciably soluble in H_2SO_4, their presence does not materially affect the percentage of available Fe_2O_3. The correlation of available Fe_2O_3 and siderite is clearly shown in fig. 6, section 10. The relation of available Fe_2O_3 and limonite is shown in fig. 5, section 4. The high available Fe_2O_3 at the base of hole Q-10 (Fig. 6), together with the absence of siderite and limonite, suggests that nontronite is responsible. The highest available Fe_2O_3 in the deposit is 36.2 percent; the lowest, 1.2 percent. The average available Fe_2O_3 for the deposit as a whole is 8.01 percent.

The percentage of total and available Al_2O_3 is dependent upon the abundance of the hydrated aluminum silicates and the aluminum hydrates. Of these the hydrated aluminum silicates are the most important since the aluminum hydrates are present only in minor amounts. The relation between available Al_2O_3 and the clay minerals is shown in figs. 5 and 6. The highest available Al_2O_3 in the deposit is 39.7 percent; the lowest, 0.9 percent. The average available Al_2O_3 for the deposit as a whole is 26.37 percent.

Total SiO_2 depends mainly upon the abundance of the hydrated aluminum silicates and free quartz; total TiO_2, upon the presence of ilmenite; and CaO and MgO, upon montmorillonite. In general, there is an excellent correlation between lithology and mineralogy on the one hand, and chemical composition on the other.

Lithology

The ore is found mainly in the Molalla formation. A small amount is also found in the No. I. Terrace deposit. Lithologically it consists mainly of plastic and semi-flint clay, breccia and weathered silt, sand, and gravel. Interbedded with the ore are silt, sand, and gravel; shale, sandstone, and conglomerate; and wood, together with gritty low-grade clay.

The breccia, which is found mainly in the northern part of the prospected area, is unsorted and unstratified, and in hole H-29 (fig. 6) it is more than 75 feet thick. It contains subordinate wood, angular fragments of volcanic rock, which may be several feet in diameter, clay fragments, and a clayey matrix. The matrix is pink, yellow, red, or brown, and the fragments are red, gray, or black. They are largely unweathered, and it is the presence of the clay matrix, deposited as such, that makes the breccia ore. It is not the highest grade ore, however, because it usually contains less than 25 percent available Al_2O_3. One or more beds of clay or sand are commonly interbedded within the breccia.

A breccia resting on an erosion surface cut in Molalla sandstone is found northeast of the prospected area on the east side of the Molalla river near the bridge. This breccia has been called a Pleistocene glacial till by Mr. Herbert Harper.22/ It is probably equivalent to that found in the prospected area, and the writer is of the opinion that these breccias were deposited as a series of mud flows. They are older than Terrace No. I and are tentatively considered to be units in the Molalla formation. Additional field work may show, however, that these breccias and the low-grade woody sands and gravels, often associated with them, belong to the Boring lavas.

Clay is common in the ore body (figs. 5 and 6). It is predominantly gray, although various shades and combinations of gray, green, yellow, brown, and red are present. The yellow clay is formed mainly from gray clay that has been stained with limonite after deposition. Some of the clay is semi-flint, but much of it is plastic and very tenacious. It contains small siderite concretions, euhedral crystals of ilmenite and magnetite, wood, sand grains, and pebbles, and it often changes color on drying. It is cut by occasional limonite veins and it may be as thick as 60 feet or as thin as an inch or two. The semi-flint clay is well-exposed in Ellis' adit (figs. 5, 6, 7, and 8). It usually contains more than 20 percent available Al_2O_3 and in hole Q-6 (fig. 7) a 10-foot thickness ran 39.7 percent available Al_2O_3. It is found both in the Molalla formation and in the No. I Terrace deposit, although the clay in the Molalla formation is generally higher grade. Petrographic studies by Mr. Victor T. Allen, U. S. Geological Survey, indicate that some of the clay

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22/ Personal communication from Mr. Herbert Harper.

in the Molalla formation is a transported clay.23/ It was probably laid down on flood plains and in lakes associated with them. The clay in the No. I Terrace deposit had a somewhat similar origin.

Decomposed silt, sand, and gravel are also common in the ore body. They are usually various shades and combinations of green and gray, although yellow and brown are not uncommon. Gray decomposed sand and gravel are generally found near the top of a decomposed bed. These often grade downward into greenish-gray and then into green decomposed sand and gravel. The latter in turn grade into green sand and gravel and finally into greenish sandstone or shale. These decomposed sediments are found both in the Molalla formation and in the No. I Terrace deposit. Those in the terrace deposit are almost without exception yellow or brown. Every gradation from completely decomposed, through partially decomposed, to undecomposed silt, sand, and gravel is present. Some of the gravels are so thoroughly altered that pebbles 3 to 4 inches in diameter can easily be cut with a knife. The decomposition is most complete near the top of an altered bed; it decreases with increasing depth. The completely decomposed material may have as much as 35 percent available Al_2O_3; with decreasing decomposition there is a corresponding decrease in available Al_2O_3; and the gray decomposed material is usually higher grade than are the other colors. Some of the decomposed beds are more than 60 feet thick. As many as three superimposed horizons, consisting of decomposed silt, sand, and gravel, separated by clay, shale, sandstone, and other units, have been identified (fig. 6). Their distribution and correlation is shown on figures 5, 6, 7, and 8.

This alteration might have resulted from hydrothermal solutions, from the movement of ground water, or from surface weathering. That it resulted from surface weathering is suggested by the following evidence: (1) No indication of hydrothermal activity has been found in the area. (2) The progressive decrease in degree of alteration with increasing distance from the top of the decomposed bed is suggestive of surface weathering. (3) There is a progressive decrease in available Al_2O_3 with increasing distance from the top of the decomposed horizon. (4) The color changes from gray through green-gray and gray-green to green with increasing depth. (5) It is difficult to account for several zones of alteration and for their characteristics by the movement of ground water. These zones of alteration, therefore, are tentatively considered in this report to be profiles of weathering. No soil zones were found at the top of the profiles. They may have been removed at the drill sites and elsewhere by erosion that might have immediately preceded the deposition of the sediments above the profiles. There is a good correlation of profiles from hole to hole (figs. 7 and 8). That it is not better is due to: (1) The difficulty of recognizing profiles in fine-grained sediments. (2) The destruction of profiles by erosion. (3) The presence in the lower Miocene of high ground water tables and other factors preventing their formation. (4) The presence of material such as quartz sand and clay which cannot be readily altered.

If the rate of weathering in the Molalla area during the lower Miocene was somewhat similar to that during the interglacial stages of the Pleistocene in the Middle West, several hundred thousand years were nec-

23/ Personal communication from Mr. Victor T. Allen, U.S. Geol. Survey.

essary to form these successive superimposed weathering profiles.24/ They represent, therefore, long halts in deposition. This intermittent deposition may have resulted from intermittent volcanic activity or from intermittent diastrophic movements. The presence of gibbsite in these profiles indicates that they were formed, in part at least, under a tropical or subtropical climate. The importance of lower Miocene residual weathering in the formation of this deposit can be appreciated when it is realized that approximately 50 percent of the ore shown in the columnar sections of figures 5 and 6 was formed in this way. These sediments were originally channel deposits. They are not excessively plastic. Some of this material which is classified as ore contains hard unweathered pebbles and solid cores of partially weathered pebbles.

Interbedded with the breccia, clay, and weathered silt, sand, and gravel are shale, sandstone, conglomerate, minor amounts of wood, and unweathered silt, sand, and gravel. The sandstone, shale, and conglomerate are usually green. Colloidal silica formed in the weathering profiles may have been responsible for the lithification of these sediments.25/ The unweathered silts, sands, and gravels are usually gray, yellow, brown, or green.

Stratigraphy

The stratigraphy of the ore body and the distribution and thickness of the ore and overburden are shown in figures 5, 6, 7, and 8. The deposit is composed of discontinuous lenses that are characteristic of fluvial deposits. It varies lithologically and chemically in both horizontal and vertical directions. The horizontal variability is due to the attitude of the beds, the lens-nature of the deposit, and to differential weathering and erosion. It is well-shown by a comparison of holes 5 and L-5 (fig. 5). Hole 5 contains 124 feet of high-alumina clay, whereas, L-5, which is at approximately the same elevation and only 650 feet away, contains only 28.5 feet. The ore varies in thickness because of differential deposition, erosion, and weathering. The greatest thickness measured was 139 feet. In places the overburden is absent; elsewhere it may be scores of feet thick. It consists mainly of silt, sand, gravel, breccia, shale, sandstone, conglomerate, and various kinds of low-grade clay.

Ore Bodies

Based on lithology, stratigraphy, chemistry, location, and on the closeness of the drilling, the deposit is divided into four ore bodies.

The North Ore body is bounded on the east by the Molalla river, on the south by the South Ore body, and on the west and north by arbitrary

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24/ Charles Schuchert and Carl O. Dunbar, Textbook of Geology, Part II, 4th edi., John Wiley and Sons, Inc., New York City, pp. 426-429, 1941.
25/ Clarence S. Ross, Origin and Geometric form of Chalcedony-Filled Spherulites from Oregon, American Mineralogist, Vol. 26, p. 732, 1941.

boundaries controlled by the distribution of the holes (fig. 9). Lithologically it is differentiated from the South and Southwest Ore bodies by the presence of breccia which constitutes approximately 25 percent of the ore. It also contains clay and weathered silt, sand, and gravel, and its average available Al_2O_3 content is approximately equal to that of the South Ore body. It consists of as many as 3 clay horizons that are above a rather prominent bed of shale (figs. 7 and 8).

The South Ore body is bounded on the west by the Southwest Ore body, on the north by the North Ore body, on the east by the Molalla river, and on the south by an area of considerable relief in part covered with Stayton lavas (figs. 1, 3, and 9). Lithologically it is characterized by the absence of breccia and by the presence of clay and weathered silt, sand, and gravel. It consists of one or two clay horizons, usually near the surface, and above a prominent bed of shale (figs. 7 and 8). Its available Al_2O_3 content is somewhat lower than that of the other ore bodies.

The Southwest Ore body is bounded on the south by the valley of Teasel Creek, on the west and north by arbitrary boundaries controlled by the distribution of the holes, and on the east by the South Ore body (fig. 10). Lithologically it is characterized by the absence of breccia, a great thickness of clay, and weathered silt, sand, and gravel. It consists mainly of one massive clay horizon; the overburden is thin; its available Al_2O_3 content is higher than that of any other ore body; but it is not as closely drilled as the other ore bodies.

The Lower Ore body is found beneath a part of the North and South Ore bodies. Twelve holes have been drilled into it and the geology indicates that it is also present beneath 22 shallow holes which did not penetrate it (fig. 11). That part of this ore body for which reserves have been calculated lies above the 420-foot contour and below a prominent bed of shale. It is, therefore, low-lying, both stratigraphically and topographically. It contains clay and weathered silt, sand, and gravel, and is higher grade than either the North or South Ore bodies. Locally it may contain 2 clay horizons, but usually only one, which may be as much as 97 feet thick. (figs. 7 and 8).

Geologic Factors Affecting Mining and Metallurgy

No attempt is made here to discuss thoroughly the mining and metallurgical problems, It does seem fitting, however, to consider briefly the geologic factors which are involved.

It will be more difficult to mine at Molalla during wet weather than at either Castle Rock or Hobart Butte. This is due in part to the fact that some of the Molalla clay is very plastic and tenacious. No great trouble should be experienced with the weathered and unweathered silt, sand, and gravel or with the breccia, shale, and sandstone because they are not excessively plastic.

Another difficulty in mining the Molalla deposit results from the horizontal and vertical variability. The horizontal variability is well-shown in fig. 8, section BB', where analysis shows that shale, breccia, clay, and weathered silt, sand, and gravel will all be encountered on the 470-foot level. The vertical variability is shown on figures 5 and 6. This lithologic variability with its resulting chemical variability will necessitate selective mining. Moreover, some of the sediments that contain less than 20 percent available Al_2O_3, and are therefore not ore, look much like those that contain more than 20 percent available Al_2O_3 and are therefore ore. Many of the large, low-grade fragments which are found in the breccia can be discarded during mining. However, if the breccia is used for ore, the smaller, abundant hard rock, low-grade fragments may present a milling problem. As these low-grade fragments may constitute one-fourth of the total weight, their removal by screening would materially increase the grade of the breccia. Some of the weathered gravels which are classified as ore contain hard unweathered pebbles and solid cores of partially weathered pebbles. Their removal would also increase the grade of this material.

RESERVES

Specific Gravity, Moisture, Analyses, and Grade

Data on apparent specific gravity were obtained for both the overburden and ore. Seven determinations of the apparent specific gravity of the overburden were weighted on a basis of the footage that they represented. The resulting 1.62 figure was used as the specific gravity of the overburden for all of the ore bodies. Because there are many lithologic types in the overburden, it is obvious that it was not accurately sampled. It is unlikely, however, that the figure used for the specific gravity can differ from the true apparent specific gravity of the overburden, when removed during mining, by as much as 20 percent.

Twenty-eight determinations of the apparent specific gravity of the ore were weighted on a basis of the footage that they represented and the 1.65 obtained was used as the apparent specific gravity of the ore in all the ore bodies. The maximum variation of any determination from this average was 15 percent. All the important lithologic types were sampled, so that it seems unlikely that the true apparent specific gravity of the ore, at the time it was sampled, can differ from this figure by as much as 20 percent.

Data on the moisture content of the various ore bodies is found in the following table:

Moisture Data

Ore Body	Percent by Weight	Number of Determinations
Southwest	32.42	Weighted average of 25 determinations
Lower	35.84	" " " 13 "
South	35.97	" " " 21 "
North	33.10	" " " 89 "

The maximum variation of the moisture content of any sampled interval from the accepted value for its ore body is 33 percent. It does not seem likely that the figures used for moisture and specific gravity will together make an error of 20 percent in the dry weight of the ore. The weight of the ore as mined may be somewhat lower or higher than the calculated wet weight, depending upon ground water conditions at the time of mining.

The data on available Al_2O_3 and Fe_2O_3 were used in calculating the grade of the ore body. A study of check analyses indicates that the error in the determinations of available Al_2O_3, for some of the samples, may be as high as 20 percent, although it seems probable that for the samples as a whole the error is very much less. In general, the length of core sampled for available Al_2O_3 and Fe_2O_3 was between 2 and 10 feet, depending upon the homogeneity of the material. The core recovery was between 90 and 100 percent. The average calculated assay for each hole was determined by weighting the individual assays on a basis of the footage they represented. The average grades for the various ore bodies were obtained from the weighted averages of the holes. The grades of the ore bodies are listed in table A.

Cut-offs

The following principles were used in making the cut-offs: (1) Because of the position of the river it was assumed that the mining base will be close to the 420-foot contour. No material below this elevation was therefore included in the ore body (fig. 8, section FF'). (2) Material with 20 percent or more available Al_2O_3 was considered to be ore (figs. 5 and 6). (3) If no assay for a footage interval within an ore body was obtained, it was assumed that the material in this interval had 20 percent available Al_2O_3 and 10 percent available Fe_2O_3. (4) Since wood is a minor constituent of these sediments, no material was discarded because of its presence (figs. 5 and 6). (5) Weathered porphyritic, vesicular, or amygdaloidal lavas, belonging to either the Stayton or pre-Molalla ? flows, were not included in the ore body. Only a small quantity of this type of material was found (figs. 5, 6, 7 and 8). (6) It was assumed that the ore body would be mined selectively and that any bed thicker than 10 feet could either be selected or discarded. Moderately low-grade intervals less than 10 feet thick within the ore body were included with it. However, if this low-grade material and the high-grade material above or below it did not average 20 percent or better, both the low-grade and high-grade material were discarded. (7) Very low-grade intervals within the ore body that were somewhat less than 10 feet thick were discarded together with the footage below them necessary to make a 10-foot minable unit. If the ore added to the very low-grade material to make a minable unit was only a fraction of an assay interval, it was assumed that the part of this interval included with the ore had the same value as the whole of the assay interval. Very high-grade units within waste zones that were somewhat less than 10 feet thick were selected together with the footage below them necessary to make a 10-foot minable unit. If the low-grade material added to the ore was only a fraction of an assay interval, it was assumed that it had the same value as the whole of the interval. (8) If a check assay was available, it was averaged with the original assay to give the accepted value. (9) High-grade material having an overburden three or more times as thick as itself was not considered to be ore. (10) It was assumed that a different type of equipment would be used for removing surface material and that units less than 10 feet could be accepted or rejected.

Area, Volume, Weight, and Grade of the Ore Body

The perpendicular bisector method was used in calculating the volume, weight, and grade of the Southwest, North, South, and Lower (measured ore) Ore bodies. 26/ It was also used to calculate the volume and weight of the indicated ore in the Lower Ore body. No allowance for the slope of the working face was made. The grade of the indicated ore in the Lower Ore body was assumed to be equal to the weighted average of the measured ore in the Lower Ore body.

The boundaries of the Southwest Ore body are: (1) Arbitrary lines controlled by the distribution of the holes. (2) The perpendicular bisectors of lines drawn between certain adjacent holes. (3) The trace of topography and a plane half way between the medial plane and the top of the ore body. The boundaries of the South, North, and Lower Ore bodies are: (1) The perpendicular bisectors of lines drawn between certain adjacent holes. (2) Lines somewhat arbitrarily drawn that are controlled by the distribution of the holes. (3) The trace of the medial plane of the ore body and topography.

The fundamental assumption underlying the perpendicular bisector method is that the ore body has continuity between holes. A study of the stratigraphy of the ore body and of the distance between holes indicates that this is justified. For purposes of calculation, the total thickness of the ore body is considered to extend to the trace of the medial plane of the ore body and topography. This is based on the assumption that the wedge of ore below and outside of the medial line is equal to the wedge of ore that was above and inside of the medial line but that has been eroded away. No great error is involved in this assumption because the slope that cuts the ore body is more or less regular. It is also assumed in the case of the Southwest Ore body that the total thickness of the ore extends to the trace of topography and a plane half way between the medial plane and the top of the ore body. This is a conservative assumption (fig. 10). If it was assumed, however, that the total thickness of the ore extended to the trace of topography and the medial plane of the ore body, as was the case with the other ore bodies, an error would have been introduced as some of the ore would have been included within two prisms of influence.

Although there are many errors involved in calculating volume, it seems likely, however, that the calculated volumes for those ore bodies for which measured ore was estimated will not differ from the true volumes by as much as 20 percent.

26/ Charles F. Jackson and J. H. Hedges, "Metal-Mining Practice", Bull. 419, U. S. Dept. Interior, Bureau of Mines, pp. 68-69, 1939.

The areas, weights, and grades of the ore bodies are found in table A.

Volume and Weight of the Overburden

The perpendicular bisector method was used to calculate the weight of the overburden. No allowance for the slope of the working face was made. The thickness of the overburden at any hole may vary somewhat from that of the average overburden of its area of influence. This is due to topography, stratigraphy, and structure. The variation is not great, however, and it is therefore assumed that the average overburden for any area of influence is equal to the thickness at the hole. The wet weight of the overburden is found in table A.

Measured, Indicated, and Inferred Ore

Measured ore was calculated for the North and South Ore bodies and for a part of the Lower Ore body. Twenty-seven holes were drilled into the South Ore body, which has an area of 159 acres; thus there is one hole on the average for every 5.88 acres. Thirty-two holes were drilled into the North Ore body; it has an area of 169 acres and one hole on the average for every 5.28 acres. Twelve holes were drilled into the Lower Ore body. That part of it for which measured ore was calculated has an area of 80 acres and one hole on the average for every 6.67 acres. These ore bodies are considered to be closely drilled. The distribution, thickness, and grade are therefore known within rather narrow limits, and it is thought that the error in estimating tonnage and grade is less than the 20 percent that has been prescribed as the accuracy for measured ore.

Indicated ore was calculated for the Southwest Ore body and for part of the Lower Ore body. Eleven holes were drilled into the Southwest Ore body, which has a total area of 113 acres and one hole on the average for every 10 acres. This ore body was not so closely drilled as those for which measured ore was calculated and its ore has therefore been classified as indicated. No holes were drilled into that part of the Lower Ore body for which indicated ore was calculated. It is nevertheless classified as indicated ore because this clay horizon was drilled in adjacent areas and because the calculations were based on measurements and assays as well as on geologic interpretations.

High-alumina clay has been found approximately 3 miles southeast of the prospected area on the properties of Messrs. Joseph Zahar and Guy Dibble, on state highway 211 northwest of the prospected area, and elsewhere. Because only a few hundred acres were prospected and because high-alumina clay has been found outside of the prospected area, it is likely that additional drilling will reveal great additional tonnages. These data, together with the general geologic picture, suggest that there may be 50 million wet tons or more of inferred ore in the Molalla district. The high-alumina clay in the Molalla district that can be mined by surface methods has a limited distribution, however, as is indicated by the following: (1) To the south, southeast, and southwest of the prospected area the relief increases and the Stayton lavas cover much of the area. (2) To the southwest the Molalla formation merges into the Butte Creek beds. (3) To the northeast and north the Molalla formation is buried by Boring lavas.

(4) To the east of the Molalla river the topography has considerable relief.

The tonnages and grades of the measured, indicated, and inferred ore are found in table A.

The reserves calculated by the Portland Office of the U. S. Bureau of Mines differ somewhat from those given in the present report. This is due to: (1) Different cut-offs were used. (2) The boundaries of the ore bodies differ. (3) The U. S. Bureau of Mines did not consider the breccia to be ore.

However, the difference in tonnage between the sum of the measured and indicated ore as given in this report and the sum of the measured, indicated, and "excluded upper clay" as calculated by the U. S. Bureau of Mines is only about 15 percent and the difference in grade approximately 5 percent. The reserves as calculated by the U. S. Bureau of Mines and the U. S. Geological Survey are therefore in substantial agreement, as the accuracy of measured ore is specified to be 20% plus or minus.

Relation Between Cut-Offs, Grades, and Tonnages

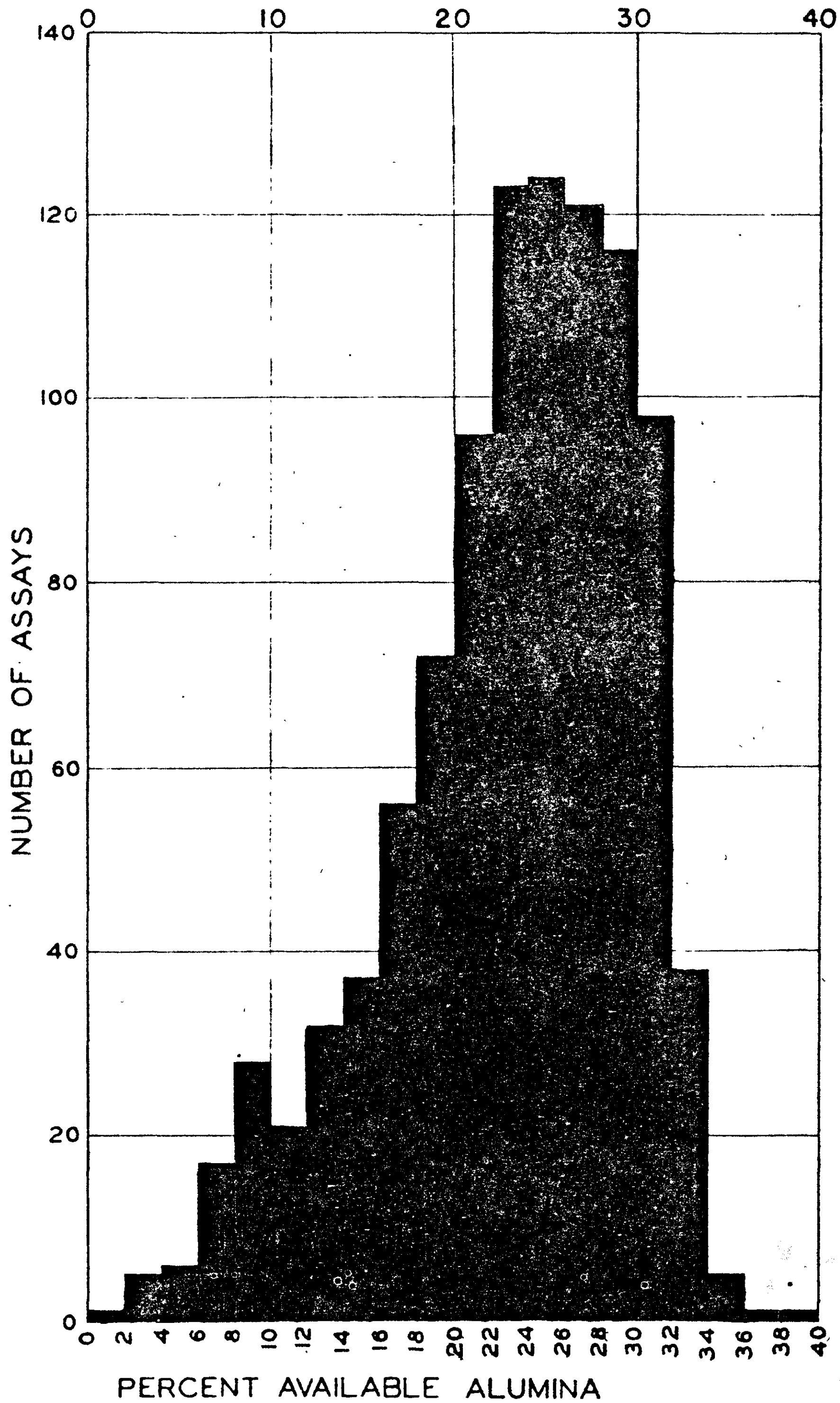
Figure 12 is a graph in which various grades are plotted against the number of assays, of the ore body and overburden, with these grades. It indicates that there is only a small tonnage of ore above 32 percent available Al_2O_3 and that 20 or 22 percent available Al_2O_3 makes a natural cut-off. A 20-percent cut-off was used in the calculations, as indicated above, because, early in the high-alumina clay work, material above 20 percent available Al_2O_3 was defined as ore by the U. S. Bureau of Mines' engineers. From the data shown in figure 12 and from the tonnages of ore and overburden obtained by the perpendicular bisector method with a 20-percent cut-off, grades and tonnages were calculated for various cut-offs running from 20 up to 32 percent available Al_2O_3. These calculations were based on the following simplifying assumptions: (1) The sample lengths are all considered to be equal. (2) The areas of influence are all equal. (3) The specific gravities of all of the overburden and ore are considered to be equal. (4) The moisture contents of the ore and overburden are equal. In other words it was assumed that all assays represent the same weight of material (table B).

That these assumptions result in an error for grade of only one percent is shown by the fact that calculations based on them gave an average available Al_2O_3 content for the whole of the ore body with a 20-percent cut-off of 26.44 percent, whereas, the value obtained by the perpendicular bisector method is 26.37 percent. The error for tonnage should be correspondingly small.

Table B shows that if the cut-off at Molalla is taken at 26 percent, the grade of the ore body is 29.41 percent. There are 25,800,000 dry tons of this material with an average overburden ration of $<1.8 : 1$.

FIGURE 12

NUMERICAL DISTRIBUTION OF AVAIL. ALUMINA ASSAYS
MOLALLA HIGH-ALUMINA CLAY DEPOSIT



MOLALLA HIGH-ALUMINA CLAY DEPOSIT, U. S. Geological Survey
TABLE A SUMMARY OF DATA FOR ORE AND OVERBURDEN

Ore Body	Area Acres	Thickness Ore, feet	Wet Ore Tons	Dry Ore Tons	Avail. Al_2O_3%	Avail. Fe_2O_3%	Thickness Overburden	Overburden Wet, Tons	Ratio to Ore	Over. Thick.
				MEASURED ORE						
South	158.63	32.90	11,712,000	7,499,000	25.29	7.61	21.76	7,602,000	1:	1.51
North	168.81	67.33	25,508,000	17,065,000	25.61	8.21	16.75	6,229,000	1:	4.02
Lower	80.06*	58.38	10,489,000	6,730,000	26.54	6.74	42.49	7,491,000	1:	1.37
Totals & averages		52.17	47,709,000	31,294,000	25.73	7.75	23.76	21,322,000	1:	2.20
				INDICATED ORE						
South-west	112.51	63.76	16,100,000	10,880,000	28.10	9.52	16.77	4,154,000	1:	3.80
Lower	128.83*	34.60	10,003,000	6,418,000	26.54	6.74	40.24	11,417,000	1:	0.86
Totals & averages		48.19	26,103,000	17,298,000	27.52	8.49	29.30	15,571,000	1:	1.64
				TOTAL MEASURED AND INDICATED ORE						
Totals & averages		50.69	73,812,000	48,592,000	26.37	8.01	25.82	36,893,000	1:	1.96

INFERRED ORE

Geologic data suggest that the inferred ore may be 50,000,000 wet tons.

* The Lower ore body is beneath the South and North Ore bodies.

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TABLE B

RELATIONSHIP BETWEEN CUT-OFFS, GRADES, TONNAGES, AND RATIOS OF THE THICKNESS OF OVERBURDEN TO ORE OF THE MOLALLA HIGH-ALUMINA CLAY DEPOSIT

Cut-Offs Avail. Al_2O_3%	Aver. Grade Avail. Al_2O_3%	Ore Dry Tons	Maximum Overburden wet tons	Maximum Ratio overburden to ore thickness
20	26.44	49,000,000	37,000,000	1 : 2.01
by perpendicular bisector method	26.37	48,592,000	36,893,000	1 : 1.96
22	27.28	42,500,000	46,800,000	1 : 1.38
24	28.32	34,200,000	59,400,000	1.15 : 1
26	29.41	25,800,000	72,100,000	1.84 : 1
28	30.53	17,600,000	84,500,000	3.17 : 1
30	31.77	9,700,000	96,500,000	6.57 : 1
32	33.44	3,050,000	106,600,000	23.1 : 1
34	35.86	470,000	110,500,000	155 : 1
36	38.0	140,000	111,100,000	524 : 1
38	39.7	68,000	111,100,000	1,078 : 1
40		0		

CONCLUSIONS, ECONOMIC CONSIDERATIONS, AND RECOMMENDATIONS

Three high-alumina clay deposits in Western Oregon and Washington have been studied and drilled by the U. S. Geological Survey and the U. S. Bureau of Mines. These deposits are near Molalla, Oregon, at Hobart Butte near Cottage Grove, Oregon, and near Castle Rock, Washington. The important features of the Molalla deposit, together with a comparison of it and the other two deposits, follow:

1. There are approximately 49,000,000 dry tons of measured and indicated ore. The reserves of measured and indicated ore at Castle Rock and at Hobart Butte are smaller.

2. The available Al_2O_3 content is 26.37 percent. This is lower than at either Castle Rock or Hobart Butte.

3. The available Fe_2O_3 is 8.01 percent. This is higher than at either Castle Rock or Hobart Butte.

4. Rough calculations indicate that there are at Molalla approximately 26,000,000 dry tons of ore with an average grade of 29 percent and an average overburden to ore ratio of less than 2 to 1.

5. There may be 50,000,000 wet tons of inferred ore. The inferred ore at Molalla is greater than that at either Castle Rock or Hobart Butte.

6. The moisture content is approximately 34 percent. This is considerably higher than at either Castle Rock or Hobart Butte.

7. The ratio of the thickness of the overburden to that of the ore for the measured and indicated ore is 1:1.96. The ratio is somewhat better at Hobart Butte. It is not quite so good at Castle Rock.

8. The deposit is 3 miles from the branch line of the Southern Pacific railroad at Molalla. It is less than 50 miles by rail from the high-alumina clay plant at Salem, Oregon. The Castle Rock and Hobart Butte deposits are more than 50 miles farther from this plant than the Molalla deposit.

9. The presence of unweathered rock fragments in the breccia and of partially weathered pebbles in some of the gravels may necessitate screening before grinding.

The areas immediately to the south and north of the Southwest Ore body appear to offer the best possibilities for the development of additional high-grade reserves.

If high available Fe_2O_3 creates no serious metallurgical problem the Southwest Ore body is the most promising as it has the highest available Al_2O_3 content and an excellent overburden to ore ratio. It was not drilled, however, as closely as the other ore bodies and additional drilling should be carried out before mining.

Respectfully submitted,

Robert L. Nichols
Field Geologist, High-Alumina Clay
U. S. Geological Survey

Eugene, Oregon
April 1, 1944

MAPS IN MAP DRAWER.

Distribution:

U.S.G.S.		U.S.B.M.	
Washington, D. C.	6	Washington, D. C.	1
Spokane	2	Salt Lake City	1
Nichols	2	Portland	1
Hall	1	Popoff	1