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United States Department of the Interior
Geological Survey
Strategic Minerals Investigations

PRELIMINARY REPORT

ON

THE COWLITZ HIGH-ALUMINA CLAY DEPOSIT

NEAR

CASTLE ROCK, COWLITZ COUNTY, WASHINGTON

By

Robert L. Nichols

OPEN FILE

Prepared at Cottage Grove, Oregon

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PRELIMINARY REPORT ON THE COWLITZ HIGH-ALUMINA CLAY DEPOSIT NEAR CASTLE ROCK, COWLITZ COUNTY, WASHINGTON

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CONTENTS

	Page
Abstract	1
Introduction	2
General Geology	4
Early Tertiary Rocks	4
Middle or Late Tertiary Rocks	4
Quaternary Rocks	5
Geomorphology	5
Geologic History	5
Ore Deposits	7
Reserves	10
Specific Gravity, Moisture, Analyses, and Grade	10
Cut-offs	11
Area, Volume, Weight, and Grade of the Ore Body	12
Adjusted Thickness, Volume, and Weight of Overburden	14
Measured, Indicated, and Inferred, Ore	14
Conclusions, Economic Considerations, And Recommendations	17

ILLUSTRATIONS

Figure

1. Index Map of Western Washington and Oregon Bnd in
2. Geologic map showing Areas Prospected
3. Structure Sections of the Cowlitz High-Alumina Clay Deposit
4. Columnar Sections of the Cowltiz High-Alumina Clay Deposit
5. Map of Reserves in Area 1
6. Map of Reserves in Area 2
7. Map of Reserves in Area 2a
8. Map of Reserves in Area 3
9. Map of Reserves in Area 4
10. Map of Reserves in Area 7
11. Graph of the Tonnage of the Ore and Overburden Bnd in
12. Graph of the Grade of the Ore – Bnd in

Table

A. Summary of Data for Ore and Overburden

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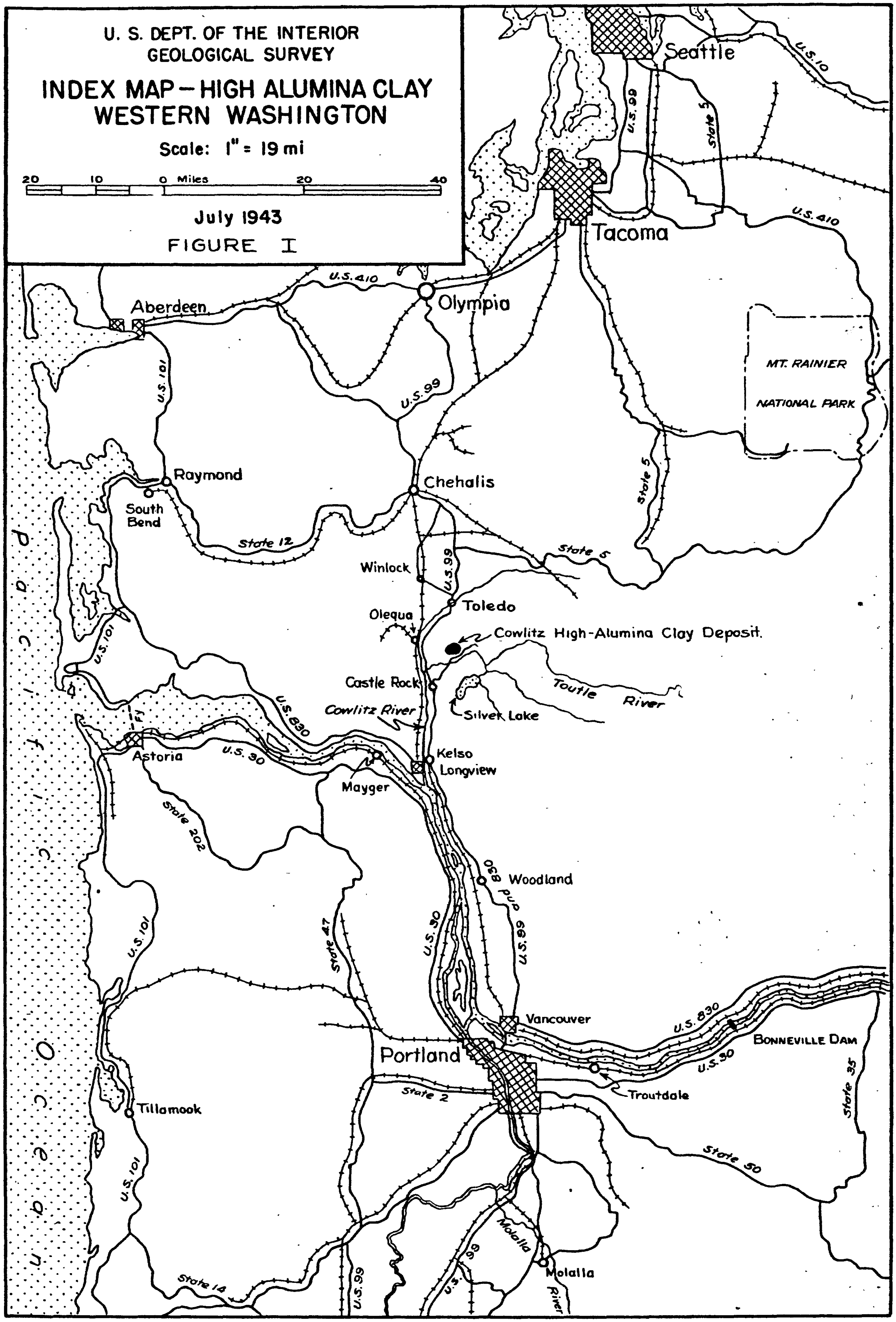
PRELIMINARY REPORT ON THE COWLITZ HIGH-ALUMINA CLAY DEPOSIT NEAR CASTLE ROCK, COWLITZ COUNTY, WASHINGTON

ABSTRACT

The Cowlitz High-Alumina Clay Deposit lies along the north side of the Toutle River in the Olequa Quadrangle, Washington, approximately 7 miles from Castle Rock, Cowlitz County, Washington. Castle Rock is on the Northern Pacific Railroad about 125 miles south of Seattle and 60 miles north of Portland.

The investigation of this deposit was carried out jointly by the U. S. Geological Survey and the U. S. Bureau of Mines. Sixty-seven holes having a total footage of 5,866 feet were drilled. The high-alumina clay is interbedded with marine and continental Tertiary sediments, the 6 ore bodies found by the prospecting are nearly flat-lying, the ore consists mainly of white, grey, and lignitic clay, and the principal ore minerals are kaolinite, gibbsite, montmorillonite, and beidellite-nontronite.

The reserves have been calculated by the perpendicular bisector method. There are 8,634,000 dry tons of measured ore with 30.01 percent available Al_2O_3 and 5.74 percent available Fe_2O_3 and 9,249,000 dry tons of indicated ore with 29.04 percent available Al_2O_3 and 6.26 percent available Fe_2O_3. It is thought that the inferred ore in the district may be between 10 and 20 million tons. The weight of the overburden on the measured ore is 6,670,000 tons and that on the indicated ore is 9,180,000 tons.


U. S. DEPT. OF THE INTERIOR
GEOLOGICAL SURVEY
INDEX MAP — HIGH ALUMINA CLAY
WESTERN WASHINGTON
Scale: 1" = 19 mi
20 10 0 Miles 20 40
July 1943
FIGURE I
Seattle
U.S. 10
U.S. 99
State 5
Tacoma
U.S. 410
Aberdeen
Olympia
U.S. 101
MT. RAINIER
NATIONAL PARK
Raymond
South Bend
Chehalis
State 12
State 5
Winlock
Toledo
Olequa
Cowlitz High-Alumina Clay Deposit
Castle Rock
Toutle River
Silver Lake
Cowlitz River
U.S. 830
Pacific Ocean
Astoria
U.S. 30
Kelso
Longview
Mayger
State 202
Woodland
U.S. 99 and 830
State 47
U.S. 30
Vancouver
Portland
Bonneville Dam
Troutdale
State 35
State 2
Tillamook
State 50
Molalla River
Molalla
U.S. 99
State 14

INTRODUCTION

The Cowlitz High-Alumina Clay Deposit lies along the north side of the Toutle River in the Olequa Quadrangle, Washington. It is in T. 10 N., R. 1 and 2 W. and is approximately 7 miles from Castle Rock, Cowlitz County, Washington. Castle Rock is on the Northern Pacific Railroad about 125 miles south of Seattle and 60 miles north of Portland (fig. 1). Glover 1/ and Hodge 2/ have briefly described this deposit. The ceramic and chemical data in their papers led to the present investigation which was carried out jointly by the U. S. Geological Survey and the U. S. Bureau of Mines.

Sixty-seven holes were drilled by the U. S. Bureau of Mines between June 1, 1942 and June 21, 1943. The shallowest hole was 18.4 feet, the deepest 170.8 feet, and the total footage was 5,866.1 feet. Drive-pipe sampling with churn drill equipment was used and there was practically a 100 percent core recovery. Most of the cores were 4 inches in diameter although a small percentage were 6 inches.

The geology of sections 16, 20, 18, 17, 19, and 7 of T. 10 N., R. 1 W. and section 24 of T. 10 N., R. 2 W. was mapped by the writer as the basis for the drilling program. On section 20, T. 10 N., R. 1 W. there are two clay pits out of which Gladding, McBean and Co. have taken several thousand tons of refractory clay. The area around these pits was the site originally selected by the U. S. Bureau of Mines for drilling. Several other areas were found

1/ Sheldon L. Glover, Clays and Shales of Washington, State of Washington, Dept. of Conservation and Development, Division of Geology, Bull. No. 24, pp. 81-83, 1941.

2/ Edwin T. Hodge, Market for Columbia River Hydroelectric Power Using Northwest Minerals, Section IV-Northwest Clays, Vol. III, pp. 784-794, 1938.

in the course of the geologic mapping, and all were drilled. In addition to the mapping and selection of prospecting areas drill cores were described and information was furnished to the Bureau engineers which was of value in the prospecting program.

In the present report the general geology and the characteristics of the ore body are briefly considered, the reserves of the Cowlitz High-Alumina Clay Deposit are given, and the method of calculation is outlined.

All of the assays, moisture and specific gravity determinations, and most of the lithologic descriptions used in this report were obtained from the U. S. Bureau of Mines. The maps are based on surveys by Pope and Talbot, Inc. and the U. S. Bureau of Mines.

The writer takes pleasure in acknowledging the help and many courtesies received from Messrs. C. C. Popoff, Project Engineer, and C. P. Purdy, Jr., Assistant Engineer, of the U. S. Bureau of Mines. Special mention should also be made of the efficient help and loyal coöperation of Mr. Wayne Hall of the U. S. Geological Survey. Mr. Hall was stationed at Castle Rock, Washington, from April to September, 1943. He helped the writer in the calculation of reserves, in making columnar sections, and in many other ways. Thanks are also due to Mr. Victor T. Allen and Mr. John J. Collins, both of the U. S. Geological Survey, for their interest in the work, for many stimulating discussions in the field, and for suggestions and help in the preparation of the manuscript and maps. The drafting was done by Mr. Philip I. Conley of the U. S. Geological Survey.

GENERAL GEOLOGY

Early Tertiary (?) Rocks

Marine conglomerates, sandstones, and shales; tuffs, breccias, agglomerates, and interbedded flows; terrestrial conglomerates and sandstones; and silt, sand, lignite, and high-alumina clay have been found in the district (fig. 2). These rocks are more than 500 feet thick and they have been folded into broad open anticlines and synclines, the dips of which in general are less than 10 degrees. They are tentatively correlated with Eocene and Oligocene rocks near the Buswell farm, T. 11 N., R. 2 W., N.W. 1/4 Sec. 25, 5 miles to the northwest 3/. The ore bodies in areas 1, 2, 2-a, 3, 4 (lower bed), and 4 (upper bed) are interbedded in these Early Tertiary Rocks. Little is known about the distribution of these high-alumina clays outside of the prospected areas. Similar clays have been found, however, near Winlock, Toledo, and Silver Lake, Washington, so that it seems reasonable to suppose that additional tonnage might be proved by further drilling.

Middle or Late Tertiary (?) Rocks

A vesicular basalt and a porphyritic basalt or andesite bury part of the Early Tertiary high-alumina clay (fig. 2). Both the porphyry and the vesicular basalt are more than 100 feet thick. The ore body in area 7 is thought to rest in part on a weathering profile developed on the porphyry. It consists of lignite, high-alumina clay, and other sediments and it may be as much as 100 feet thick. Little is known about the distribution or attitude of this clay series.

3/ Charles E. Weaver, Tertiary Stratigraphy of Western Washington and Northwestern Oregon, Univ. of Washington Publications in Geology, Volume 4, plates 4 and 8, 1937.

No definite data were obtained on the age of these rock units, although assigning them to the Middle or Late Tertiary seems reasonable.

Quaternary Rocks

Stream gravels were deposited and fans, mud flows, and landslides were formed during this period. The landslide deposits are as much as 50 feet thick in area 1 and they rest, in part, on high-alumina clay.

Geomorphology

The ore bodies in areas 1, 2, 2a, 3, 4 (lower bed), and 4 (upper bed) are in a maturely dissected area with a relief of approximately 500 feet (fig. 2). The presence of this type of topography makes these ore bodies limited in extent and tonnage. The ore body in area 7 (fig. 2), on the other hand, is located on an extensive flat which is about 150 feet above the Toutle River. This type of topography makes possible the existence of great tonnages of high-alumina clay in this area.

Geologic History

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

Early Tertiary (?) 1. Sedimentation

deposition of marine conglomerate, sandstone, and shale;
" " breccia and agglomerate;
" " terrestrial conglomerate and sandstone; and extrusion of interbedded flows.

2. Erosion and weathering

weathering profile developed on breccia which is immediately below the high-alumina clay in areas 1, 2, 2a, 3, and 4 (lower bed) (fig. 2).

3. Sedimentation

deposition of source material for lignite;

" " high-alumina clay in areas 1, 2, 2a, 3, and 4 (lower bed);

" " sand, silt, and high-alumina clay in 4 (upper bed).

Middle or Late Tertiary (?)

4. Diastrophism (?)

5. Short period of erosion (?)

6. Extrusion of vesicular basalt

7. Erosion

cutting of valleys several hundred feet deep.

8. Extrusion of porphyry

9. Erosion and weathering

weathering profile developed on porphyry.

10. Sedimentation

deposition of source material for lignite;

" " high-alumina clay in area 7; and

" " other sediments.

Quaternary

11. Erosion and deposition of upper stream gravels

12. Erosion

13. Clay in part calcined

14. Clay fan, landslides, and mud flows

15. Deposition of lowest stream gravels

16. Erosion of lowest stream gravels

formation of terraces, meander scars, etc.

Such a complicated erosional, depositional, and igneous history, of course makes ~~prospecting difficult.~~

ORE DEPOSITS

The ore in areas 1, 2, 2a, 3, and 4 (lower bed) all belongs to the same horizon, the ore in area 4 (upper bed) is stratigraphically between 100 and 200 feet above this main clay horizon, and the clay in area 7 is considered to be much younger than either of these beds (figs. 2 and 3).

The ore bodies consist mainly of lignitic, grey, white, silty, sandy, pebbly, and sideritic clay together with lignite and breccia (fig.4). Most of the clay is semi-flint although plastic clay is found in area 4 (upper bed) and as a thin veneer on top of some of the flint clay. Ovaloid clay pellets are common and a small amount of the clay has been calcined by the burning of lignite. The ore varies in thickness because of differential erosion and deposition. The greatest thickness measured was 67.2 feet. The ore body in areas 2, 2a, and 3 dips gently to the north, it is nearly horizontal in area 4, and it dips to the northeast in part of area 1 (figs. 2 and 3). These dips are in part diastrophic, in part initial.

The thickness of the overburden on the various ore bodies varies greatly. In places it is only a few feet, elsewhere it may be as much as 104.6 feet (figs. 3, 5, 6, 7, 8, 9, 10). It consists mainly of lignite, basalt drift, basalt in place, landslide material, sand, silt, gravel, soil, and various kinds of low-grade clay.

Kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$), montmorillonite (perhaps $(Mg,Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot nH_2O$), gibbsite ($Al_2O_3 . 3H_2O$), and beidellite-nontronite ($Al_2O_3 . 3SiO_2 . 3H_2O$-$Fe_2O_3 . 3SiO_2 . 2H_2O$) have been identified petrographically by Victor T. Allen of the U. S. Geological Survey 4/.

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

Joseph A. Pask of the Northwest Experiment Station of the U. S. Bureau of Mines has identified by thermal analysis the above minerals together with halloysite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) 5/. With this mineralogical composition it is not surprising that some of the ore has a pyrometric cone equivalent of 36 6/. Siderite ($FeCO_3$) is disseminated through some of the clay as small oolites approximately 1/10 inch in diameter. It is also found as large concretionary masses as much as one foot in diameter. Limonite ($2Fe_2O_3 \cdot 3H_2O$) stains much of the clay, especially that near the surface, and it also occurs in solid masses which have resulted from the oxidation of the siderite concretions. A small amount of hematite (Fe_2O_3) is found in the calcined clay. It resulted from the oxidation of siderite oolites under high temperature, near burned lignite beds.

The ore in areas 1, 2, 2a, 3, and 4 (lower bed) rests on a water-laid breccia on which a weathering profile was developed before the deposition of the clay. The high-alumina clay is mainly of sedimentary origin. Some of it may have been derived from that part of the weathering profile, developed on the breccia and probably on other rocks, which was outside of the area where the clays were deposited. The presence of decomposed gravels, sands, and silts, and of gibbsite, which according to Victor T. Allen, of the U. S. Geological Survey, was formed in situ, indicates that residual weathering, in part under a warm moist climate, was also a factor in the development of the deposit 7/. It is in part a stream deposit, in part a swamp deposit, and some of it, especially the fine grained facies, may be of lacustrine origin.

5/ Personal communication from Mr. Wayne Hall, U. S. Geol. Survey.

6/ Personal communication from Mr. Gordon Adderson of Gladding, McBean and Co.

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

The ore body in area 7 is a transported clay and it may have been derived from the erosion of the Early Tertiary high-alumina clays and from that part of the weathering profile, developed on the porphyry and on other rocks, which was outside of the area where these clays were deposited.

RESERVES

Specific Gravity, Moisture, Analyses, and Grade

Data on apparent specific gravity were obtained for both the overburden and ore. Fifteen determinations of the apparent specific gravity of the overburden were weighted on a basis of the footage which they represented. The resulting 1.71 was used as the specific gravity of the overburden for all of the areas. The maximum variance of any hole from this average was 13 percent. Sixty-four determinations of the specific gravity of the ore in areas 2 and 4 (lower bed) were weighted and the 1.82 obtained was used as the specific gravity of the ore in areas 1, 2, 2a, 3, and 4 (lower bed). The greatest variance of any hole from this average was 13 percent. Based on 4 determinations, 1.86 was used as the specific gravity of area 7 and 1.68 obtained from one determination was used for area 4 (upper bed). It seems doubtful if the figure used for areas 2 and 4 (lower bed), for which measured ore was calculated, can differ from the true specific gravity by as much as 10 percent.

Seventy determinations of the moisture content of the ore in areas 2 and 4 (lower bed) were weighted and the 26.00 percent obtained was used for the ore in areas 1, 2, 2a, 3, and 4 (lower bed). In this case the maximum variation of any hole from the average was 26 percent. Based on 8 determinations, 26.4 percent was used as the moisture content of the ore in area 7 and 34.2 percent obtained from one determination was used for area 4 (upper bed). The figures used for the moisture content of the ore might be in error as much as 10 percent.

Nearly 3,000 chemical determinations were made of the Cowlitz High-Alumina Clay by the Salt Lake, Seattle, and Reno laboratories of the U. S. Bureau of Mines. The determinations included total Al_2O_3,

Fe_2O_3, TiO_2, and SiO_2, loss on ignition, and available Al_2O_3 and Fe_2O_3. The available Al_2O_3 is usually between 80 and 90 percent of the total Al_2O_3. It is the percentage by weight which is obtained by a 20 percent solution of H_2SO_4 in one hour on clay calcined to 700°C. The available Al_2O_3 is calculated on the weight of the sample after drying at 130°C. The data on available Al_2O_3 and Fe_2O_3 were used in calculating the grade of the ore body.

On the basis of a study of check analyses, the error in the determinations of available Al_2O_3, for some of the samples, may be as high as 10 percent, although it seems probable that for the samples as a whole the error is 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 average calculated assay for each hole was determined by weighting the individual assays on a basis of the footage which they represented. This weighted calculated average was arithmetically averaged with the chemical composite assay of the hole and this figure, the accepted average grade of the hole, was used to calculate the grade of the ore body. There is no appreciable error involved in the calculation of grade because of poor core recovery. The accepted average grades for the various ore bodies are listed in table .

Cut-offs

The following principles were used in making the cut-offs: (1) Material with about 20 percent or more available Al_2O_3 was considered to be ore. (2) Material with more than 20 percent available Fe_2O_3 was not considered to be ore. (3) Where no assay for a footage interval was obtained, it was assumed that the material in this interval had zero percent available Al_2O_3. (4) Where lignite was near the top or the bottom of the ore body, it and the intervening material was cut out. This procedure was followed because of the possibility that lignite might present some difficulties in the calcining process. (5) Small low-grade intervals within the ore body were included with it because of the difficulty and cost of selectively mining such units. 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. (6) Material which contained only slightly more than 20 percent available Al_2O_3, but with 15 percent or more Fe_2O_3 was not considered to be ore. There is, however, very little of this material.

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

The perpendicular bisector method was used in calculating the volume, weight, and grade of the ore body 9/. The boundaries of the ore bodies are: (1) The trace of the medial plane of the ore body and topography. (2) Lines which connect points having a 1:1 and 2:1 overburden to ore ratio. (3) Lines controlled by the marginal holes. These lines were located by means of a consideration of overburden to ore ratios and of the size of areas of influence. The areas of influence of the holes are bounded by these lines and by the perpendicular bisectors of the lines drawn between adjacent holes.

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

The fundamental assumption underlying the perpendicular bisector method is that the ore body has continuity between holes. That this assumption is justified in the present case is indicated by the following: (1) A preliminary study of the correlation between holes. (2) The grade of the ore in the various holes is nearly the same. (3) The thickness of the ore in the various holes is nearly the same, except where erosion has reduced its thickness. (4) The holes are only a few hundred feet apart. For purposes of calculation the total thickness of the ore body was considered to extend to the trace of the medial plane of the ore body. 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 which was above and inside of the medial line but which has been eroded away. No great error is involved in this assumption as the slope which cuts the ore body is more or less regular.

Volumes were calculated separately for the areas where the ratio of the overburden to ore is less than 1:1 and where the ratio is less than 2:1 but more than 1:1 (fig. 5). 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 more than 10 percent. A tonnage factor for the ore was calculated. The wet weight of the ore was obtained by dividing the volume by this factor. The moisture factor was calculated as follows:

$$\text{Moisture factor} = 100\% - \%\ \text{moisture}$$

The dry weight of the ore was calculated by multiplying the wet weight by the moisture factor. The average grade of each hole multiplied by the dry weight of its prism gave tons-percent. The sum of the tons-percent of all the prisms divided by the sum of the dry weights gave the average grade of the ore body. The areas, weights, and grades of the ore bodies are found in table A.

Adjusted Thickness, Volume, and Weight of the Overburden

The thickness of the overburden at any hole may vary greatly from the average overburden of its area of influence. This is due in large part to topography. In those areas where the clay crops out on a slope, some of the overburden has been removed by erosion and the average overburden for the area is less than that at the hole. On the other hand where the area of influence extends up a slope from its hole, the overburden is increased, and the average for the area will be more than that at the hole (fig. 5). An adjusted overburden, approximately equal to the average overburden, was therefore calculated which was based on the overburden at the hole and on the influence of topography on the thickness of the overburden. The adjusted overburden for any area of influence times its area gives the volume. A tonnage factor for the overburden was calculated and the wet weight of the overburden was obtained by dividing the volume by its tonnage factor. The adjusted overburden and the wet weight of the overburden are found in table A.

Measured, Indicated, and Inferred Ore

Measured ore was calculated for areas 2 and 4 (lower bed) (figs. 6 and 9; table A). In area 2 there is one hole on the average for every 4.13 acres and in area 4 (lower bed) one hole for every 3.95 acres. These areas are closely drilled. The distribution, thickness, and grade of the ore bodies 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 which has been prescribed as the accuracy for measured ore.

Indicated ore was calculated for area 4 (upper bed) because: (1) Only one determination of specific gravity was made for this ore body. (2) Only one determination for moisture was obtained. (3) It was not as closely drilled as were the areas for which measured ore was calculated. (4) Only 4 holes were drilled into this clay horizon. (5) This clay bed varies considerably in thickness along the strike.

No specific gravity or moisture determinations were made for area 3 and it was not so closely drilled as were those areas for which measured ore was calculated. Moreover the geology of hole 63 suggests that an undetermined volume of this ore body could have been removed by faulting or erosion. The reserves, therefore, may not be so large as the calculations indicate. The material in hole 8, however, correlates rather well with that in hole 9. For these reasons the ore in this area has been classified as indicated ore.

The ore in area 7 has been classified as indicated ore because: (1) Only 4 holes were drilled into this ore body; (2) The ore body varies greatly in thickness; (3) The boundary lines are not so accurately located as in the areas for which measured ore was calculated.

The reserves for areas 1 and 2A are not known so accurately as those for areas 3 and 7. The ore in areas 1 and 2A is nevertheless classified as indicated ore as the calculations for these areas are based on specific measurements, many assays, and good topographic maps as well as on geologic interpretations.

The tonnages of the measured ore, indicated ore, and overburden are shown in figure 11 and the grade of the ore in figure 12.

The grades, tonnages, and ore classifications are in very close agreement with those originally made by Mr. C. C. Popoff, project engineer for the U. S. Bureau of Mines at Castle Rock, and in substantial agreement with the final calculations of the Salt Lake Office of the U. S. Bureau of Mines.

High-alumina clay has been found at Buswell's farm about 5 miles northwest of the area drilled, near Winlock, Washington, about 10 miles to the northwest, on Taylor Brothers' property 4 miles to the northwest, on Brown's farm and on Graham's coal property both of which are about 10 miles to the northeast, and near Silver Lake, Washington, about 5 miles southeast. These data together with the general geologic picture and the fact that only a small area has been mapped suggest that there may be between 10 and 20 million tons of inferred ore in the Castle Rock district, in addition to the measured and indicated ore.

CONCLUSIONS, ECONOMIC CONSIDERATIONS, AND RECOMMENDATIONS

Due to the scarcity of domestic bauxite 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 U. S. Geological Survey and the U. S. Bureau of Mines. Three deposits have been studied and drilled in Western Oregon and Washington. These deposits are near Molalla, Oregon, at Hobart Butte near Cottage Grove, Oregon, and near Castle Rock, Washington. The important features of the Cowlitz High-Alumina Clay Deposit near Castle Rock, Washington, are:

1. There are approximately 18,000,000 dry tons of measured and indicated ore. The reserves at Molalla are greater, those at Hobart Butte somewhat less.

2. The available Al_2O_3 content is 29.51 percent. This is considerably higher than at Molalla and approximately the same as at Hobart Butte.

3. The available Fe_2O_3 content is approximately 6 percent. This is much higher than at Hobart Butte but less than at Molalla.

4. The moisture content is approximately 26 percent. This is lower than at Molalla--considerably higher than at Hobart Butte.

5. Most of the ore has an overburden to ore ratio of less than 1:1. The ratio is somewhat better at Hobart Butte. It is about the same at Molalla.

6. The deposit is 5 miles from the main line of the Northern Pacific Railroad and from U. S. Highway 99. It is approximately 20 miles from tidewater at Longview, Washington.

7. It is centrally located with regard to the aluminum plants at Longview, Troutdale, Vancouver, and Tacoma.

8. There is an excellent plant site 5 miles from the deposit. This site is on U. S. Highway 99 and on the main line of the Northern Pacific Railroad. There is adequate electric power and the water necessary for an alumina from clay plant is available. There are many plant sites within 20 miles of the deposit.

Closer drilling of the known ore bodies could be carried on by the U. S. Bureau of Mines without additional field work by the U. S. Geological Survey. It is recommended, however, that no other drilling be initiated in the Castle Rock district before additional field work has been done by the Survey.

Respectfully submitted,

ROBERT L. NICHOLS
Field Geologist for High-Alumina Clay
U. S. Geological Survey

Cottage Grove, Oregon
October 20, 1942

COWLITZ HIGH-ALUMINA CLAY DEPOSIT, U. S. GEOLOGICAL SURVEY

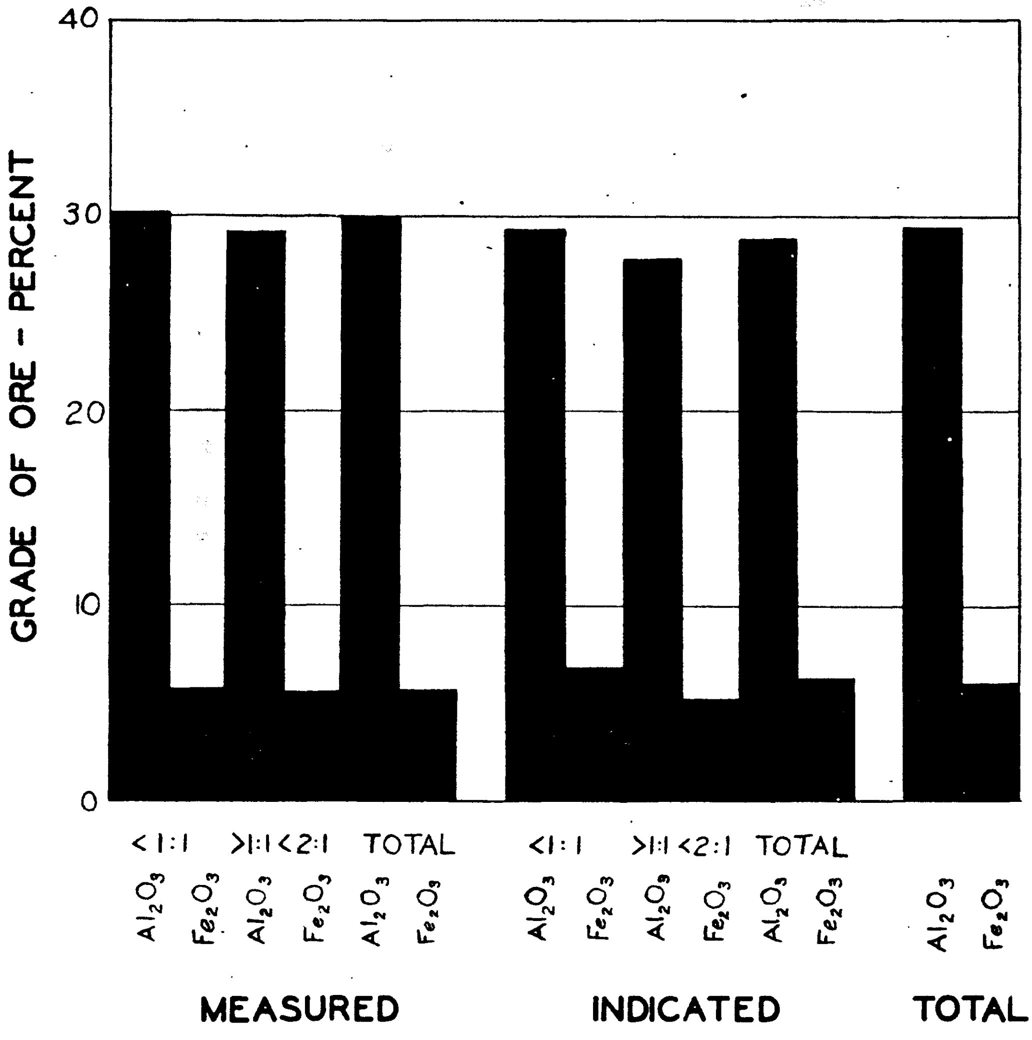
TABLE A SUMMARY OF DATA FOR ORE AND OVERBURDEN

Area No.	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 Overburden to Ore Thickness
MEASURED ORE									
Ratio of overburden to ore is less than 1 to 1:									
2	65.64	43.55	7,074,000	5,235,000	30.53	5.93	16.1	2,467,000	1 : 2.70
4 (lower)	23.33	40.02	2,311,000	1,710,000	29.27	5.44	19.9	1,082,000	1 : 2.01
Totals & Avgs.	88.97	42.63	9,385,000	6,945,000	30.22	5.81	17.13	3,550,000	1 : 2.49
Ratio of overburden to ore is greater than 1 to 1 but less than 2 to 1:									
2	8.61	46.56	992,000	734,000	29.85	5.84	69.1	1,386,000	1 : 0.67
4 (lower)	12.22	42.69	1,291,000	955,000	28.60	5.14	61.0	1,735,000	1 : 0.70
Totals & Avgs.	20.83	44.29	2,283,000	1,689,000	29.14	5.44	64.33	3,121,000	1 : 0.69
Total Measured Ore	109.80	42.94	11,668,000	8,634,000	30.01	5.74	26.08	6,670,000	1 : 1.65
INDICATED ORE									
Ratio of overburden to ore is less than 1 to 1:									
1	30.02	34.56	2,568,000	1,900,000	28.80	5.55	20.23	1,415,000	1 : 1.71
2-A	26.00	47.67	3,068,000	2,270,000	29.94	5.70	25.36	1,536,000	1 : 1.88
3	20.40	23.89	1,206,000	893,000	32.00	10.47	3.35	159,000	1 : 7.13
4 (upper)	14.00	33.08	1,056,000	695,000	27.82	9.96	18.0	588,000	1 : 1.83
7	17.05	36.56	1,575,000	1,160,000	27.52	5.54	24.59	976,000	1 : 1.49
Total & Avgs.	107.47	35.8	9,473,000	6,918,000	29.27	6.68	18.7	4,674,000	1 : 1.91
Ratio of overburden to ore is greater than 1 to 1 but less than 2 to 1:									
1	12.78	37.00	1,170,000	866,000	27.30	3.35	55.55	1,653,000	1 : 0.67
2-A	14.27	47.73	1,685,000	1,247,000	29.34	5.55	71.59	2,379,000	1 : 0.67
4 (upper)	4.41	33.00	332,000	218,000	26.66	8.70	46.1	473,000	1 : 0.72
Totals & Avgs.	31.46	41.3	3,187,000	2,331,000	28.33	5.03	61.5	4,505,000	1 : 0.67
Total Indic. Ore	138.93	37.07	12,661,000	9,249,000	29.04	6.26	28.37	9,180,000	1 : 1.31

INFERRED ORE

Geologic data suggest that the inferred ore may be between 10 and 20 million tons

FIGURE 12



COWLITZ HIGH - ALUMINA CLAY DEPOSIT

GRADE OF ORE

$<1:1$ - Overburden to ore ratio

$>1:1 <2:1$ - Overburden to ore ratio

Grade - Available Al_2O_3 and Fe_2O_3