UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

BUREAU OF MINES
R. R. Sayers, Director

War Minerals Report 8

MOLALLA CLAY

CLACKAMAS COUNTY, OREG.

Supplement to War Minerals Report 7

Aluminum

WASHINGTON: 1943

The War Minerals Reports of the Bureau of Mines are issued by the United States Department of the Interior to give official expression to the conclusions reached on various investigations relating to domestic minerals. These reports are based upon the field work of the Bureau of Mines and upon data made available to the Department from other sources. The primary purpose of these reports is to provide essential information to the war agencies of the United States Government and to assist owners and operators of mining properties in the production of minerals vital to the prosecution of the war.

WAR MINERALS REPORT

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

W.M.R. 8 - Aluminum	August 1943

MOLALLA CLAY

Clackamas County, Oreg.

Supplement to W.M.R. 7

SUMMARY

The Molalla clay deposit is in the west central part of Clackamas County, Oreg., a short distance south of the town of Molalla. The Bureau of Mines drilled on the most favorable areas from October 1942 to January 1943, and as a result an estimated 29,680,000 tons of high-alumina clay with a moisture content of 34 percent was indicated. The indicated tonnage, calculated on a dry basis, is 19,589,000 tons of clay containing 25 percent available alumina and 8.05 percent available Fe_2O_3. The ratio of waste to clay is 1 to 5.4. An additional 12,750,000 tons of clay containing 27 percent available alumina and 7 percent available Fe_2O_3 is indicated, but for lack of exploration this reserve is classified as inferred and is not included in the calculations.

An excellent plant site lies directly north of the clay area within half a mile of the Molalla River. The river is estimated to contain enough water the year around to supply all requirements in the production of alumina. A 57,000-volt power line of the Portland General Electric Co. passes within 2 miles of the plant

site, and the Bonneville Power Administration has a 110,000-volt power line 17 miles distant. Molalla is on a branch line of the Southern Pacific Railroad. Additional railroad facilities could be obtained by rebuilding a spur track to the plant and clay area on a grade formerly utilized in logging operations.

Mining and plant operation would require the construction of houses and the importation of labor, as neither is available.

The most important factor in processing the clay is fuel. About 3 tons of coal is required per ton of alumina produced. Several coal-producing areas in Oregon and Washington may produce additional coal. It is estimated that Washington coal could be delivered for $6.22 to $7.41 a ton. A thorough study should be made of the coal resources within shipping distance of Molalla to determine if an adequate supply can be obtained.

The Molalla deposit is located favorably to supply alumina to all or any one of the five aluminum-reduction plants in Washington and Oregon.

INTRODUCTION

Owing to the exigencies of war, the present demand for aluminum is great, and the relatively limited domestic reserves of commercial bauxite are being depleted rapidly to supply it. It is possible that at the present rate of consumption many, if not all, of the deposits will be exhausted in 2 or 3 years, so that it is imperative to investigate other types of aluminum-bearing deposits.

The Oregon State Department of Geology and Mineral Industries described the occurrence of refractory clays in western Oregon.[1] The United States Army Engineers also have made a study of the northwest clays. The Molalla deposit is described in both of these reports.

1 Wilson, Hewitt, and Treasher, R. C. Preliminary Report on Some of the Refractory Clays of Western Oregon: Oregon State Dept. of Geol. and Min. Ind., Bull. 6, 1938.

This deposit was chosen for investigation as a possible source of alumina because of the following favorable factors that would have an important bearing on the ultimate cost of producing aluminum therefrom: (1) Proximity to a railroad, (2) proximity to an ample supply of water (the Molalla River), (3) proximity to electric-power facilities, and (4) proximity to aluminum-reduction plants at Troutdale, Oreg., and Vancouver, Tacoma, and Longview, Wash.

The Bureau's preliminary investigation was made in cooperation with the Federal Geologic Survey. A geological map of the Molalla area by W D. Wilkeson of the Department of Geology, Oregon State College, and a topographic map by the United States Army Engineers were helpful. The Bureau prospected by hand augering and found a favorable area in parts of secs. 15, 16, 21, 22, 27, and 28, T.5 S., R.2 E., of the Willamette meridian, which was recommended for extensive drilling. A project to explore this area by core drilling with drive-pipe equipment was initiated in October 1942 and completed in January 1943.

The area machine drilled, which is privately owned, is contained in secs. 21, 22, 27, and 28, T.5 S., R.2 E. Names of owners, acreage owned by each within the area explored, and number of drill holes put down on each property are given below:

Owner	Section	Acreage	Drill holes
L. L. Ellis	27	80	6
P. J. Kaylor	27	75	4
F. G. Dougherty	27	74	6
O. R. Dougherty	27	20	1
L. W. Sawtell	27	90	3
D. Miller	28	90	1
O. K. Bell	28	240	1
B. Dixon	21	50	1
F. Muller	22	148	7
A. Shaver	22	71	3
F. E. Lay	22	80	2
C. E. and C. W. Lay	22	140	6
T. Kyllo	22	105	1
On Ostrander Lumber Co. railroad grade	15	--	2
On Clackamas County roads	--	--	5
			49

Five holes were also drilled along the county roads in the vicinity of these properties. Other properties were not intensively drilled owing to unfavorable results obtained or to the necessity for concentrating the exploration in favorable areas indicated by the first preliminary holes.

HISTORY

Beds of refractory clays have long been known to exist in the Molalla area. According to reports, the Dibbles clay deposit in the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 1, T.6 S., R.2 E. of the Willamette meridian was developed earliest and perhaps most extensively. Development is reported to have consisted of several adits and a shaft, which have long since caved. Another deposit, the Ellis clay mine, in the northeast corner of NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 27, T.5 S., R.2 E., has been exposed by a short adit.

Several unsuccessful attempts have been made to utilize these clays in the manufacture of pottery. Their unsuitability for any but heavy, cheap ceramic products was given as the reason for these failures. However, small quantities of brick and tile were made from these clays at Mulino, Oreg.

The use of high-alumina clays in making alumina for reduction to aluminum has been the object of many experiments. In the course of building the Bonneville Dam, the United States Army Engineers conducted a widespread investigation of the mineral and other natural resources of the Pacific Northwest. One of their reports, "Market for Columbia River Hydroelectric Power Using Northwest Minerals, Northwest Clays," by E. T. Hodge, consulting geologist, describes the known processes for obtaining alumina from clays. Several processes for obtaining alumina from clays have resulted from investigations in the United States in recent years. Only the most important developments based upon Northwest clays are mentioned here.

For more than 2 years the Salt Lake City Station of the Bureau of Mines has conducted metallurgical tests on extraction of alumina from clays. A suitable process developed is now being tested further in a pilot plant at the Boulder City (Nevada) Experiment Station. The Chemical Construction Co., a subsidiary of American Cyanamid Co., also has developed a process similar to that of the Bureau of Mines. The Kalunite Corporation, a subsidiary of Olin Corporation, has adapted its process for treating alunite to the treatment of clays. This corporation has shipped several carloads of Molalla clay to their Salt Lake City pilot plant for treatment.

PHYSICAL FEATURES

The town of Molalla and the area investigated lie at the eastern edge of the Willamette Valley. The entire prospected and explored area is farm land, on most of which very little timber remains. Its surface is gently irregular and it slopes to the northwest. Altitude ranges from 700 feet at the southeast to 450 feet in the northwest. The area is bounded by Teasel Creek on the south, basalt hills to the southeast, and by the Molalla River on the east. It has been cut in the central and northern portions by small westward-flowing tributaries of Bear Creek. Figure 1 shows the nature of the terrain.

Measurements of the Molalla River flow, taken at a station 1½ miles south of Canby, Oreg., are available for 1940 and 1941; the average monthly minimum and maximum flows were 50 and 2,951 second-feet, respectively. Low water usually occurs late in summer, and the level is usually highest during late autumn and winter.

A 57,000-volt power line of the Portland General Electric Co. runs south from Oregon City and within a mile west of Molalla. There is also a 1,200-kv.-a. substation in this vicinity. The Molalla area takes power from the substation at 2,400 volts on several lines running east and south from Molalla near and through the explored area.

Bonneville Power Administration has a 110,000-volt line to Wilsonville, 15 miles directly northwest of Molalla. This line could be extended to the Molalla area.

LABOR AND LIVING CONDITIONS

Molalla and nearby towns are farming and logging communities and are sufficiently near Portland, Oreg , and Vancouver, Wash., to be affected by defense industries. Virtually all surplus labor has been drawn to these areas, so that extreme scarcity exists at Molalla. A number of men now commuting to Portland no doubt would prefer to work nearer their homes provided equivalent wages were paid. Not more than 100 men could be recruited, however. The prevailing wage for common labor in the district is now 90 cents to a dollar an hour.

Housing at Molalla is only sufficient for the present population. There are no vacant residences or apartments in neighboring communities. Living quarters would have to be built to house nearly all of the workers needed for construction of the alumina plant and for plant and mining operations.

GEOLOGY

The Geological Survey examined and described all drill cores and made geological field studies. In this work a topographic map of the Molalla Quadrangle made by the Army Engineers and a geologic map made by W. D. Wilkeson, Oregon State College, were very helpful.

The most important geologic formations in the vicinity are the Molalla formation, Pleistocene gravels, Stayton lavas, and Boring lavas. The principal formations in the area drilled are the Molalla and the Pleistocene gravels. The Stayton lavas lie immediately south and west, and the Boring lavas lie at a considerable distance north and northeast of the drilled area.

The Molalla formation is several hundred feet thick and consists mainly of clay, silt, sand, gravel, tuffaceous sediments, shale, and sandstone. Much of the sand, silt, and gravel is highly altered or kaolinized.

The Pleistocene and recent gravels are unconsolidated and extensive, covering large areas south and west of Molalla.

THE DEPOSITS

The various types of sediments encountered by holes spaced at about 660-foot intervals were found to occur irregularly. Consequently, it was impossible to correlate most of them according to rock type. However, by analyses an upper bed of good-quality clay was correlated.

Correlation also was obtained of a lower bed of higher-quality material by both analyses and continuity of the clay. The most persistent rock type in both beds was clay. Other kinds were largely kaolinized gravel, sand, and conglomerate. The alteration of gravel, sand, conglomerate, and other materials to clay within the limits of the beds appeared to be nearly complete.

The upper clay bed is overlain by a small amount of overburden and is usually underlain by low-grade material and sandstone. Under these sediments is a thick clay bed of higher available alumina content. In a few places the two beds merge with no low-grade or other separating material between them.

Thickness of the overburden ranges from 0 to 32 feet and of the upper clay bed from 19.5 to 133 feet. The ratio of overburden to upper clay is 1 to 5.4. The overburden occurs principally at the southern edge, near the center, and at the northeastern corner of the area. A substantial tonnage of good-quality upper clay was indicated by four adjacent holes at the northeastern corner of the drilled area. Here thicknesses ranged from 113 to 133 feet.

The bottom of the upper clay series drains naturally to the Molalla River; it is trough-shaped, its axis sloping towards the Molalla River to the northeast. The axis runs from the northeast corner, where the clay is thick, to the southwest corner. The low-grade material lying between the upper and lower clay beds ranges in thickness from 9 to 78 feet.

Twelve deep holes encountered the lower clay bed, but only three, B-15, G-13, and G-2, passed through it into sandstone or low-grade material. The thickness of the lower bed in these holes ranged from 22 to 107 feet and will probably average more than 55 feet in thickness within the area included by the deep holes.

EXPLORATION BY BUREAU OF MINES

Investigation by the Bureau consisted of preliminary prospecting and exploring by drilling with drive-pipe and churn-drill tools.

The preliminary prospecting, by hand-augering, was done during the summer of 1942. About 275 auger holes were started, but, owing to the general presence of overlying gravels, only a few favorably located holes reached clay. From the results obtained, a favorable area of about 3½ square miles, lying 3/4 to 3 miles southeast of Molalla and along the Molalla River, was outlined. Detailed exploration of this area by hand augers was not considered feasible because of the difficulty experienced in penetrating the surface gravels and because the deep-lying clay beds could not be reached by this method.

Churn-drill rigs equipped with drive-pipe equipment for coring clay and unconsolidated material were obtained. Exploring with this equipment was begun on October 24, 1942, and completed in January 1943. Forty-nine holes totaling 5,365 feet were drilled. A number of "scout" holes were drilled first, about half a mile apart, starting at the southeast corner of the indicated favorable area. When about half this area had been drilled, enough information was available to indicate the most promising portion of the area. Drilling was concentrated around the more favorable holes in the southeast and eastern portion of the area. Holes spaced at approximately 660 feet were drilled over the northern half of sec. 27 and over the central portion of sec. 15, T.5 S., R.2 E.

All holes except one were more than 50 feet deep; some were more than 100 feet. The clay and unconsolidated beds were cored by churn drills equipped with sampling tubes 2 feet long, with an outside diameter of 6 inches and an inside diameter of $5\frac{1}{4}$ inches. They were attached below the jars and driven into the clay for measured distances. The cores were removed by special core pressers.

A topographic map was made showing contours, at 10-foot intervals, of the intensively drilled area. The Bureau also aided in excavating seven carloads of clay, which was shipped to the pilot plant of the Kalunite Corporation at Salt Lake City.

CLAY RESERVES

Indicated tonnage of overburden and clay for both the upper and lower clay series is shown in the appendix at the end of this report. Area maps of the upper and lower clay beds (figs. 2 and 3) show the area of influence of each hole. This was determined by perpendicular bisectors of lines drawn from each hole to all surrounding holes.

Of the 49 holes drilled, 8 are outlying and 41 are located at 660-foot intervals. Of the latter, 38 are spaced over an area of 340.25 acres; the tonnage estimate for the upper clay is based upon these. The scope of the individual holes varies in area from 3.63 to 11.24 acres; the average is 8.95 acres. It was found necessary to separate the upper clay into accepted and excluded area to emphasize the best possibilities. The excluded area is more unfavorable than the accepted area because of the thinness and lower quality of the clay and the thickness of the overburden.

The apparent specific gravity and moisture content of the upper clay were determined on 25 samples obtained from various holes. The average apparent specific gravity was 1.59, and average moisture content was 34 percent. The wet and dry tonnages per acre-foot calculated from these data are 2,100 and 1,400 tons, respectively.

Most of the 12 deep holes drilled penetrated the lower clay bed and are included in the accepted or excluded upper clay areas. Only the clay contained within the scopes of these holes was considered as indicated ore, whereas that in the surrounding area was classed as geologic. The tonnages of indicated and inferred clay reserves and other pertinent data are shown in the following table.

Since the upper clay contained 34 percent moisture, the dry tonnage in the accepted area is indicated to be 19,589,000 tons. It averaged 25.0 percent available alumina and 7.54 percent available Fe_2O_3. Calculations of average grade, based upon determinations on composite samples for each hole, gave 25.17 percent available alumina and 8.04 percent available Fe_2O_3. This may be regarded as an excellent analytical check with the analyses shown above and in the table, obtained by averaging a number of assays over various intervals in each hole.

Of particular interest is the average 56.1-foot thickness of clay and the small amount of overburden in the accepted area. The overburden is indicated to be only 5,492,800 tons, natural basis; the ratio of overburden to ore is 1:5.4.

The excluded area, not favorably considered, contains an indicated 4,608,000 tons, natural basis, of upper clay, which averaged 22.15 percent available alumina and 7.21 percent available Fe_2O_3. Its ratio of overburden to ore is about 1:1.63.

Clay series and areas	Number of holes	Area, acres	Thickness, feet		Indicated tons (wet) at 2,100 T/A/ft.		Weighted analyses of clay, percent available, dry basis	
			Overburden	Clay	Overburden	Clay	Al_2O_3	Fe_2O_3
Upper clay series in accepted area.	27	251.91	10.38	56.1	5,492,800	29,680,700	25.01	7.54
Upper clay series in excluded area.	11	88.34	15.22	24.84	2,824,300	4,608,500	22.15	7.21
Lower clay series.	12	115.26	[1] 46.23	55.55+	[1] 11,190,800	13,445,200	27.97	7.22
Lower clay series.		121.65		50		12,750,000	Inferred ore 27.00+	7.0+

1 Includes only low-grade material between upper and lower clay series.

The indicated lower clay is appreciably higher in grade than the upper clay and averages more than 55 feet in thickness. The bed is probably thicker than this, as only three of the deep holes penetrated this series. Considering the low-grade material between the upper and lower beds as the overburden for the latter, the ratio of this material to the lower series is about 1:1.2. This ratio would be less if the actual thickness of the lower clay is much more than 55 feet.

There are other inferred reserves that have not been mentioned. A large tonnage of high available alumina in the lower clay is indicated by holes H-10, H-11, H-12, and 3. With the exception of hole 3, they penetrated a thin bed of upper clay. The lower clay cannot be correlated; its importance cannot be known until additional drilling is done. Hence the tonnage within the scope of these holes is considered separately. The total scope of these holes is 36.69 acres, the average thickness of overburden and low-grade material is 44.3 feet, and the average thickness of the clay is 52.6 feet. Indicated quantity is 4,057,000 tons, natural basis. The average analysis on a dry basis is 27.57 percent available alumina and 7.49 percent available Fe_2O_3.

Of the other holes, most of which are outlying, three encountered clay. Hole 8 intersected two series of good-quality clay 61 and 46 feet in thickness separated by 27 feet of low-grade material and covered by 20 feet of overburden. Hole 9 intersected 44 feet of high-quality clay overlain by 2 feet of overburden. Hole 13 encountered two beds of clay of intermediate quality, 33 and 27 feet in thickness, separated by 10 feet of low-grade material and covered by 22 feet of overburden. If additional ore reserves are desired, these holes suggest areas for future exploration.

ADDITIONAL EXPLORATION

From the nature of the exploration and the data obtained, there is assurance of a large tonnage of suitable clay. The information obtained is adequate for determining the feasibility of recovering alumina from the Molalla clay on a commercial scale. No additional drilling is contemplated unless an alumina plant is seriously considered.

If an alumina plant is to be constructed intermediate holes should be drilled at or near the corners of the areas of influence of the present holes. The scope of each hole would then be from 4 to 5 acres in area. This is about half the area included by the present holes.

The value of additional drilling at closer intervals would be of considerable importance. It would furnish additional information as to the amount of overburden, quality, thickness, and attitude of the clay beds and would enable the operator to maintain much closer control in mining suitable material for the alumina plant.

From 26 to 30 additional holes are suggested, which will amount to approximately 4,500 feet of drilling. This work would include 20 deep holes to determine the characteristics of both the lower and upper clay beds. The estimated costs, based upon work already accomplished, are shown below:

Drilling at $2.70 per foot.	$12,150.00
Casing at $0.06 per foot.	270.00
Labor at $1.04 per foot	4,680.00
Supplies at $0.16 per foot.	720.00
Supervision at $0.18 per foot	810.00
Transportation at $0.06 per foot.	270.00
Assaying.	2,000.00
Engineering	2,000.00
	22,900.00

It is estimated that by working two shifts a day, two drill rigs could complete this drilling in 3 months, or three drill rigs could complete it in 2 months.

PLANS FOR OPERATION

The Olin Corporation of Tacoma, Wash., and the Columbia Metals Corporation of Seattle, Wash., have shown interest in the

Molalla clays. The Olin Corporation has shipped seven carloads of clay to their subsidiary, the Kalunite Corporation at Salt Lake City, Utah, for pilot-plant testing. The process used is a modification of their process for treating alunite.

Five of these carloads were taken from the T. Kyllo farm, about 1,600 feet north of the northwest corner of sec. 22. This material averaged, on a dry basis, 25.5 percent available alumina and 4.2 percent available Fe_2O_3.

The analysis of one carload of clay taken from the Elmer Sawtell farm in the area between holes 9 and 13 was 26.21 percent available alumina and 7.70 percent available Fe_2O_3. The analysis of another carload taken from the F. Muller farm in the area of hole G-4 was 21.16 percent available alumina and 10.66 percent available Fe_2O_3. Of these areas, only that in the vicinity of hole G-4 on the F. Muller farm is included in the present tonnage estimates.

Property owners in the Molalla district report that both the Olin Corporation and Columbia Metals Corporation have shown interest in obtaining leaseholds on property rights on clay areas. Other companies, perhaps, are interested in producing alumina from clays and would be prepared to submit proposals as soon as they learn of the location and character of this deposit.

MINING

A model was made of the explored area, which greatly aided in determining the continuity and characteristics of the clay series. Study of this model revealed two places where the clays are readily accessible and where it could be mined with little or no development. One of these is the thick, upper clay bed at the northeast corner of the explored area and the other is the lower clay bed at the southwest corner of the area.

Special attention is called to the thick bed of high-quality clay. This clay was encountered in holes 2, H-3, H-2, H-5, H-6, and H-7, which indicate an area of 50.46 acres estimated to contain 9,600,000 tons of clay, natural basis. The clay ranges in thickness from 50 to 133 feet and contains 26.08 percent available alumina and 8.44 percent available Fe_2O_3. The overburden is indicated to be only 800,000 tons. Tonnage enough for an 18-year operation, mining at the rate of 1,500 tons per day, is indicated in this portion of the area alone.

Removal of this upper clay would allow the entire remaining upper bed to drain into the Molalla River. The bottom of the upper-clay series forms a natural trough whose axis slopes to the Molalla River and extends northeast from hole 5 to hole H-3.

Because of the tonnage, quality, and accessibility of the clay, as well as the good drainage conditions, this part of the explored area is the most favorable for development. The upper clay would be mined by opening a pit in this vicinity. The pit sides would be benched where thickness of the clay made this necessary. As the pit was widened, it would also be deepened, until the bottom of the upper clay series was reached. The remainder of the upper clay bed could be mined in a similar manner by extending the pit and benches.

The lower clay series is readily accessible at the southwest corner of the explored area near hole K-4. The upper clay is not present here, and the lower clay is covered by only 9 feet of overburden. The clay is 51.5 feet thick and, on a dry basis, analyzed 31.2 percent available alumina and 8.1 percent available Fe_2O_3. This locality drains naturally into the westward-flowing Teasel Creek. As mining is extended towards holes F-16, 5, and G-13, overburden, upper clay, low-grade material, and lower clay will be encountered. The overburden and the low-grade material between the upper and lower beds can be deposited on the Teasel Creek flats.

A pit with benched sides could be opened in this locality if it were desirable to obtain lower clay for treatment in the alumina plant. It is possible that the lower bed could be mined to better advantage elsewhere. Before this can be ascertained, additional drilling must be done to determine the character of this bed.

It would be advisable to strip the overburden only during the dry summer months. The heavy rainfall of autumn and winter would make this operation rather difficult; mining should not be too severe then if fairly steep benches or faces are maintained and good drainage slopes are provided on the benches and the pit bottom.

The size of mining equipment necessary would depend on the scale of operation. Both size and type of mining equipment must be considered carefully in view of the unusual amount of clay to be handled and the extremely wet weather that prevails occasionally. It will probably be found impracticable to haul the clay from the pit by trucks during the wet season. A cableway system of transporting the material from the pit might be found more practical. The fixed point of the cableway could be at the loading terminal. Waste also would be deposited here and hauled to waste dumps. The movable terminal of the cableway could be on rails surrounding the bank at the extremities of the pit. Power shovels could excavate and load directly into the cableway carriers. Such cableways are described on page 1,788 of the 1927 edition of Robert Peele's Mining Engineers Handbook. The capital cost of cableways would be somewhat greater than the cost of a fleet of trucks, but their lower operating cost would more than offset this difference before the deposit was exhausted.

Some blasting might be necessary to loosen the sandstone overlying the lower clay bed in some parts of the area, which would somewhat increase the cost of stripping.

A railroad could be constructed from the plant site along the west bank of the Molalla River to the vicinity of hole H-3. An old logging-railroad grade along this route probably could be utilized. Whether rail or truck transportation would be most economical would depend on the scale of operation.

PLANT SITE

Several tracts in the vicinity of Molalla could be used as plant sites. Perhaps the most suitable one (shown in fig. 1) is a comparatively flat area immediately north of the explored ground in secs. 15 and 16. It comprises about 400 acres and is bounded on the north by a paved road and on the east, south, and west by unsurfaced roads. It is $\frac{1}{2}$ to $1\frac{1}{2}$ miles southeast of Molalla and 1 to 2 miles northwest of the approximate center of the drilled area.

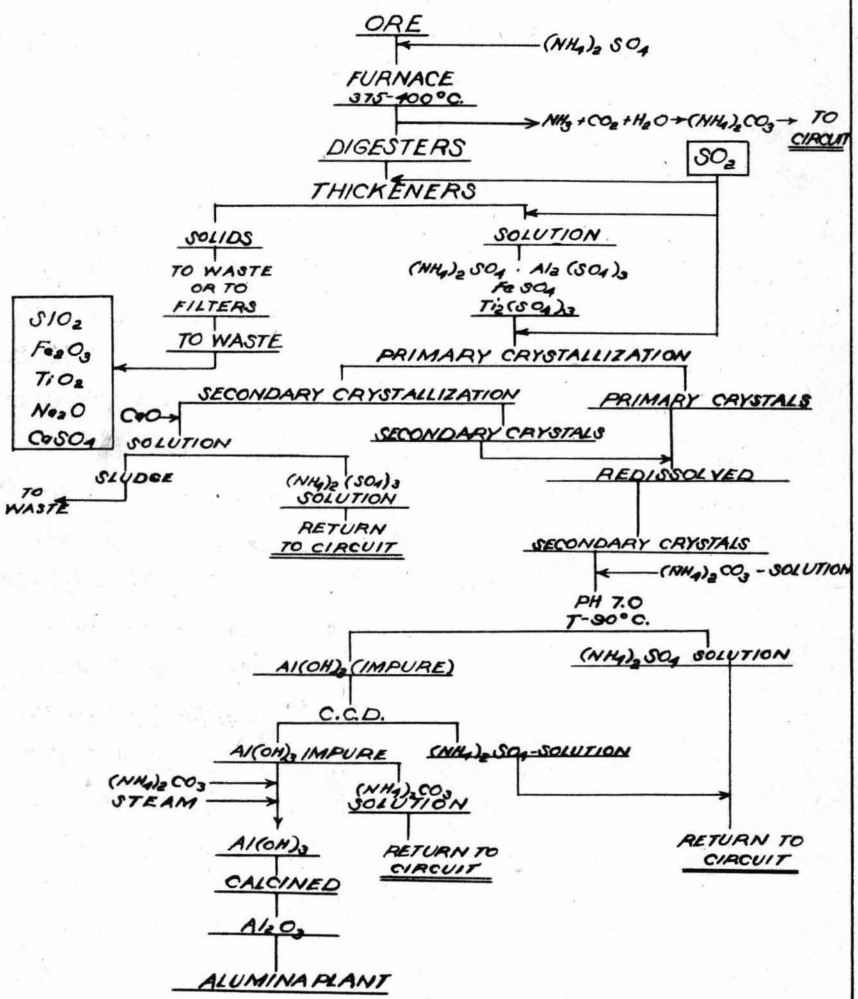
Altitude on this tract ranges between 410 and 460 feet. There is good drainage into a tributary of Bear Creek. This tributary rises near the center of the tract and flows west. Drainage could also flow into the Molalla River, which is within half a mile of the area. The elevation of the Molalla River east of the plant site is about 375 feet; maximum static head in pumping to the highest elevation on the plant site would be about 100 feet.

There are no available records of the water flow of the Molalla River at Molalla, but such records have been made for streams near Canby, about 10 miles northwest of Molalla. These include Milk Creek, which is smaller than the Molalla River. As these records show mean monthly minimum and maximum flows of 50 to 2,951 second-feet, there is no doubt that ample water for an alumina plant is available from the Molalla River in the vicinity of the plant site.

COAL

One of the essential requirements for an alumina plant is fuel, which may be oil, coal, or both. It is probable that most of the heat required would have to be supplied by coal.

The heat required for processing the clay has been estimated at 75 million B.t.u. per ton of alumina for a clay containing 20



GENERAL FLOW SHEET
AMMONIUM SULPHATE PROCESS
FIGURE-5

percent available Al_2O_3. On this basis, 3 tons of coal having a heating value of 12,500 B.t.u. per pound will be required for 1 ton of alumina, or 0.6 ton per ton of clay.

There are many coal deposits of various extents and types in Washington but comparatively few in Oregon. The most prominent and most extensively developed deposits are in western Washington. Production from six western counties for September 1942 was as follows:

County	Tons
King	53,125
Kittitas	71,968
Lewis	4,100
Pierce	2,198
Thurston	7,056
Whatcom	18,355
	156,802

The total coal production in Washington for 1941 was 1,876,830 tons. The principal drawback to increasing production is the shortage of labor and experienced miners.

The principal coal deposit in Oregon is situated near Coquille and extends northward. It is described by J. S. Diller in Geological Survey Bulletins 431 and 546. This deposit was examined in 1942 by James W. Evans and Albert Toenges, both of the Bureau of Mines. The coal bed lies in synclinal folds whose axes run north and south. The dip of the bed ranges from 8° at the Southport mine to 30° at the Beaver Hill mine, 4 miles south. At the Sumner mine the bed lies in a small syncline, whose members are nearly vertical. This mine is situated 4 or 5 miles east of the Southport mine.

The coal bed at the Southport mine is 44 inches thick and has a clay parting 8 inches thick. At the Beaver Hill mine the coal seam is 73 inches thick, 41 inches of which is good coal. According to the geological sections, the synclines range in width from $1\frac{1}{4}$ to $4\frac{1}{2}$ miles, and the underlying coal members extend to a depth of 2,000 feet.

According to F. M. Anderson's report of April 2, 1906, for Prof. E. T. Dumble, consulting geologist, Houston, Tex., the old Beaver Hill mine was developed and operated as early as 1900. This mine, in secs. 8 and 17, T.27 S., R.13 W., produced 224,517 tons from 1900 to 1905. The blocked-out coal was estimated at 1,335,000 tons, and the mine was in condition to produce 500 tons per day. For short periods it produced as much as 600 tons per day. The quality of the coal, as indicated by analyses, is as follows:

	Percent
Moisture.	9.56-16.30
Volatile matter	32.6 -49.85
Fixed carbon.	35.98-50.21
Ash	2.35- 9.77
Sulfur.	Trace to 0.94

The old Beaver Hill and other mines have long since been abandoned, but records of operations indicate the activity that once prevailed in the area and the quality of coal produced.

The estimated cost of coal delivered at Molalla depends on the locality from which it is obtained. According to Evans' report, coal cannot be produced in the Coos Bay area under present conditions for $3.50 a ton. Allowing $4 a ton for mining and $4.55 for freight to Molalla, the cost per ton of this coal delivered at Molalla would be approximately $8.55. Raymond Miller, of the Bonneville Power Administration, estimated the cost of Centralia-Chehalis and Pierce County, Wash., coal delivered at Molalla to be $6.22 and $7.41 per ton, respectively.

A thorough study should be made of present coal-producing areas and known dormant coal areas in Oregon and Washington. The purpose of this study should be to determine the amount and cost of coal available from them and to outline further exploratory work for favorable dormant areas.

METALLURGY

The process developed by the Bureau of Mines for recovering alumina from clays is essentially as follows: The clay is baked with a slight excess of ammonium sulfate at 375° to 400° C. During the baking, anhydrous ammonium alum is formed from the alumina present in the clay as kaolinite and similar minerals, and an equivalent amount of ammonia is liberated. The ammonia is collected as either ammonium hydroxide or ammonium carbonate solution, depending on whether it is allowed to mix with products of combustion. The baked product is leached with water containing enough sulfuric acid (about 0.5 percent) to prevent hydrolysis; sulfur dioxide is passed through the leach solution to reduce ferric iron to ferrous; and ammonium alum is crystallized out. The alum is purified by recrystallization and converted to aluminum hydroxide by treatment with the ammonium hydroxide or carbonate obtained from the baking step. Ammonium sulfate recovered from the filtrate after precipitation of aluminum hydroxide is re-used for the treatment of more clay. The precipitate is calcined to alumina. By this process, 80 to 90 percent of the "available" alumina in the clay is recovered as a light, granular product sufficiently low in impurities to be suitable for the production of aluminum.

MARKETS

Five aluminum reduction plants and one rolling-mill plant are now in operation in Oregon and Washington. Four of the reduction plants are near the Molalla clay deposit. Their present supply of alumina comes largely from plants at East St. Louis, Ill., Mobile, La., and Sheffield, Ala. The capacity and location of these plants is given below:

Plant	Location	Annual capacity, pounds	Miles by rail from Molalla
Alcoa.	Vancouver, Wash.	180,000,000	49
Do.	Troutdale, Oreg.	130,000,000	55
Do.	Spokane, Wash.	200,000,000	410
Olin Corporation .	Tacoma, Wash.	40,000,000	173
Reynolds Metal Co.	Longview, Wash.	60,000,000	82

Of the five aluminum plants in Oregon and Washington, two are within 55 miles by railroad from Molalla. They are at Vancouver, Wash., and Troutdale, Oreg., and have an annual production capacity of 310,000,000 pounds of aluminum. The Molalla deposit has enough indicated reserves to supply these plants for about 20 years, or one of them for 35 to 45 years. Development of other favorable areas would keep such plants supplied for a much longer period.

CONCLUSIONS

From its investigation of the Molalla clay deposit as a source of alumina, the Bureau of Mines concludes that:

1. There are in the upper and lower clay series an indicated 29,680,000 and 13,400,000 wet tons, respectively, of high-quality clay, natural basis, containing 34 percent moisture. In addition, there is also an estimated 12,750,000 tons of inferred clay in the lower clay series. There are excellent possibilities of finding large additional quantities of suitable clay in other areas covered by the Molalla formation.

2. One important feature in mining is that the attitude of the clay beds is such that they can be mined from pits that would have natural drainage; another is that at two places advantageous for starting mining operations the clay is thick and readily accessible.

3. The upper clay contains approximately 34 percent moisture and 25.01 percent alumina and 7.54 percent Fe_2O_3 on a dry basis. The lower clay analyzes 27.97 percent alumina and 7.22 percent Fe_2O_3 on a dry basis.

4. On the basis of careful analyses, the upper clay is estimated to contain 4,900,000 tons of available alumina and the lower clay 2,500,000 tons of available alumina.

5. A tract of approximately 400 acres adjacent to the drilled area is available as a plant site. It is within a mile of a railroad, half a mile of an ample

supply of water (the Molalla River), within $2\frac{1}{2}$ miles of a 57,000-volt power line, and within 15 miles of a 110,000-volt power line at Wilsonville. The plant site is within 130 miles of the Centralia-Chehalis and 200 miles of the Pierce County, Wash., coal fields, and is within 220 miles of the Coos Bay, Oreg., coal fields.

6. The Molalla deposit and the alumina plant site are favorably situated with reference to aluminum-reduction plants at Vancouver, Longview, Tacoma, and Spokane, Wash., 34, 80, 186, and 406 miles, respectively, from Molalla. Another plant, at Troutdale, Oreg., is only 41 miles from Molalla.

RECOMMENDATIONS

The Bureau of Mines recommends that an alumina plant be constructed at an early date to treat Molalla clay, provided (a) that the Bureau of Mines pilot-plant investigation is successful, and (b) that either the estimated cost of alumina from clay as delivered to the nearest aluminum plants is comparable to the cost of that now being supplied from bauxite; or that a critical shortage of aluminum develops.

If an alumina plant is constructed, the Bureau suggests also that additional drilling be done at closer intervals than 660 feet to furnish further information to the operator to aid in maintaining close control of the material mined for treatment. The Bureau, however, believes that sufficient drilling has been done on the Molalla deposit to justify construction of an alumina plant.

APPENDIX

MOLALLA CLAY SERIES

Clackamas County, Oreg.

Molalla Upper Clay Series, Accepted Areas

Hole	Area scope		Thickness of –		Tons of overburden	2,100 tons per acre-foot clay series (natural basis)	Weighted analyses of clay series, dry basis, percent available –	
	Acres	Sq. ft.	Overburden, feet	Clay series, feet			Al_2O_3	Fe_2O_3
B-14	5.78	251,800	5	50	60,700	606,900	23.17	6.03
F-4	9.69	422,300	0	60	0	1,220,900	23.70	8.70
F-16	8.76	381,600	8	26	147,200	478,300	24.18	8.50
G-2	10.08	439,300	16	28	338,700	592,700	20.89	3.18
G-3	8.53	371,700	10	31.5	179,100	564,300	25.20	8.00
G-5	11.24	489,500	30	23.5	708,100	554,700	28.60	6.20
G-6	10.23	445,700	4	36	85,900	773,400	25.50	4.40
G-7	10.07	438,600	32	52	676,700	1,099,600	23.41	7.14
G-8	10.54	459,000	0	51.5	0	1,139,900	25.19	7.59
G-9	9.86	429,300	13	44	269,200	911,100	25.81	8.88
G-10	10.34	450,600	3	69	65,100	1,498,300	23.33	7.01
G-11	10.09	439,500	25	62	529,700	1,313,700	25.76	6.87
G-12	10.12	441,000	2	93.5	42,500	1,987,100	26.22	6.38
G-13	9.94	433,000	14	23.5	292,200	490,500	20.58	8.80
G-14	10.54	459,300	0	73	0	1,615,800	25.64	6.60
G-15	9.15	398,600	4	74	76,900	1,421,900	23.43	6.95
H-2	7.63	332,300	0	133	0	2,131,100	24.41	9.36
H-3	5.98	260,300	31	118.5	389,300	1,488,100	24.28	8.31
H-5	10.06	438,000	3	49.5	63,400	1,045,700	28.35	8.14
H-6	10.22	445,000	0	84.5	0	1,813,500	27.83	8.07
H-7	9.20	400,700	18	91.3-119	347,700	2,026,800	25.55	9.01
H-8	8.87	386,300	26	60	484,300	1,117,600	23.68	8.44
H-9	10.28	448,000	2	32	43,200	690,800	23.11	7.07
H-13	8.27	360,300	16	24.5	277,900	425,500	24.64	6.79
L-2	9.19	400,300	0	43	0	829,900	26.84	8.83
1	9.88	430,300	20	35.1	415,000	728,300	21.70	6.51
2	7.37	321,000	0	72	0	1,114,300	27.69	6.71
Totals and weighted av.	251.91	10,973,300	10.38	56.1	5,492,800	29,680,700	25.01	7.54

MOLALLA CLAY SERIES
Clackamas County, Oreg.

Molalla Upper-Clay Series, Excluded but Adjoining Areas

Hole	Area scope		Thickness of –		Tons of overburden	2,100 tons per acre-foot, clay series	Weighted analyses, percent available –	
	Acres	Sq. ft.	Overburden, feet	Clay series, feet			Al_2O_3	Fe_2O_3
A-16	8.44	368,000	0	24	0	425,400	21.97	7.60
B-13	7.62	332,000	29	19.5	464,100	312,000	24.50	7.60
B-15	3.63	158,000	30	10	228,700	76,200	20.60	6.00
G-4	6.55	285,500	23	28	316,400	385,100	22.94	5.61
G-16	8.68	378,000	2	19.5	36,500	355,400	22.55	6.81
H-10	9.76	425,300	0	11	0	225,500	22.95	8.18
H-11	9.91	431,600	15	8.5	312,200	176,900	27.99	6.66
H-12	9.45	411,600	48	39	952,600	774,900	22.12	7.30
I-5	5.75	250,500	0	63	0	760,700	21.76	6.14
L-3	9.14	398,000	0	33.5	0	643,000	20.30	7.40
5	9.41	410,000	26	24	513,800	474,300	20.66	9.42
Totals and weighted averages	88.34	3,848,500	15.22	24.84	2,824,300	4,608,500	22.15	7.21

Note. – The above 11 holes (areas) border the main or accepted area but have been excluded therefrom until more closely drilled for one or more of the following reasons: (1) Thinness of the clay series; (2) thickness of the overburden in relation to that of clay series; (3) irregularity of deposition; (4) less favorable location or conditions for mining; (5) below the average quality of the clay series of the main area.

Molalla Lower Clay Series, Volume and Grade Indicated by Drilling

Hole	Area scope, acres	Thickness overlying - Overburden or low grade, feet	Thickness overlying - Upper clay series, feet	Low-grade material between upper and lower clay series, feet [1]	Lower clay series, feet	Weighted analyses, percent available - Al_2O_3	Weighted analyses, percent available - Fe_2O_3	Tons at 2,100 tons per acre-foot - Low-grade cover [2]	Tons at 2,100 tons per acre-foot - Lower clay series
A-16	8.44	60	24	60	50 +	27.20	6.80	1,063,400	886,200
B-15	8.68	68	10	78	96	27.70	6.60	1,421,800	1,749,900
G-2	10.08	45	28	29	42	27.83	8.53	613,900	889,100
G-5	11.24	90	23.5	60	37.5 +	24.29	8.38	1,416,200	885,100
G-7	10.07	75	52	43	53.5 +	30.60	6.03	909,300	1,131,400
G-8	10.54	53	51.5	53	69 +	27.05	7.61	1,173,100	1,527,200
G-9	9.86	62	44	49	16.5 +	28.50	8.40	1,014,600	341,600
G-11	10.09	101	62	76	22	27.12	5.86	1,610,400	466,200
G-13	9.94	43	23.5	29	36	28.02	5.78	605,300	751,500
F-16	8.76	20	26	12	99 +	26.27	6.74	220,800	1,821,200
K-4	8.15	9	--	9	51.5 +	31.21	8.09	154,000	881,400
5	9.41	26	24	50	107 +	29.57	7.86	988,000	2,114,400
Totals and weighted averages	115.26	--	--	46.23	55.55	27.97	7.22	11,190,800	13,445,200

Inferred clay is in the lower clay series from the following 13 areas totaling 121.65 acres: B-13, B-14, F-4, 1, G-3, G-6, G-10, G-12, G-14, G-15, L-2, L-3, G-16. With a thickness of 50 feet[3] the tonnage would be 12,750,000.

1 After upper clay series has been stripped of overburden and low-grade material and mined off, except in B-15 and 5, where all material overlying the lower clay series is considered as overburden and low grade.

2 Low-grade material, sandstone, etc., between upper and lower clay series except as in (1).

3 Average thickness of lower clay series as considered for this estimate.

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LEGEND
SURFACE ELEVATION
ELEV. OF BOTTOM LOWER CLAY SERIES
AV. ANALYSIS IN AVAILABLE
% Al_2O_3 —
% Fe_2O_3 —
COMBINED THICKNESS OF OVERBURDEN AND LOW GRADE + THICKNESS OF UPPER CLAY SERIES
THICKNESS OF LOWER CLAY SERIES — FT.
SCOPE OF DRILL HOLE BY PERPENDICULAR BISECTOR METHOD
SHOWING DRILL DATA — AREAS OF LOWER CLAY SERIES AS INDICATED BY DRILLING
SHOWING NO DRILL DATA — GEOLOGIC CLAY AREAS
MOLALLA CLAY DEPOSIT
CLACKAMAS CO., OREGON
LOWER CLAY SERIES
DRILLING PLAN - VOLUME & GRADE ESTIMATE
SCALE
200 100 50 0 200 400
MOLALLA
RIVER
N

FIGURE-3

LWM # 8-4

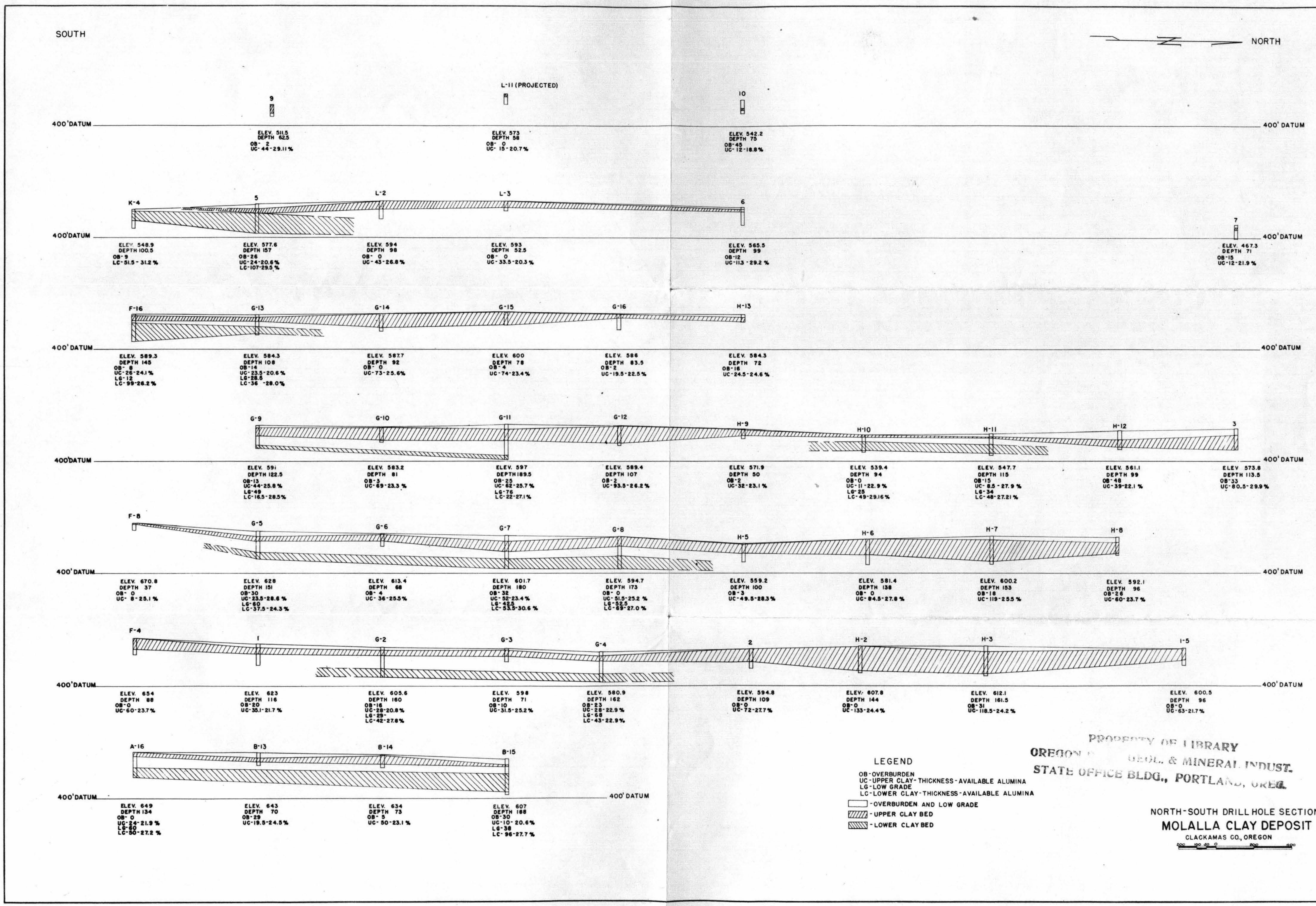

FIGURE-4

WMH 8-3

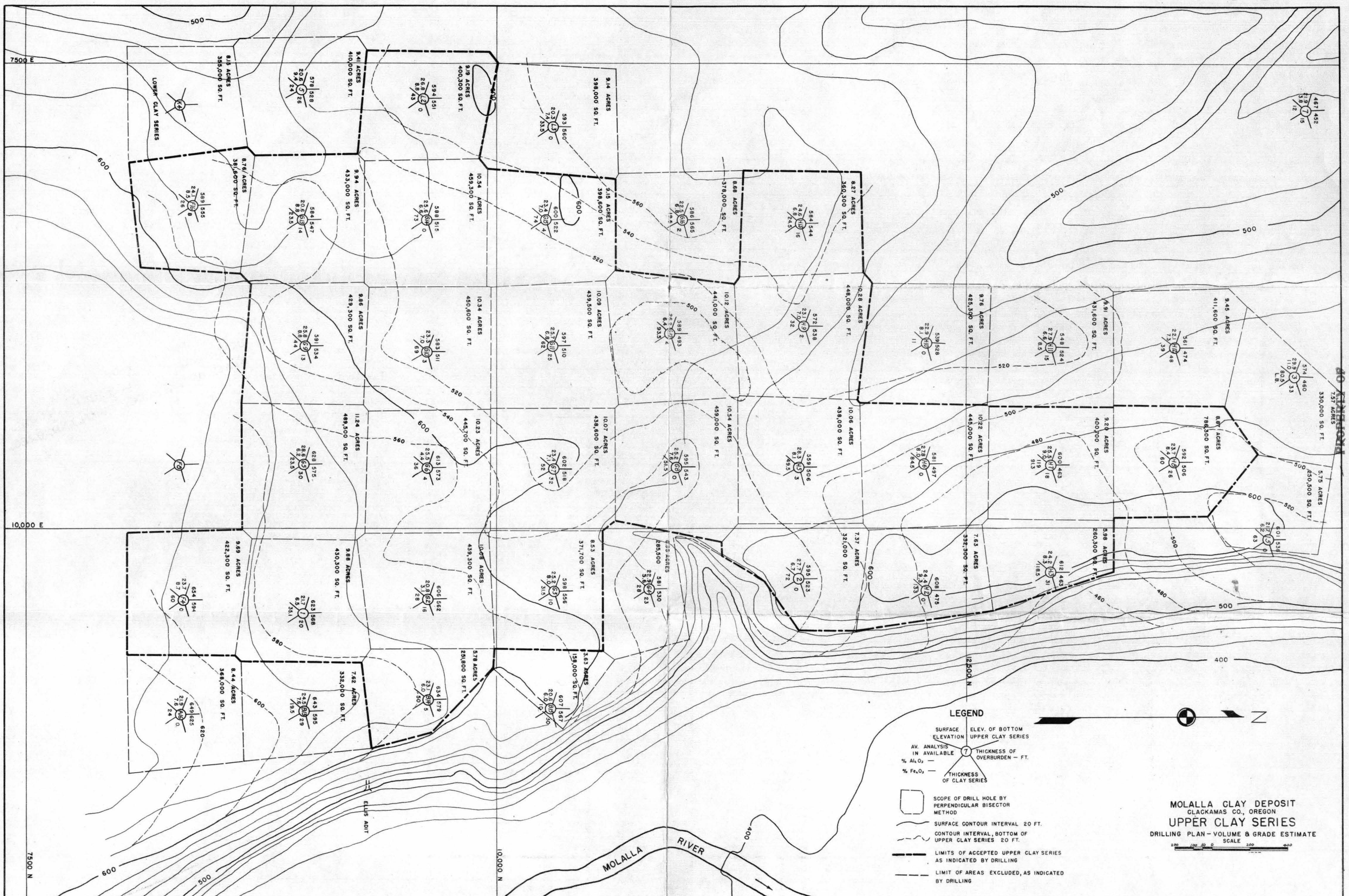

FIGURE-2

WM #8-2

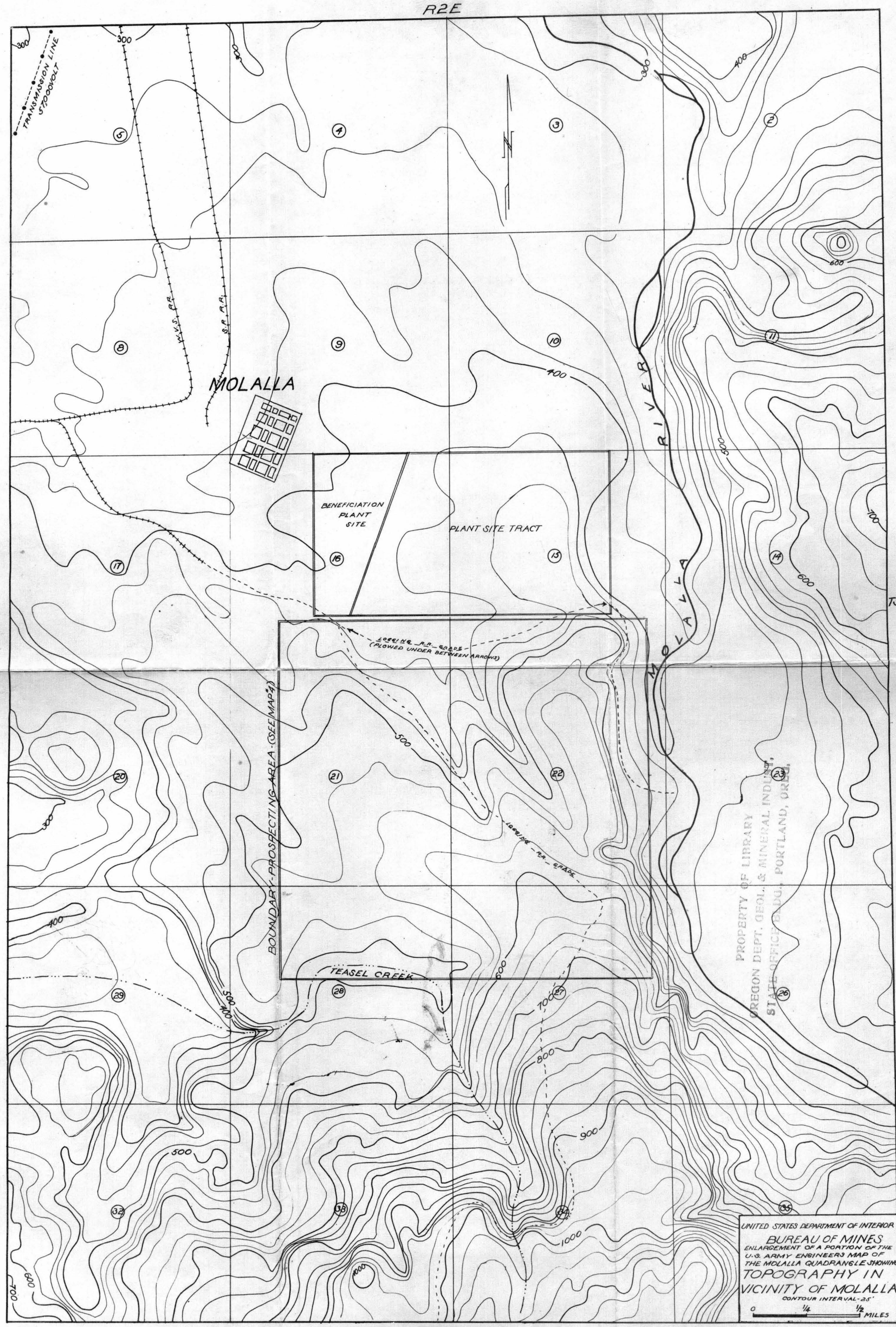

FIGURE - I