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Preliminary Report
of some of the
REFRACTORY CLAYS
of
Western Oregon

by

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This paper presents the results of work done under a cooperative agreement between the Bureau of Mines, the University of Washington, and the Oregon State Department of Geology and Mineral Industries.

FOREWORD

Anticipating the refractory clay requirements of metallurgical industries that should be attracted to the lower Columbia area by the availability of electrical power at favorable rates from Bonneville Dam, this Department carried out an investigation of western Oregon refractory clay deposits. This was done in cooperation with the U. S. Bureau of Mines and the University of Washington in order to obtain facilities this Department does not have, such as adequate laboratory equipment and competent technical advice on firing data and commercial usability of the clays.

Results of the investigation indicate that, contrary to former opinion, western Oregon has large deposits of high refractory clay materials and can supply the future requirements of electrometallurgical and of other industries in the Northwest. Preparation and issuance of this report is in line with the policy of the State Department of Geology and Mineral Industries to inform the general public and capital of possibilities in the development of Oregon's mineral resources.

Earl K. Nixon, Director

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ABSTRACT

This is a preliminary report of some of the refractory clay deposits of western Oregon, prepared in cooperation with the U. S. Bureau of Mines' Northwest Experiment Station, the University of Washington, and the Oregon State Department of Geology and Mineral Industries. The economic aspects are stressed; the quality of clays with fusion of cone 30 or better are considered by means of physical and chemical tests of the clay; the estimated quantity, mining and transportation conditions are discussed; and recommendations are made for continued work. Geologic data were secured incidental to the main project, but conclusions based on these data must be considered tentative. Such conclusions are submitted as contributions to a very complex subject on which little work has been done.

The clays appear to be derivatives of flows, pyroclastics, and gravels that were predominately andesitic and rhyolitic in composition and lower Eocene to post-middle Miocene in age. Alteration was effected by descending meteoric waters and by hydrothermal solutions; similarity of the products points toward a common epoch of alteration, probably post-middle Miocene. The occurrence of gravel, so thoroughly altered that the entire mass can be cut easily with a knife, is noted in the valleys of the McKenzie and Santiam Rivers, near Sublimity east of Salem, at Fransen's clay pit west of Rainier, and in southern Lewis County, Washington. It may represent the remnant of a series of old gravel terraces.

Refractory clays are found throughout the area west of the Cascade Mountains in Oregon and are characterized by moderately high fusion, high shrinkage, and dark fired colors. Precalcination reduces shrinkage and cracking. Preliminary samples were obtained for firing-test data, and from these results four deposits were selected for additional study on the basis of quality, probable tonnage, and transportation conditions.

<u>The first is the Fransen clay pit</u> in northwestern Columbia County. The pit is composed of thoroughly altered gravel, has an average fusion of cone 30 plus, high shrinkage, dark fired color, 430,000 to 1,720,000 short tons available, and transportation can be handled by a 1400-foot tram line to deliver clay at railside or to ships on the Columbia River.

<u>The second is the Ellis deposit</u> in southwestern Clackamas County, typical of the bentonitoid Molalla clays, with an average fusion of cone 31 plus, high shrinkage and severe cracking which can be improved by calcination, 31,000 to 73,000 short tons available, and requiring a $4\frac{1}{2}$ mile truck haul to railside at Molalla.

<u>The third is the King clay</u>, east of Salem, which fuses at cone 32 plus to dark brown. There are 240,000 to 330,000 short tons available, and a $6\frac{1}{2}$ mile truck haul to railside at West Stayton will be necessary. This clay is unique for its original white color, large amount of water required for plasticity, large dry pore space, cracking, and high shrinkage. The area to the north seems to be underlain by similar material. The future value is for use as a plasticizer with its own calcined grog or other nonplastic refractories.

The fourth is the Hobart Butte clay quarry in southwestern Lane County, controlled by the Willamina Clay Products Co. The clay is a hard, light-colored flint clay with conchoidal fracture, fusing at cone 32 plus to light colors. Tonnage is estimated in excess of 46,000,000 short tons, and a 16 mile truck haul to railside at Cottage Grove is necessary. This represents the best clay studied, and tests indicate possibilities of whiteware and a paper filler use for some of the material.

Although not refractory, a discussion of the Willamina clay is included; this black material burns to a white vitrified body at low temperatures and is used for light firing face brick and pottery and as plastic material for the Hobart Butte refractory clay.

Recommendations for future work include suggestions for thorough and systematic sampling of all deposits, research to determine a method to overcome high shrinkage, more accurate data on the uniformity of the clay deposits, and a careful study of the geology and petrography of the clay and associated rocks to determine the origin and age of the clay materials.

INTRODUCTION

PURPOSE AND SCOPE

There are no published data on refractory clay deposits in Oregon, although for many years some manufacturers of clay products have known of several occurrences. The probability of large blocks of electric power being available at Bonneville for industrial use should attract ferroalloy and other electro-metallurgical plants to the lower Columbia River area. These industries will require high-grade refractory clay products and the State of Oregon should be prepared to supply any demand that might develop.

The purpose of this report, therefore, is to describe certain deposits of refractory clay in the Willamette Valley and to present technical data showing the commercial possibilities of the clay described. The report stresses the economic phases of the clay study and geological relationships pertaining to the age and origin of the clay were secured incidental to the economic study.

It was impracticable to visit and sample all the occurrences, nor did funds permit tests of all the clays. The most important were selected on the basis of existing information and their more favorable transportation facilities. The geology and description of the various formations is considered to be of some service by indicating the more favorable areas for future prospecting, and data pointing toward the probable age and origin of the clay also may prove helpful. An unique occurrence of a completely altered gravel is described for the first time.

It appears that refractory clays may be expected in Tertiary rocks of lower Eocene to middle Miocene age which were originally of andesitic or rhyolitic composition, namely, andesitic flows, pyroclastics, or gravels composed of felsite pebbles. In some cases, evidence of hydrothermal alteration is indicated. Careful petrographic and stratigraphic studies will be necessary before definite conclusions can be drawn. It is hoped that the conclusions presented herein will be received in the spirit in which they are offered, namely, an attempted contribution to a complicated problem on which comparatively little work has been done.

ACKNOWLEDGEMENTS

This study was made under a cooperative agreement between the Northwest Experiment Station of the United States Bureau of Mines, the University of Washington, and the Oregon State Department of Geology and Mineral Industries. The Northwest Experiment Station, at Seattle, Wash., Dr. H. F. Yancey, superintendent, contributed the services of Dr. Hewitt Wilson to direct the laboratory work on the clays. The University of Washington contributed part of the time of Dr. Wilson while he was engaged in his capacity as professor of Ceramic Engineering, and loaned certain equipment and space. The Oregon State Department of Geology and Mineral Industries, Earl K. Nixon, director, supplied certain laboratory equipment, the expenses of Dr. Wilson on his trips in the field, the cost of chemical analyses, the salary of a laboratory assistant to Dr. Wilson, and also contributed the time and expense of Ray C. Treasher, Department geologist, and his assistant in the field collecting samples and geologic information and in the preparation of the report.

Examination of the refractory clay areas of western Oregon was made at intervals from August 1937 to January 1938 under the direction of Mr. Treasher, assisted by John A. Ross and C. O. Greenwood, Jr. Technical work on the clays was under the direction of Dr. Wilson, assisted by Robert W. Cline, ceramic engineer.

The writers gratefully acknowledge the help and courtesies extended to them in the field by property owners and operators. They are especially indebted to O. K. Edwards, president of the Willamina Clay Products Co., who furnished samples and valuable information; to Sig Fransen, owner of the Fransen (Columbia County) deposit; to L. L. Ellis, owner of the Ellis (Molalla) deposit; to Fred L. Mills, manager, and C. J. Madsen, superintendent, Quick Silver Syndicate, Black Butte.

Acknowledgement is made, likewise, to Dr. Charles E. Weaver, professor of geology, University of Washington, and to A. M. Piper, geologist, United States Geological Survey, for their review and criticism of that portion of the manuscript describing the general geology; and to Earl K. Nixon and A. M. Swartley, of the Oregon State Department, for their criticism and assistance throughout the entire manuscript.

TECHNICAL RELATIONSHIPS.

This report is a brief study of the refractory and light-colored clays of western Oregon, which in general are of rarer occurrence and of greater unit value than the more common red-brown and dark-firing clays of lower refractoriness.

Refractory clays of good working properties have an unquestionable value in any district where high temperatures are required, such as used in the development of heat, power, or metallurgical operations. Light-firing clays, or those that fire to white, cream, buff, or light brown in ceramic kilns, have varying values, depending upon the color produced and the ease with which they can be transformed into ceramic products.

White-firing clays are valuable for china, porcelain, and earthenware for the table, the chemical laboratory, or white floor and wall tile, but these articles are not manufactured in the Pacific Northwest.

The china clays or kaolins that are white or nearly so in their original condition are the rarest of all and can be used as fillers in paper, kalsomine, paints, cosmetics, etc. Many of these also fire white and thus have service in both the ceramic industry and in unfired nonmetallic products.

Cream and buff clays are used in the production of the heavier grades of pottery, including stoneware, brightly colored luncheon ware, and most art pottery. Stoneware is produced by the Pacific Stoneware Co. in Portland, from a mixture of Oregon and Washington buff clays. Some art pottery is produced in Washington, and one company uses a small portion of the white-firing clay from Willamina, Oreg. Light-colored structural products, including glazed terra cotta, face brick, and building tile, roof tile, floor and wall tile, require buff-firing clays having good plasticity and a long vitrification range without excessive shrinkage and cracking. These clays are not plentiful and they command a higher price than the more common red-brown surface clays or shales because of present architectural preferences and the ease of adjustment to light-colored glazes. Buff-firing clays in most cases are more refractory and usually have a longer vitrification range in comparison with the red-brown clays. The latter are difficult to hide with a white glaze and often soften and fuse before the better type of glazes can be matured in firing.

Previous Investigations

Three reports have been made of Oregon clays. Parks 1/ stated that eastern Oregon is liberally supplied with basaltic clay, that the clays of the Willamette Valley are principally lacustrine, and gives some statistics of production.

Samuel Geijsbeek 2/ published a description of the clay industry as it existed 25 years ago. He reported the manufacture of common brick, tile, sewer pipe, and face brick of the dark variety and the white brick of the Pacific Face Brick Co. of Willamina. Some low-grade fireclays had been tried, but, he stated, "this material had not equaled the products imported from other States." Some stoneware clays were shipped to Portland for the Pacific Stoneware Co.

The thesis (unpublished) of Howard Glen Wilcox 3/ was invaluable as an index to probable localities and quality of the clay and made it possible to cover a large area within the time allotment.

The United States Engineer Corps 4/ is releasing a preliminary survey of many clay occurrences in the Pacific Northwest, but no tests other than chemical analyses were made.

Figure 1 gives the production values of clay products in Oregon.

The chief technical items of historical interest include the improvement of manufacturing methods to produce more highly vitrified products with a greater variety of color in structural brick and tile, and the

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1/ Parks, Henry M., The economic geological resources of Oregon: Oregon State Bureau of Mines, Extension Series 5, no. 2, pp. 76-77, 1912.

2/ Geijsbeek, Samuel, The clay deposits of Oregon: American Ceramic Society, Trans., vol. 15, pp. 644-658, 1 pl., 1913.

3/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington library, Engineer of Mines thesis, 54 pp., 1935 (unpubs.)

4/ Hodge, Edwin Thomas, Market for Columbia River hydroelectric power using Northwest minerals, section II, Northwest clays; Corps of Engineers, U. S. Army, Office of Division Engineer, Portland, Oregon, 1938.

Figure 1

Number of Establishments Producing Clay Products and Value of Products in Oregon: 1909 to 1936
(Dept. of Commerce, Bureau of Census)

Year	Number of Establishments	Value of products
1909	64	1/ $674,520
1914	43	2/ 521,368
1919	25	3/ 386,000
1921	22	2/ 471,472
1922	13	2/ 569,289
1923	12	2/ 621,385
1924	14	2/ 765,512
1925	17	2/ 836,679
1926	20	725,188
1927	16	2/ 643,445
1928	14	484,751
1929	20	2/ 624,765
1930	18	393,955
1931	16	269,296
1932	9	197,653
1933	12	157,137
1934	13	136,307
1935	14	291,022
1936	15	478,480

1/ Does not include value of products reported by three establishments classified in the pottery, terra cotta and fire clay products industry because it is not available.

2/ Does not include value of products reported by one establishment classified in the pottery industry because it is not available.

3/ Does not include value of products reported by two establishments classified in the pottery industry because total is not available.

consolidation of a number of plants into larger companies, and the elimination of many smaller village plants by more efficient methods of transportation, and the reduction in volume of business in the smaller communities. Sewer-pipe manufacture ceased when the Denny-Renton Clay & Coal Co. closed its Portland factory.

A small quantity of fireclay brick was made with clay from Grand Ronde by the Monarch Fire Brick Co. in Portland during its operation from 1921 to 1926, but use of this clay was abandoned in favor of clay from La Grande, Wash. Operations by this company ceased in 1926.

Samples of fireclay from Hobart Butte were sent by Robert and H. R. Philips, near Cottage Grove, to the University of Washington. Receiving a favorable report, they communicated with the Willamina Clay Products Co., who acquired the Hobart Butte property and started testing this material for fireclay brick on a commercial scale. This enterprise has proved successful and has been continued with improvements in methods of mining and manufacture. The large quantity of uniform, high-grade material available and the present marketing success indicate a favorable future in the local refractory service. A description of this property will be found later in this report.

The value of clay and clay products.

The delivered cost of raw clay materials is a small part of the selling price of the finished product. It may reach 20 percent in the manufacture of china and earthenware pottery wares; it is much lower for structural wares, such as brick and tile, where labor costs are over 50 percent of the total.

Recent selling prices of the best china clays or kaolins produced in the United States and imported from England are given for December 1937 by Ceramic Industry 1/ as follows:

China clay, f.o.b. Georgia	$7.50 to $8.00 per net ton.
China clay, f.o.b. Georgia washed, dried, and crushed	$8.50 to $11.00 per net ton.
China clay, crude, f.o.b. Virginia. . . .	$7.00 to $7.50 per net ton.
China clay, refined, 50-lb. paper bags. .	$10.50 to $12.50 per net ton.
China clay, powdered and air-filtered, f.o.b. Virginia	$11.50 to $15.50 per net ton.
China clay, imported, lump bulk.	$18.50 to $25.00 per long ton
China clay, imported, powdered	$40.00 to $80.00 per long ton

Such clays are carefully washed free of impurities in water, dried, and pulverized at special preparation plants in Florida, Georgia, and North Carolina, before shipping to the potteries of Ohio or New Jersey.

The manufacturer of structural or refractory products cannot pay high royalties for raw material in the ground and also spend heavily for testing, mining, and transportation to his factory.

1/ Industrial Publications, Inc., 59 E. Van Buren St., Chicago, Ill.

The value of a clay property is a comparative figure, varying with the

(1) Quality of clay.
 a. Included impurities, such as sand, pebbles, iron stain, etc.
 b. Previous laboratory and factory tests.
 c. Previous commercial production from the deposit.

(2) Accessibility.
 a. Distance to improved highway, railroad, and factory.
 b. Length and type of new road to be constructed.

(3) Methods and cost of mining.
 a. Thickness and type of overburden.
 b. Thickness and area of the clay.
 c. Drainage facilities.

(4) Competition.
 a. With other sources of similar clays.
 b. With other clay-products manufactures.

(5) Demand for this type of clay products.

Thus, the valuation of a clay property may vary from that of the sale price of real estate to a much higher value when it has already been prospected and tested. The valuation will be still higher when the property is in successful production and returns a profit on the investment, or will drop to lower values either through the financial and marketing troubles of the organization or by the discovery of similar clay in that district. For further discussion of valuations and general problems connected with clays, clay mining, and manufacturing see 1/ the accompanying references.

Lovejoy 2/ summarizes the values of red-firing clays and shales at 5 cents per ton unmined in the ground. The National Brick Manufacturer's Association in a report, "The Progress in Clay Mining," shows an average royalty or depletion charge of 3.8 cents per ton with a range of from 0.5 to 13 cents among its membership.

The corresponding figures for plastic buff-firing clays, not

1/ Ries, H., Clays, their occurrence, properties and uses: John Wiley & Sons, Inc., New York, 1927.
Greaves-Walker, A. F., Clay Plant construction and operation: Brick and Clay Record, 59 E. Van Buren St., Chicago, 1919.
Clayworking Problems: Brick and Clay Record, Chicago, 1915.
Garve, T. W., Factory design and equipment and manufacture of clay wares: T. A. Randall & Co., Inc., Indianapolis, Ind., 1929.
Wilson, Hewitt, Ceramics-clay technology: McGraw-Hill Book Co., New York, 1927.
Tyler, P. M., Clay: U. S. Bureau of Mines, Inf.Circular No. 6155, 63 pp., 1929.

2/ Lovejoy, E., Fundamentals and economics in the clay industries: Randall Publishing Co., Wellsville, N. Y., 51 pp., 1935.

necessarily refractory, is placed by Lovejoy 1/ at 10 cents per ton and "The Progress in Clay Mining" gives an average of 7 cents, with a range of from 2 to 17.5 cents per ton.

Lovejoy 1/ values flint fireclay and some refractory plastic clays at 12.5 cents to 25 cents per ton. He suggests that a limitation of 40 years' supply be applied to avoid overloading a manufacturing company with an excessive clay-property valuation. A clay property is more valuable if a manufacturing company has prospected it thoroughly, determined the tonnage available, the uniformity, and has successfully developed the commercial process peculiar to this clay by the actual manufacture and sale of clay products, than a clay deposit of unknown acreage, thickness, uniformity, from which a few samples have been drawn and tested in some laboratory.

The percent recovery of clay in the ground estimated by Lovejoy 1/ for open-pit mining is 100 percent (for usable material), but ranges from 20 to 60 percent, with an average of 50 percent for underground mining. For refractory and white-clay products, the percent of usable material often falls short of 100, due to iron staining, irregular distribution of material of low refractoriness, and variable content of other impurities producing poor color or low fusion. Refractory and white-firing clays are rare, and when such occur, as they do in western Oregon surrounded by low melting lavas that carry a high concentration of fluxes and iron oxides, the chances for uniformity are poor. A thorough investigation of the variations should be made in advance of commercial development.

The tonnage and volumes of clay in terms of brick units are given in figure 2 for approximate estimation of clay-deposit values.

Fig.2 - Weight and volume of clay for brick.

Type of clay	Bulk specific gravity	Pounds per cubic ft.	Tons per cu.yd.	Tons 3/ per acre foot	1,000's brick per acre foot 2/		
					5-lb. brick	6-pound brick	7-pound brick
Soft	1.85	115	1.55	2500	900 M	750 M	644 M
Shale	2.22	138	1.86	3000	1080	900	772
Hard fire-clay	2.44	152	2.07	3300	1190	990	850

1/Lovejoy, E., Fundamentals and economics in the clay industries: Randall Publishing Co., Wellsville, N.Y., 51 pp., 1935.
2/Ten percent loss in weight from the damp ground condition to fired weight of brick, includes original moisture with water and carbon losses in firing.
3/Recommended weights of materials given by Lovejoy, E., Fundamentals and economics in the clay industries: Randall Publishing Co., Wellsville, N.Y., 51 pp., 1935.

GEOGRAPHY

LOCATION AND EXTENT OF AREA.

The clay deposits considered in this report lie in western Oregon east of the Coast Ran e and west of the High Cascades. Six general districts were studied, from north to south, as follows: (1) Northwestern Oregon district, of which the Fransen deposit near Mayger in northwestern Columbia County is the only known refractory-clay locality; (2) Molalla district, south and east of the town of Molalla, in southwestern Clackamas County; (3) Salem district in northwestern Marion County; (4) Eugene district, which includes scattered occurrences near the city of ~~that name~~ Eugene in Lane County; (5) Hobart Butte district, south of Cottage Grove in southwestern Lane County; and (6) southwestern Oregon district, which includes areas in both northern and southeastern Jackson County and one in Josephine County. The location of these districts is shown in figure 5.

GEOLOGY

GENERAL FEATURES.

The refractory-clay deposits of western Oregon are derived from andesitic tuffs, lavas, or gravel composed of andesitic pebbles. Thorough decomposition of the initial rock-forming minerals was caused by descending meteoric waters and perhaps hydrothermal solutions. South of Cottage Grove, the occurrences are in Eocene formations; those in the Eugene district are probably Oligocene; and northward they are middle Miocene or younger. Rock units in which clay is found are:

Astoria formation	Middle Miocene
Fern Ridge tuffs	
Columbia River basalt	
Stayton Lavas	
Eugene formation	Middle Oligocene
Calapooya formation	Upper Eocene
Umpqua formation	Lower Eocene

The humid climate and the physical and chemical nature of the andesitic tuffs and flows hasten rock weathering, consequently the whole region is covered with a thick mantle of residual soil. This condition makes it very difficult to find fresh outcrops that may be studied closely in order to determine the character, structure, and distribution of the formations.

The deep alteration that gave rise to the clay deposits is a problem well worthy of a more extended study. There appears to be a striking similarity in the physical properties of the clay at these various clay occurrences, although the parent rocks vary in age from middle Eocene to middle Miocene, and the wide distribution of these altered rocks presents many difficulties to any hypothesis of contemporaneous alteration. Many other puzzling geologic problems in western Oregon may be simplified by its solution.

CORRELATION TABLE
Western Oregon

[1] after Hodge
[2] after Weaver
[3] after Thayer
[4] after Schenk
all others from U.S.G.S.

Pleistocene not complete		Troutdale [1]				
Pliocene not complete		Rhododendron [1]	Empire [2]			
Miocene	Upper	No Record				
Miocene	Middle	Astoria formation [3] Columbia River Basalt Stayton Lava [3]	Fern Ridge Tuff [3]		Sardine Series	
Miocene	Lower	No Record				
Oligocene	Upper	Nye & Acila shales [3]				
Oligocene	Middle	Yaquina formation; Eugene formation [4]; Pittsburg Bluffs beds; Tunnel Point beds; Illahe & Mehama formations [3]				Coaledo formation
Oligocene	Lower	Toledo formation; Fisher formation [4]; Moody, Keasey, Bassendorf, shales [2]				of Diller / of Dall / of Schenck
Eocene	Upper	Calapooya: Igneous facies / Sediment facies	Eocene diabase / Tyee sandstone	Burpee & Cowlitz frms. [2]		
Eocene	Lower	Umpqua				Pulaski formation
Cretaceous		Myrtle frm. Cherts & amphibole schists	Horsetown Knoxville	Early Cretaceous or Late Jurassic Intrusives		Craggy Gneiss
Jurassic		Dothan Galice	indurated sandstone shale & chert			
Triassic						
Carboniferous		Chert argillites quartzites limestones slates & lava flows				
Devonian			May Creek frm.			
Silurian						Colebrook Schist
Ordovician			Greenstones & Metamorphics			
Cambrian						
Pre-Cambrian		Salmon Hornblende schists Abrams schists				

Figure 3

STRATIGRAPHY

Pre-Eocene Formations

Rocks of pre-Eocene age occur in southwestern Oregon, but, having no importance in this investigation, are only briefly described. The oldest are the pre-Cambrian Abrams schist and the Salmon hornblende schist. The Paleozoic series consists of argillites interbedded with some fine sand stones and conglomerates, volcanic tuffs, and lenses of limestone; and all have been severely metamorphosed. Jurassic sandstones and argillites have been identified in northwestern Josephine County and Cretaceous conglomerates, sandstones, and shales represent remnants of what was once a continuous blanket. A granitoid batholith of Jurassic or early Cretaceous age has intruded the older rocks, caused some metamorphism, and has been responsible for much of the mineralization of southwestern Oregon.

Eocene

Umpqua Formation (lower Eocene) 1/

The Umpqua formation consists of 3,000 to 12,000 feet of sandstone that is poorly cemented, shale, conglomerate, and intercalated volcanic flows and tuffs. The sandstone is largely composed of grains derived from volcanic material to a degree that at places it could properly be called a tuff. Quartz and mica are present in considerable quantities, indicating the acidic composition of the original. The gradation from sandstone to shale is abrupt, the separate beds standing out distinctly. Shale predominates in the lower part of the formation and sandstone in the upper.

Pebbles of various kinds, including basalt, quartz, chert, sandstone, shale, quartz diorite, metagabbro, and porphyritic felsite make up the conglomerate. The pebbles are rounded to sub-rounded and have diameters of one-quarter of an inch up to seven inches. The presence of acidic and metamorphic pebbles and the absence of andesite pebbles distinguish the Umpqua conglomerate from the upper Eocene Calapooya conglomerate.

The amygdaloidal and ellipsoidal nature of the lavas and the palagonite of the tuffs cause these rocks to be particularly susceptible to alteration. Both the lavas and the tuffs have been altered by later solutions, which were probably contemporaneous with the formation of the cinnabar deposits.

Calapooya Formation (upper Eocene)

The Calapooya formation consists of 5,000 feet or more of tuff, breccia, conglomerate, and lava flows, and is separated from the Umpqua formation by an angular unconformity. The lower portion of the formation is dominantly sedimentary and composed mainly of conglomerate with rounded andesite

1/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geological Survey, Bull. 850, pp. 6-11, 1934.

fragments from sand size to boulders two feet in diameter. Most of the pebbles are of hypersthene-augite andesite. Associated with the conglomerates are beds having a tuffaceous matrix with large rounded or angular blocks of andesite. Mud flows are characteristic of the upper portions of this lower phase.

The upper portion of the Calapooya formation consists principally of igneous flows that show little petrographic variation and for the most part are hypersthene-augite andesites. Glassy flows resembling dacites are present at certain localities, for example, northeast of Black Butte. The conglomerates of the lower facies frequently grade upward into the upper series.

Decomposition of the lower part of the Calapooya formation, to an unusual depth and completeness, by descending surface waters is characteristic. The well-cemented phases of conglomerate have gypsum as the cementing material; however, locally this cement has been removed, and commonly nothing but decomposed conglomerate of about the consistency of cheese is to be seen in cuts as much as 20 to 30 feet deep. 1/

There was little change in volume during decomposition, so the structure of the pebbles has been preserved. In some cases the feldspar phenocrysts retain their original outlines even though completely altered to clay minerals. The exceedingly porous character of the formation was doubtless an important factor in the decomposition of these conglomerates.

The Calapooya formation is upper Eocene and it has a thickness of 5,000 feet plus.

Oligocene

Fisher Formation (lower Oligocene) 2/

The Fisher formation is a non-marine sandstone composed of rhyolite tuff, agglomerate, clays, sand, and gravel, which has been identified in the Eugene area. Here it is underlain by Eocene sandstone and overlain unconformably by the Eugene formation, and may represent the time interval between the retreat of Eocene and the advance of the Oligocene seas. Its age is considered to be lower Oligocene.

1/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geological Survey, Bull. 850, pp. 6-16, 1934.

2/ Schenck, Hubert C., Marine Oligocene of Oregon: University of California Publications, Bull. of Dept. of Geological Sciences, v. 16, no. 12, p. 451, 1927.

———————— Stratigraphic relations of western Oregon Oligocene formations: University of California Publications, Bull. of Dept. of Geological Sciences, v. 18, no. 1, pp. 8-9, 1928.

Eugene Formation (middle Oligocene)

The Eugene formation consists of marine sandstone, sandy shale, conglomerate, and tuff, all cut by basaltic dikes and sills that have been identified in the Eugene quadrangle by Schenck. 1/ Minor faults occur throughout the formation, although no evidence of folding has been found. There is a prevailing dip of 10 degrees to the northeast, and the formation apparently dips under the Miocene volcanics. The estimated thickness is 500 feet.

Illahe Formation (middle Oligocene) 2/

The Illahe formation is identified in the Salem area by Thayer as a marine formation made up of fairly well bedded tuffaceous sediments varying in coarseness from pebble conglomerate to chalky massive white ash; silty sandstones are most abundant. The grains are mainly of plagioclase, quartz, and small rock fragments of andesite or basalt, with pyroxene and amphibole in minute amounts, and occasional mica flakes - all in a fine matrix containing some carbonates. In the coarser beds, rhyolite pebbles are locally plentiful. Marine fossils characteristic of Pittsburgh Bluffs and Eugene beds are abundant. The base of the formation is probably not far southwest of the Salem Hills. The thickness locally is of the order of 2000 to 2500 feet.

Mehama Volcanics (middle Oligocene) 2/

The Illahe formations thicken and contain no marine fossils east of the Salem district. Although it is impossible to trace these formations continuously, they apparently grade into the terrestrial Mehama volcanic deposits, which in this section are composed of fine white or greenish tuffs, some of which contain fossil wood and agglomerates. The tuffs are dominantly andesitic, but more acid rhyolitic types are found locally. In the crest of the Mehama anticline the maximum thickness of this series is about 600 feet.

Miocene

The lower portion of the Miocene is missing in Oregon and Washington, indicating erosion during that epoch. There is a possibility that the

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1/ Schenck, Hubert G., Marine Oligocene of Oregon: University of California Publications, Bull. Dept. Geol. Sciences, v. 16, no. 12, p. 451, 1927.
-------------- Stratigraphic relations of western Oregon Oligocene formations: University of California Publications, Bull. Dept. Geol. Sciences, v. 18, no. 1, pp. 8-9, 1928.

2/ Thayer, Thomas P., Structure of the north Santiam River section of the Cascade Mountains in Oregon: Journal of Geology, v. 44, no. 6, pp. 701-716, August-September 1936.
---------------- The general geology of the north Santiam River section of the Oregon Cascades: California Inst. Tech., Div. of Geol. and Paleo., Ph.D. thesis, 91 pp., 18 pls., 1934 (unpublished).

upper portion of the Blakeley formation (Oligocene) may continue into the lower Miocene.

Astoria Formation (middle Miocene) 1/

The Astoria formation near Astoria, Oregon, is made up of a lower sandstone member, a middle member consisting of a thick series of sandy shales, and an upper sandstone member. The latter stratum is dominantly marine and represents one of the earliest fossil localities of the Pacific Northwest. East of Astoria, in Columbia County, the formation is composed of thick flows of basalt, agglomerate, and tuff, with lenses of sandstone and shale. Traced still farther eastward, these volcanics appear to merge into lava flows known as the Columbia River basalts. The thickness of the Astoria is given as 1,500 to 5,000 feet.

Stayton Lavas (middle Miocene) 2/

The Stayton lavas are dominantly black and aphanitic to finely porphyritic basalts. Porphyritic varieties contain phenocrysts up to one millimeter in length and are somewhat porous where not vesicular. The finer flows are glassy and characterized by blocky structure. The black basalts have a diabasic texture of labradorite feldspar laths and granular augite in the groundmass, the gray lavas are almost identical in mineral composition to the black lavas. There are some andesite flows, of which the hypersthene-bearing augite andesite near West Stayton is an example.

The Stayton lavas cover the Illahe formation in the Salem hills, but in the foothills of the Cascade Mountains they underlie dip slopes up to 1,500 feet in elevation. There is a marked unconformity between the Illahe-Mehama and Stayton formations.

Fern Ridge Tuffs (late middle Miocene) 2/

Fern Ridge tuffs, consisting of both tuffs and agglomerate, are exposed in the north Santiam region and presumably in the area east of Salem. The basal beds of the series, where not tuffaceous, are pebble agglomerates and even sandstone, whereas most of the conglomerate higher up contains large boulders. Some fossil leaves have been recovered and fossil wood is quite plentiful at certain points.

The formation lies conformably on Stayton lavas and has a thickness of 0 to 1,200 feet.

1/ Weaver, Charles Edwin, Tertiary stratigraphy of western Washington and northwestern Oregon: University of Washington Publications in Geology, v. 4, pp. 182-183, 1937.

2/ Thayer, Thomas P., Structure of the north Santiam River section of the Cascade Mountains in Oregon: Journal of Geology, v. 44, no. 6, pp. 701-716, August-September 1936.

---------------- The general geology of the north Santiam River section of the Oregon Cascades: California Inst. Tech., Div. of Geol. and Paleo., Ph.D. thesis, 91 pp., 18 pls., 1934 (unpublished).

Pliocene

Rhododendron Formation (Upper Pliocene to Early Pleistocene) 1/

The Rhododendron formation is a coarse clastic, in which the felsite pebbles are frequently so well rotted that a sharp blow completely shatters them. Hodge 2/ mentions Thayer's classification of the Fern Ridge tuffs and states that these same beds are a part of the Rhododendron formation and are early Pleistocene in age.

IGNEOUS ACTIVITY

Virtually all the pre-middle-Pliocene formations are intruded by sills and batholithic masses. The country rock frequently is altered adjacent to these intrusions, and some mineralization has resulted.

In the north Santiam is an intrusion of Halls Diorite. 3/ It is a fine-grained, purplish-gray porphyry at the edge and changes to a medium-grained almost white porphyry at the center. Quartz and orthoclase do not amount to over 5 percent each, and the rock is classed as a tonalite or possibly a quartz diorite.

This plug of Halls Diorite intruded but did not particularly disturb the Miocene lavas in the base of a syncline near the town of Halls. The intruded lavas were epidotized and chloritized, and where there was more intense alteration secondary quartz, sericite, pyrite, and hematite were introduced. In hand specimens the main effect of the alteration appears to have been a bleaching without destruction of the original texture of the rock.

Breitenbush Springs indicates continuing igneous activity in this

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1/ Hodge, Edwin T., Age of the Columbia River and lower canyon: (abst.) Geol. Soc. America, Bull. v. 44, p. 156, 1933.
Allen, John Eliot, Contributions to the structure, stratigraphy and paleontology of lower Columbia River gorge: Univ. of Oregon, Master's thesis, 1932 (unpublished).
Barnes, Farrel F., and Butler, John W. Jr., The structure and stratigraphy of the Columbia River gorge and Cascade Mountains in the vicinity of Mt. Hood: Univ. of Oregon, Master's thesis, 1930 (unpublished).
Sheets, M. Merideth, Contributions to the geology of Cascade Mountains in the vicinity of Mount Hood: Univ. of Oregon, Master's thesis, 1932 (unpublished).

2/ Hodge, Edwin Thomas, The Cascade plateau province: Geological Society of the Oregon Country, Geological News Letter, v. 4, no. 2, Portland, Oregon, January 25, 1938.

3/ Thayer, Thomas P., Structure of the north Santiam River section of the Cascade Mountains in Oregon: Journal of Geology, v. 44, no. 6, pp. 701-716, August-September 1936.
---------------- The general geology of the north Santiam River section of the Oregon Cascades: California Institute of Technology, Division of Geology and Paleontology, Ph.D. thesis, 91 pp., 18 pls., 1934 (unpublished)

part of the Cascade Range. The Breitenbush Hot Springs are east and slightly south of the King's clay in the Salem area.

STRUCTURE

The pre-Cretaceous formations of southwestern Oregon were mainly deposited parallel, if not conformable, to each other and were affected by the same deformative movements. They were folded, overturned, and faulted by the great Jurassic epoch of mountain-building. The older rocks and the Cretaceous formations were further deformed by movements at the close of the Cretaceous. The hiatus between the Eocene Umpqua and Calapooya deposition represents a time interval during which there was less intense folding. All three of these deformative periods produced folds with northeast-southwest trending axes. 1/

A still later period of deformation produced a series of four northeast-southwest trending folds in Miocene and older rocks. 2/ From west to east these are the Willamette syncline, the Mehama anticline which nearly coincides with the Eagle Creek anticline of the Columbia Gorge, the Sardine syncline, and the Breitenbush anticline which may project northward to the Ortley and Bingen anticlines of the Columbia Gorge. Thayer assumes that the folding is upper Miocene and later than the intrusion of Halls diorite.

A fault of the Basin-Range type can be traced from Crater Lake to Mount Hood, according to Callaghan. 3/ It separates the Cascade Mountains into the Western Cascades of folded volcanics and pyroclastics, and the High Cascades of young lavas which form the higher peaks.

The Willamette Valley apparently is eroded into the northeast-dipping flank of a geo-anticline, the axis of which may be near the crest of the Coast Range. A synclinal axis which approximately coincides with the Columbia River northwest from Portland is postulated by Weaver 4/, but its relationship to the major fold is not clear.

1/ Diller, J. S., and Kay, G. F., Riddle folio no. 218: U. S. Geol. Survey, Geologic Atlas no. 218, p. 6, 1924.

2/ Thayer, Thomas P., Structure of the north Santiam River section of the Cascade Mountains in Oregon: Journal of Geology, v. 44, no. 6, pp. 701-716, August-September 1936.

------------------ The general geology of the north Santiam River section of the Oregon Cascades: California Inst. Tech., Division of Geol. and Paleo., Ph.D. thesis, 91 pp., 18 pls., 1934 (unpublished).

3/ Callaghan, Eugene, Some features of the volcanic sequence in the Cascade Range in Oregon: Am. Geophysical Union, Trans., 14th Ann. Meeting, pp. 243-249, 1933.

Thayer, Thomas P., op. cit.

4/ Weaver, Charles Edwin, Tertiary stratigraphy of western Washington and northwestern Oregon: University of Washington Publications in Geology, v. 4, pp. 182-183, 1937.

CORRELATION OF CLAY DEPOSITS

ORIGIN OF THE CLAY.

The two standard theories of the origin of clay materials in general are that (1) the original rock was altered by descending meteoric waters, and (2) that it was altered by hydrothermal or pneumatolytic action. The meteoric-waters theory probably explains the greater proportion of the occurrences and is frequently adopted when it is difficult to find sufficient evidence of hydrothermal alteration.

The statement by McKitrick (see page 22) that the weathered gravel at the Fern Ridge damsite on the Willamette River is firmer and more resistant below ground water level, would tend to support the descending waters theory.

The Fransen weathered gravel is 15 to 25 feet thick and completely altered. The overlying soil is "residual from the basalt", according to the Department of Agriculture soil survey, and has a heavy iron content, yet the underlying clay is remarkably free from iron staining as the analyses show. These data are difficult to adjust to a descending-water theory.

In the Molalla and Salem districts the clay occurs above basalt and is apparently the lower part of a tuff bed. The rest of the tuff is certainly not altered to the same degree as the clay.

At Hobart Butte, Wells and Waters 1/ state that the alteration of the conglomerate now refractory clay material has been caused by descending surface waters. At Black Butte, a short distance southeast, cinnabar was deposited by hydrothermal solutions that altered the country rock to such a degree that portions of it are suitable for refractory purposes. Faulting, mineralization, alteration, and "iron ribs" are characteristic of Black Butte. Similar conditions prevail at Hobart Butte, where the rock is impregnated with the sulfides, realgar, and cinnabar. There is evidence of faulting, and "iron ribs" are present. It would appear that Hobart Butte has been subject to similar conditions to those at Black Butte, and, on this basis, at least a portion of the Hobart Butte alteration must be hydrothermal.

The above statements indicate that an hydrothermal hypothesis may be satisfactory for the origin of certain of these clays. Before the matter is settled, more careful study and some petrographic work must be done.

1/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bulletin 850, 1934.

AGE OF THE CLAY MATERIALS

Over an area extending from southern Jackson County, Oregon, to central Lewis County, Washington, are occurrences of fire clay in which the parent rock ranges in age from middle Eocene to middle Miocene, or younger. The altered material usually is andesitic flows, tuffs, or gravels. Any hypothesis based on similar conditions of alteration over such a wide area has many difficulties, especially as the age of the parent rock is lower Eocene to post-middle Miocene, yet the similarity of the altered material certainly gives the impression that the alteration generally was accomplished under similar conditions and probably during one epoch. Descending meteoric waters have been effective in some cases.

This geologic study of the clays is of a reconnaissance nature, and all conclusions are offered to stimulate further study in the area. The tentative hypothesis favored by the writers is that of contemporaneous alteration some time after middle Miocene, with alteration from both descending meteoric waters and hydrothermal solutions being effective.

THE WEATHERED GRAVEL

A gravel, composed of pebbles that still retain their original shape and mineralogic texture, although so thoroughly altered that they can easily be cut with a knife, is an unusual formation to be observed in the study of refractory fire clays. Published geologic data on this weathered gravel apparently are lacking, so it is deemed advisable to record herewith observations and inferences. The altered gravel was studied at two localities, Fransen no. 1 and Sublimity no. 26, as a probable source of fire clay, and it has been observed at several other points in the McKenzie and Santiam Valleys, Oregon, and the Cowlitz and Lewis Valleys, Washington.

LITHOLOGY

The gravel, as it occurs at the Fransen locality no. 1, is taken as typical (see fig. 7). The pebbles, ranging in diameter from 1 to 8 inches, are chiefly felsite with a small percent derived from metamorphic rocks, usually quartzite. The matrix was originally coarse-grained arkose containing, in addition to felspathic minerals, quantities of quartz grains and white mica. At one point a lens of quartz sand with a maximum thickness of four feet was observed.

Alteration has proceeded to such a degree that igneous pebbles and matrix can be cut with a knife with equal ease, the metamorphic pebbles alone being resistant. The igneous pebbles retain their original shape and can be separated intact from the mass. In some cases the mineral texture and color are preserved; in others, the pebbles are altered to a structureless cream-colored clay. The feldspars of the matrix have been changed to clay, thus providing the plastic binder to hold together the quartz and mica grains. A fresh exposure of the clay presents a striking appearance. It appears to be an ordinary gravel, and the investigator must dig into it to convince himself it actually is as soft as reported.

Figure 4. Age of Clay Materials

Locality	Age	Kind of Material
Southwestern Oregon		
Dead Indian, #44-45-46	Eocene ?	Volcanics and tuffs, associated with basic igneous intrusions.
Gaines, #38	Eocene ?	Altered rhyolites and tuffs.
Rogers, #39	Eocene Umpqua 1/	Altered flows and tuffs, associated with cinnabar.
Hobart Butte		
Hobart Butte, #35	Upper Eocene, lower Calapooya 1/	Altered tuffs, flows, and conglomerates
Blackbutte, #36	Upper Eocene, upper Calapooya 1/	Altered igneous flow.
Elkhead, #37	Lower Eocene, Umpqua 1/	Altered zone in Umpqua formations
Eugene		
Localities #29-34	Oligocene, Eugene formation 2/	Altered clastics of marine origin
Salem		
Localities #11-25	Middle Miocene, Fern Ridge 3/	Altered tuffs and pyroclastics
Sublimity, #26	Middle Miocene ?	Weathered gravels, overlying Stayton lavas.
Macleay, #27	Middle Miocene, Stayton Lavas 3/	Weathered basic igneous flows.
Molalla		
Localities #6-10	Middle Miocene, Fern Ridge ?	Altered tuffs and pyroclastics
Northwestern Oregon		
Fransen, #1	Middle Miocene or younger	Weathered gravels overlying Astoria volcanics.
Toutle River, Washington	Eocene or Miocene 4/	Altered flows or pyroclastics.
Southern Lewis County Washington	Post Oligocene	Weathered gravels overlying Oligocene sediments and underlying Vashon outwash.

1/ Wells and Waters, op. cit.
2/ Schenck, Hubert G., op. cit.
3/ Thayer, Thomas P., op. cit.
4/ Weaver, Charles E., op. cit.

STRATIGRAPHIC POSITION

The weathered gravel at the Fransen locality lies on basalt that is identified as middle Miocene age, 1/, a portion of the intercalated basalt in the Astoria formation. At the Sublimity locality no. 26, one-half mile north of the town of that name, the base of the weathered gravel is not exposed. A short distance northward, at a slightly lower elevation, an outcrop of Stayton lava (middle Miocene) occurs, which would justify the conclusion that the weathered gravel lies on Stayton lava.

The age of the weathered gravel is either that of the upper portion of the basalt flows or younger than them, and it is thought to be post-middle Miocene.

Field parties of the U. S. Department of Agriculture 2/ have recorded that the Salkum and Winlock soil series of southwestern Washington and the Salkum and Veneta soil series of Oregon are underlain by weathered gravel. In two instances particular mention is made of the extreme weathering, in one, that the gravel can be cut by a spade in wells and excavations 2/, and in another case that it can easily be cut with a knife or spade 2/. In other occurrences the references state that the mass is very deeply weathered, particularly in areas underlying Salkum soil. Weathered gravels found under Winlock and Veneta soils are not as completely altered as those under Salkum.

Areas mentioned in these references include those in the McKenzie Valley, in Lane County, in the south Santiam Valley in Linn County, near Sublimity in Marion County, in Polk County, and also in Lewis County, Washington, from Toledo Winlock to Chehalis and eastward.

Bretz 3/ records the presence of "till", which underlies Admiralty Hill in the Puget Sound and Little Rock (Thurston County) areas, and he also

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1/ Weaver, Charles Edwin: Tertiary stratigraphy of western Washington and northwestern Oregon: University of Washington Publications in Geology, v. 4, pp. 182-183, 1937.

2/ Mangum, A. W., and Party, Reconnaissance survey of southwestern Washington: U. S. Dept. of Agriculture, Bureau of Soils, Advance Sheets, Field Operations for 1911, pp. 73-77, issued May 15, 1913.

Torgerson, E. F., and Hartmann, Charles Jr., Soil survey of Polk County, Oregon: U. S. Dept. of Agriculture, Bureau of Soils, Advance sheets, Field Operations for 1922, pp. 1701-1702, 1927.

Torgerson, E. F., and Glassey, T. W., Soil survey of Marion County, Oregon: U. S. Dept. of Agriculture, Bureau of Chemistry and Soils, Series of 1927, no. 32, p. 23, 1927?

Kocher, A. E., Carpenter, E. F., and Harper, W. G., Soil survey of Linn County, Oregon: U. S. Dept. of Agriculture, Bureau of Chemistry and Soils, Series of 1924, no. 25, p. 61, 1924?

Carpenter, E. J., and Glassey, T. W., Soil survey of the Eugene area, Oregon: U. S. Dept. of Agriculture, Bureau of Chemistry and Soils, Series of 1925, no. 33, pp. 24-28, 1925?

3/ Bretz, J. Harlan, Glaciation of the Puget Sound Region: Washington Geological Survey, Bull. no. 8, pp. 176-177, 1913.

refers to a weathered till in a conglomerate near Ayers Point on Hood Canal. Only mere mention is made of the occurrences.

CONDITIONS OF DEPOSITION.

A careful study was not made of the evidence bearing on the original deposition conditions of this gravel. In the McKenzie area 1/ and in the south Santiam, mention is made that the underlying weathered gravel appears to be a portion of an old, high terrace. Piper makes a similar suggestion 2/. The distribution of the localities suggests that the formation represents remnants of old valley fills now recognized as a series of terrace deposits.

CONDITIONS ACCOUNTING FOR ALTERATIONS.

In the Hobart Butte area, in southwestern Lane County, Wells and Waters 3/ discuss the alteration of the conglomerate in the lower portion of the Calapooya formation. "Commonly nothing but decomposed conglomerate of about the consistency of cheese is to be seen in cuts as much as 20 or 30 feet deep. Despite the complete alteration of the andesitic pebbles, there has been no large change in volume during decomposition and the original structure of the once resistant conglomerate is well preserved. - - In many places feldspar phenocrysts that have been altered entirely to clay minerals retain their original sharp outline". Although the Calapooya formation is upper Eocene and the weathered gravels considered here are post-middle Miocene, the description by Wells and Waters could be copied, word for word, as a description of the later gravels. They conclude that the Calapooya conglomerate was altered by descending surface waters.

In the McKenzie area, McKitrick 4/ observed that test pits at the Fern Ridge damsite on the McKenzie River, 18 miles northwest of Eugene, exposed weather gravel. Above permanent ground water level the gravel was altered completely, whereas below, the pebbles were harder and reasonably resistant, so that it was necessary to use a pick to drive through them.

In the Chehalis, Wash., area, the Soil Survey states that in their opinion the gravel is an old glacial till, but they give no opinion as to the method of alteration. All of the deposits (Fransen, Sublimity, McKenzie, Hobart Butte, Chehalis) investigated by the writers and others are above the present permanent water levels. On this basis, the assumption that alteration is the result of descending ground water is the more reasonable.

1/ Carpenter, E. J., and Glassey, T. W., Soil Survey of the Eugene area, Oregon: U. S. Dept. of Agriculture, Bureau of Chemistry and Soils, Series 1925, no. 33, pp. 24-28, 1925?
Kocher, A. E., Carpenter, E. F., and Harper, W. G., Soil Survey of Linn County, Oregon: U. S. Dept. of Agriculture, Bureau of Chemistry and Soils, Series of 1924, no. 25, p. 61, 1924?

2/ Piper, Arthur M., personal communication, January, 1938.

3/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bulletin 850, 1934.

4/ McKitrick, W. E., personal communication, January 20, 1938.

AGE OF THE WEATHERED GRAVEL

The weathered gravel is post-middle Miocene in age, as it lies either on top of middle Miocene basalt or is intercalated with it. The upper limit for its age is not determined at present; the degree of weathering is greater than that of Admiralty till, the oldest recognized in western Washington, and it is greater than Satsop and of Troutdale and observed Rhododendron. 1/ Rhododendron is late Pliocene to early Pleistocene. There are serious objections to fixing the age of any rock on its degree of weathering, as conditions may vary considerably within a small area. The most ambitious statement possible at this time is to say that the weathered gravel is probably post-middle Miocene and pre-glacial.

METHODS OF TESTING

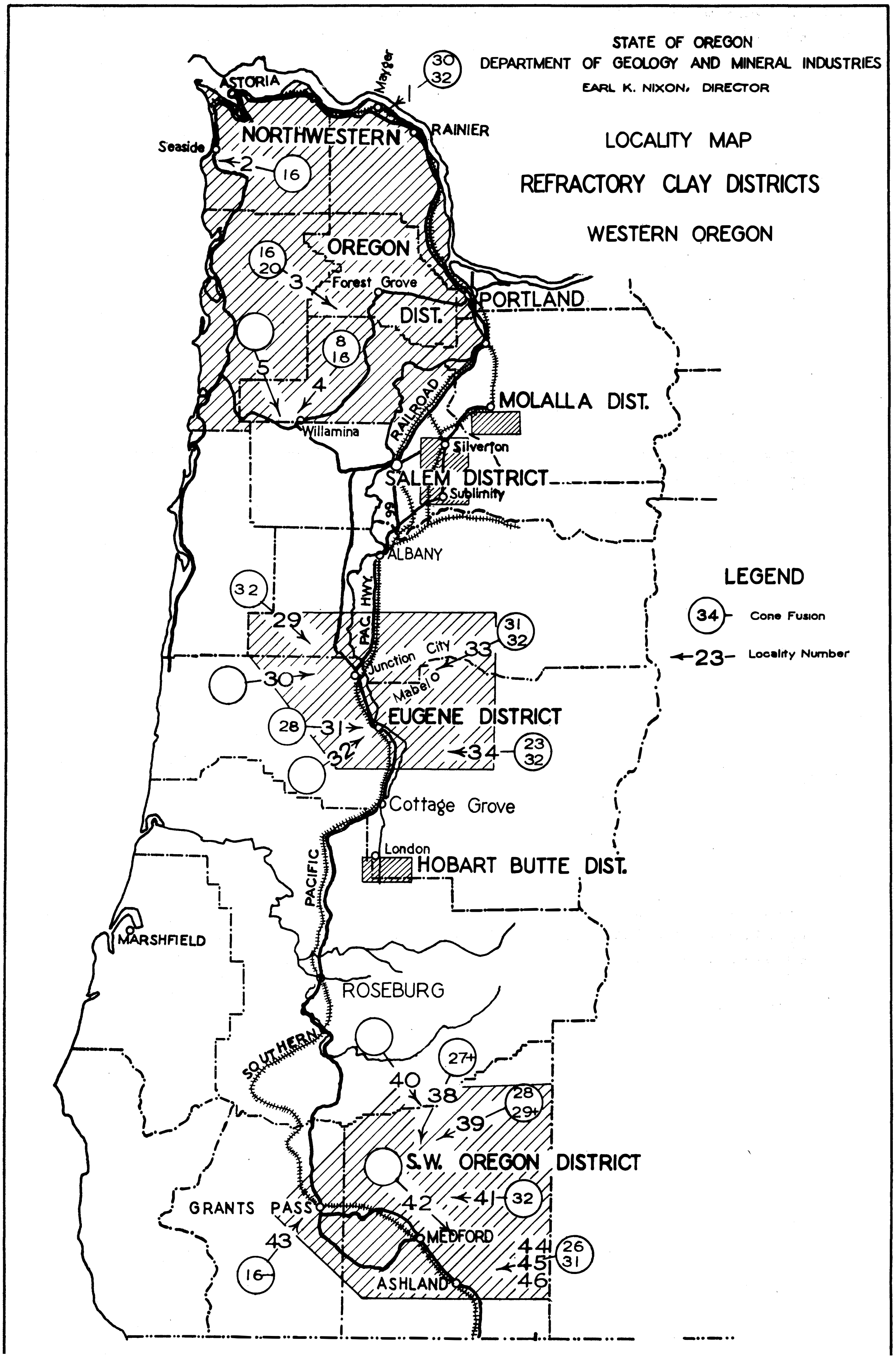
Preliminary samples were shipped to the ceramic engineering laboratory of the University of Washington, dried, ground finer than 65 mesh, molded into the standard pyrometric cone shape, and fused according to the specifications of the American Society for Testing Materials, standard method for "Pyrometric Cone Equivalent for the Fire Clay and Fire Brick," A. S. T. M., designation C 24-35. The original color, hardness, plasticity, impurities, melted color, and general character of the clay were noted, and those that gave P. C. E. values above cone 30 or light-colored melts were separated from the low-refractory and dark-colored materials for further sampling and study.

After the above classification tests, larger samples of the better clays were tested for behavior in manufacturing products. These tests consisted of the production of 1 by 1 by 8 inch test bars for the determination of drying and firing shrinkage, vitrification range, warping, cracking, and other troubles, fired colors at different temperatures, and the general indications for success or failure in manufacturing. Special tests were made on several typical clays, and private reports were drawn upon for the results of other determinations.

Chemical analyses were made by Lerch Brothers, Inc., Hibbing, Minn., and by Crowell and Murray, Cleveland, Ohio.

More tests will be made with these clays in the future, since the indicated values of many are high. The quantities available and the accessibility of the deposits are satisfactory for commercial service when the market warrants their development.

1/ Hodge, Edwin T., Age of the Columbia River and lower canyon: (abst.) Geol. Soc. Am., Bull. v. 44, p. 156, 1933.
-------- History of the Columbia River Gorge: (abst.) Geol. Soc. Am., Bull. v. 43, pp.131-132, March 1932.


STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
EARL K. NIXON, DIRECTOR
LOCALITY MAP
REFRACTORY CLAY DISTRICTS
WESTERN OREGON
LEGEND
34 Cone Fusion
23 Locality Number
ASTORIA
Mayger
RAINIER
Seaside
NORTHWESTERN
OREGON
DIST.
Forest Grove
PORTLAND
Willamina
MOLALLA DIST.
RAILROAD
Silverton
SALEM DISTRICT
Sublimity
99
ALBANY
PAC. HWY.
Junction City
Mabel
EUGENE DISTRICT
Cottage Grove
London
HOBART BUTTE DIST.
PACIFIC
MARSHFIELD
ROSEBURG
SOUTHERN
S.W. OREGON DISTRICT
GRANTS PASS
MEDFORD
ASHLAND
1
30
32
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32
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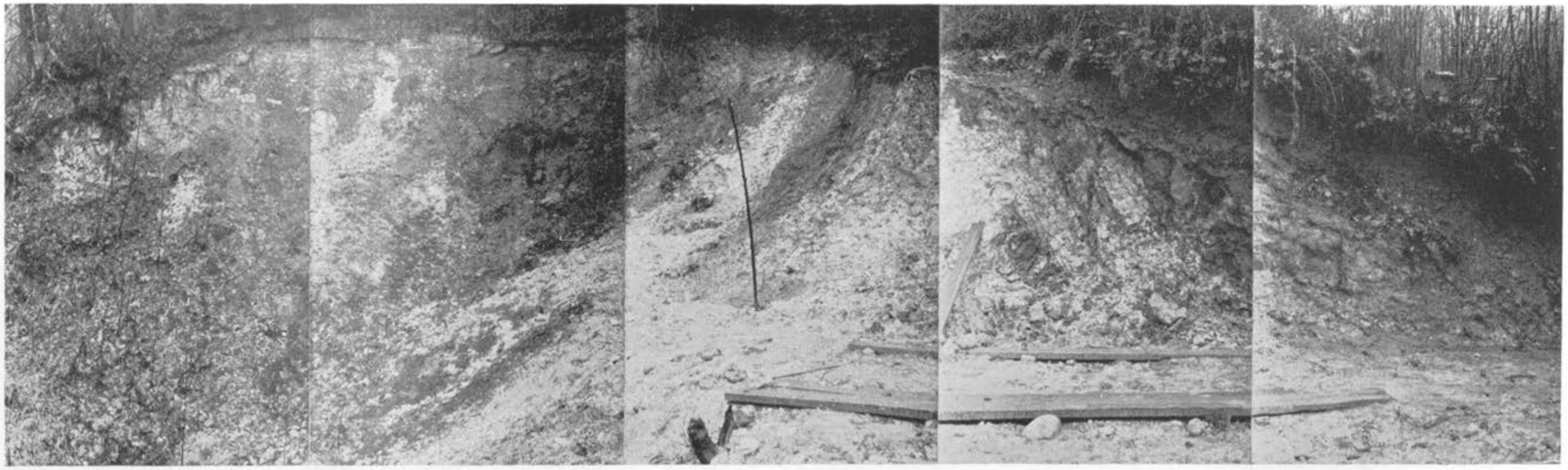


Figure 6. Fransen Clay Pit

Figure 7. Detail of Fransen Gravel

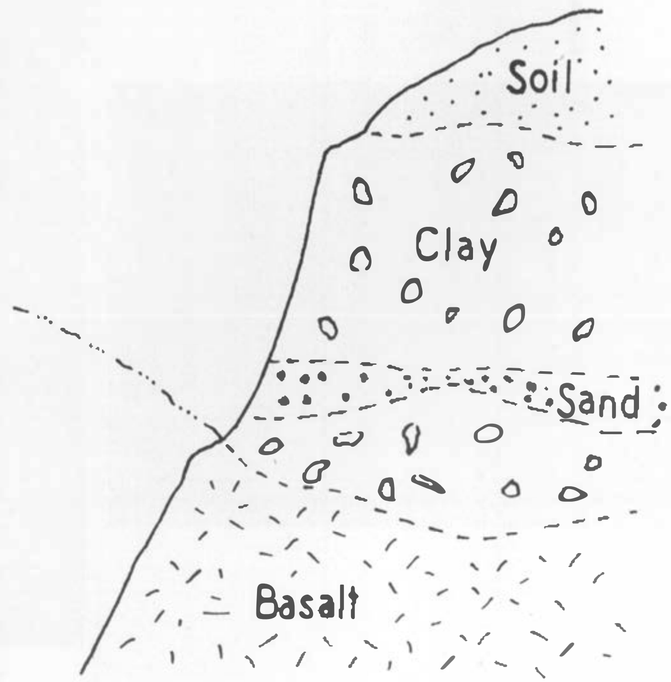


Figure 8. Diagrammatic Sketch, Cross-section of Fransen Clay Pit

Figure 20. Ellis Clay Adit

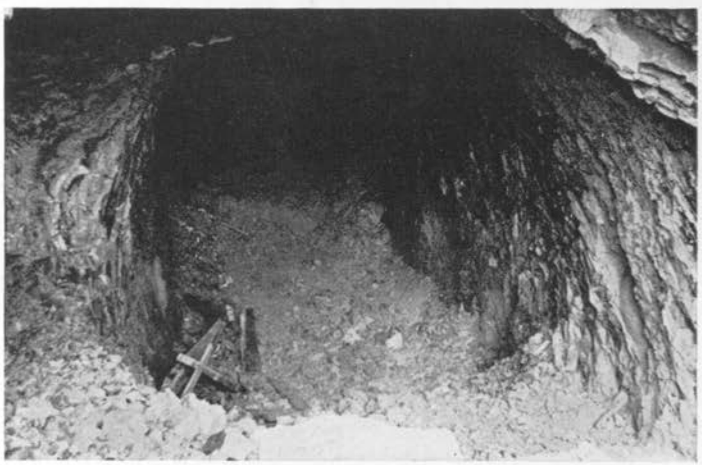


Figure 21. Interior of Ellis Clay Adit

Figure 22. Ellis Clay Adit Contact of Clay and Tuff

CLAY DISTRICTS

NORTHWESTERN OREGON DISTRICT

There is only one clay deposit known at present in northwestern Oregon that has the proved characteristics of high-refractory clay. The Sig Fransen deposit in northwestern Columbia County apparently has quality and quantity sufficient to justify commercial development, and is described in detail. The P. C. E. values of the other deposits visited were too low for classification as high-refractory clays.

Sig Fransen Deposit, Locality No. 1

Location.

The Sig Fransen clay deposit is located in northwestern Columbia County in the NE$\frac{1}{4}$ sec.33, T.8 N., R.3 W. (See fig.10.) Rainier, 6 miles east, is the nearest town, and Mayger, 3.5 miles west, is the nearest railroad station of the Spokane, Portland and Seattle Railway. The NE$\frac{1}{4}$ sec.33 has been subdivided into thirds in the form of east-west rectangles each having the length of the quarter-section, and the Sig Fransen third is the middle one. Details are shown on figure 9. No published topographical maps of this area are available.

Topography.

The Columbia River bounds the area on the northeast at virtually sea-level elevation. From the southwest bank of the river the land surface rises 500 to 600 feet in a quarter of a mile to form a plateau-like surface, which has rounded hills and wide valleys typical of late mature topography. As this mature surface is perched well above sea level, headward-cutting streams erode V-shaped youthful canyons through the hard underlying basalt. Thus, the normal cycle of erosion has been reversed and the streams rejuvenated. Rock outcrops are usually well concealed under a heavy soil cover or a dense growth of underbrush, or both.

Climate.

Climatic conditions are characteristic of western Oregon in that the annual range of temperature is moderate, the winters are "open", and rainfall is principally confined to the colder months of the year. The annual precipitation is about 60 inches, and snow is seldom an interfering agent. Fog, which rolls up from the Columbia River valley, becomes a handicap to transportation at times.

Front Pit.

The Front Pit lies 200 feet southeast of Fransen's house and 60 feet below it, near the crest of a 500-foot bluff overlooking the Columbia river. The clay was discovered when county engineers started a quarry for road metal in the underlying basalt. A "coyote" hole was driven into the basalt, and a large powder charge was exploded with the expectation that the basalt would be completely shattered. The charge blew out at the back, removing enough soil overburden to expose the clay.

Small amounts of clay were sold to the Pacific Stoneware Co. over a period of time, and a 25-foot vertical face was maintained in the quarry. The Denny-Renton Clay & Coal Co. contemplated development of this clay for their Portland plant in 1922, but a decision against the manufacture of refractories in the Portland area caused the matter to be dropped. 1/ Since that time, Mr. Fransen has not worked the deposit, as the expense of keeping the pit in condition for small, intermittent sales is too great.

Description of the Clay Pit:

The clay pit is 80 to 100 feet wide, 40 feet from front to back, and has a vertical height of about 30 feet. Overburden consists of 3 feet of soil and impure clay; but as the quarry face extends farther into the hillside, the overburden doubtless will increase to a maximum of 60 feet under Fransen's house. (See fig.6.)

The clay material is formed from gravel that has been weathered and altered so thoroughly that the pebbles are soft enough to be carved with a knife. A complete description has been given in the section on Weathered Gravel. The clay is quite uniform in quality except for a lens of quartz sand that occurs 15 feet below the top of the clay. This lens is 4 feet thick at the south side of the pit and pinches out at the north.

The attitude of the clay bed was not determined. The clay is underlain by basalt, and the overlying soil is reported as a residual derivative of basalt. 2/ Weathered basalt is identified at both ends of the quarry some 18 feet above the floor of the pit. These conditions may indicate that the conglomerate was originally deposited in an old river channel eroded from the basalt.

The clay was sampled over a vertical distance of $31\frac{1}{2}$ feet, as shown in the columnar section, figure 12. The first or top 15 feet of clay was channel-sampled and then 2 feet of quartz sand was encountered. An auger hole (A) was started below the sand and continued through 14 feet of clay plus 2 feet of weathered basalt at the bottom. Hole B was started at the quarry floor and only weathered basalt was recovered.

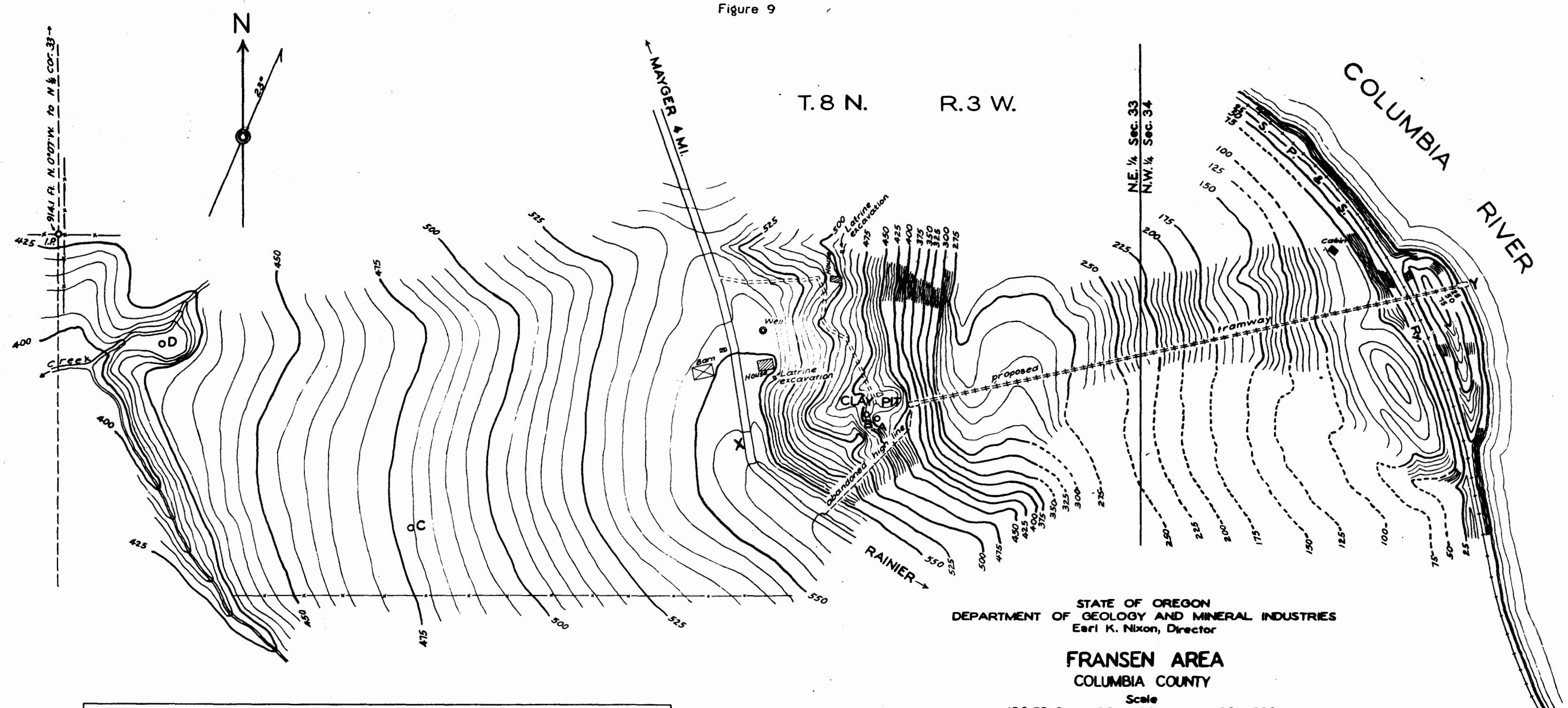
Quality:

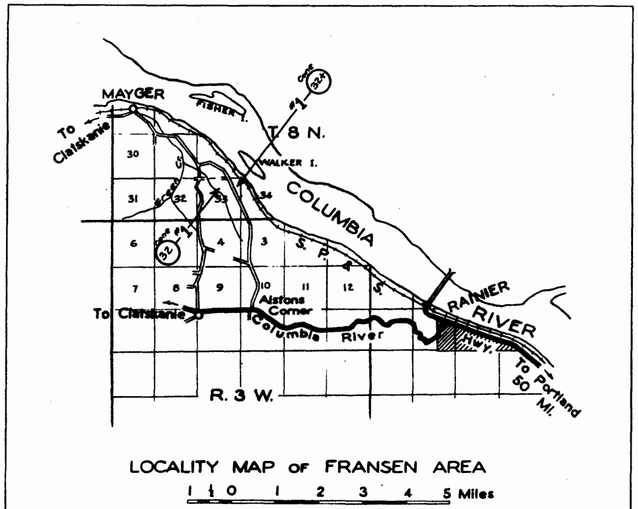
Tests on Fransen clay from the front pit: The preliminary samples from the softened gravel in the present working face were divided into three parts: A-1, a gray plastic clay; A-2, a light-cream moderately plastic clay; and A-3, a hard quartzite mass with no plasticity, representing some of the quartzite pebbles. All, as shown in figure 8, gave P. C. E. values near cone 32. However, with the larger channel sample (1-d) taken from the upper 15 feet (see fig.12) of the exposed gravel, representing a mixture of all varieties of the softened pebbles, the P. C. E. dropped to cone 30. Analysis of this sample showed only 25.6 percent alumina,

1/ Lemley, W. G., personal communication, December 29, 1937.

2/ Harper, W. G., and Torgerson, E. F., Soil Survey of Columbia County, Oregon: U. S. Dept. of Agriculture, Bureau of Chemistry and Soils, Series 1929, number 35, p. 13 (1934?)

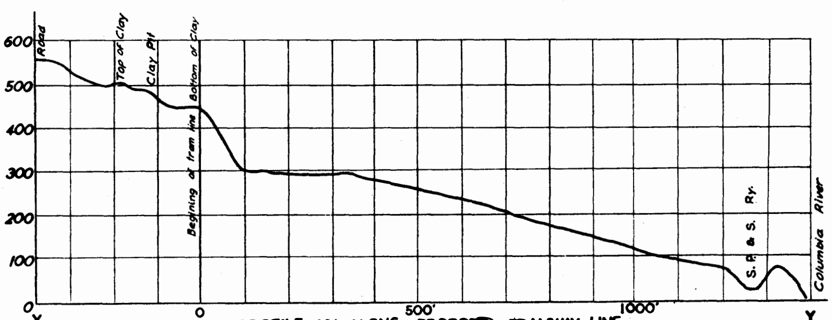
Figure 9





LOCALITY MAP OF FRANSEN AREA

Figure 10



PROFILE XY ALONG PROPOSED TRAMWAY LINE
Horizontal Scale = Vertical Scale

Figure 11

63.6 percent silica, with 2.55 percent iron oxide. The auger sample in the floor of the pit (1-f), from 17.5 to 31.5 feet, had a fusion of cone 31-minus, with a higher alumina content of 39.8 percent and lower silica, 39.4 percent with 6.7 percent iron oxide.

The special tests of (1-d), (shown in figures 46 and 47) indicated a highly plastic material requiring a high percentage of tempering water. It gave a high shrinkage on firing but remained soft and otherwise unaffected by the high temperatures until above cone 15, becoming steel hard at cone 20, with 6.7 percent linear shrinkage and 10.2 percent absorption. A high degree of vitrification was developed at cone 29, with a linear shrinkage of 11.5 percent and an absorption of 1.6 percent. The brown surface covered a white-spotted black interior without vesicular development or deformation.

A similar test of (1-f) fired to cone 20 showed 3.3 percent absorption after 14.5 percent shrinkage. The greenish-gray surface covered a black interior and the samples showed evidences of softening and deformation.

These data indicate a possible usefulness in refractory service if these clays are properly mixed with grog (the preheated, preshrunk clay) to reduce the shrinkage to commercial limits. Their resistance to high temperature is not the best, according to the present firebrick standards, since many bricks on the market now will give P. C. E values of cone 33 and above. The uniformity of the clay when large quantities are to be mined and the content of the hard quartzite pebbles are unknown factors that require further study. But, despite the peculiar appearance and apparent variation of the weathered gravel face, the tests indicate that further investigation is well worth while.

Quantity:

Top of the clay seam in the quarry is at an elevation of 490 feet. A well 50 feet north of Fransen's house was dug through soil, and clay was struck at elevation 490 feet. (See fig. 9.) A latrine excavation 300 feet northeast of the house exposed this same clay at elevation 490 feet. Louis Fransen opened a pit on his land south of Sig Fransen's property, and similar material was exposed. Two shallow auger holes located between the Louis Fransen and the Sig Fransen clay occurrences showed indications of the same clay. It is concluded, therefore, that the clay body has a linear extent of at least 1000 feet across Sig Fransen's land (see fig. 9), a minimum width of 250 feet, and a depth of 25 feet.

The minimum quantity, on the basis of the figures given above, is computed to be 430,000 short tons. There is reason to believe that the clay has a greater width than 250 feet and probably extends clear through the hill, in which case the dimensions would be 1000 feet by 1000 feet by 25 feet, making a total of 1,720,000 short tons on Sig Fransen's property. Further exploration may reveal that the clay has a still greater linear extent. The locality should be checked by core drilling.

COLUMNAR SECTIONS

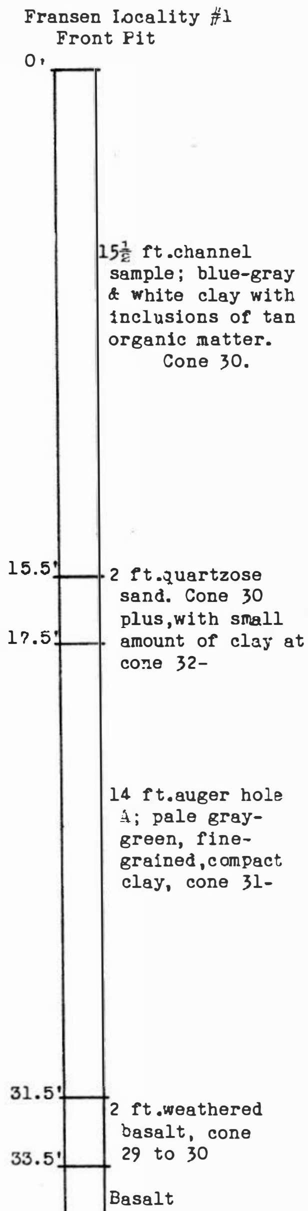


Fig. 12

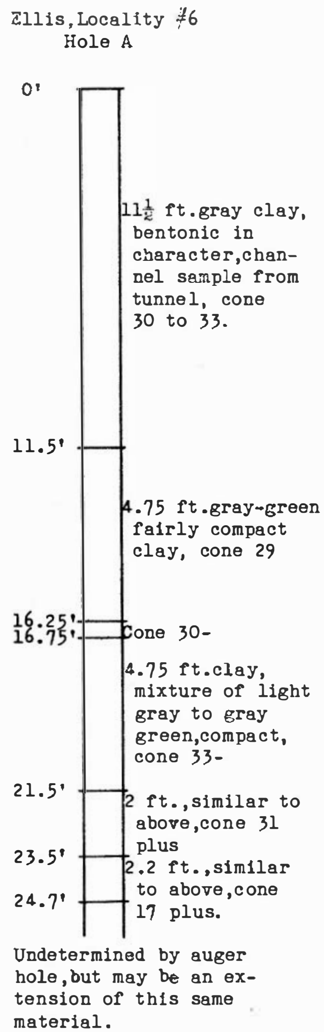


Fig.13

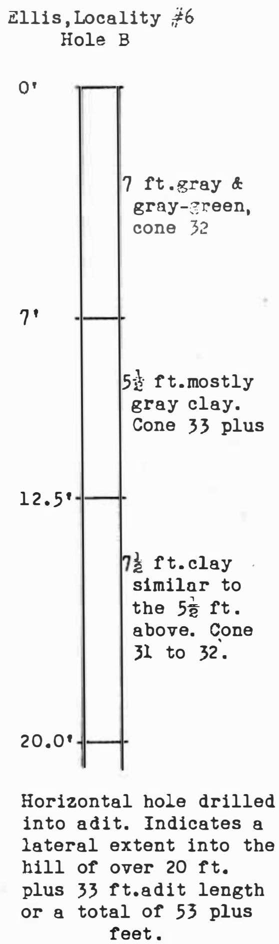


Fig.14

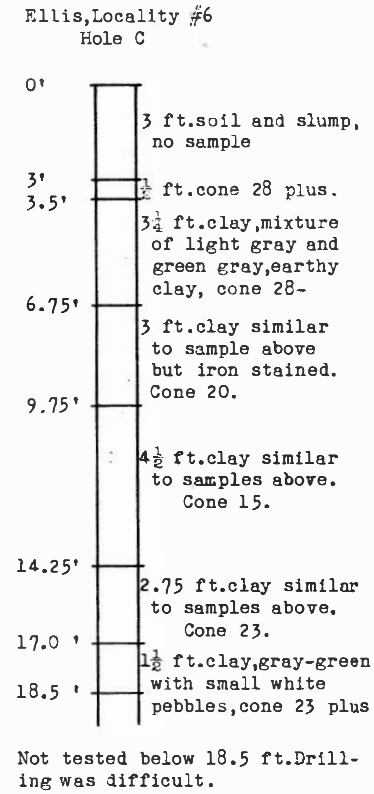


Fig.15

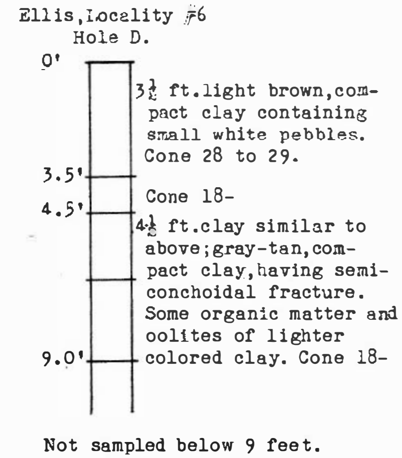


Fig.16

Mining:

The clay could be mined by open-pit or underground means, or a combination of both. With open-pit or quarry operations, the soil overburden 3 to 60 feet thick could be stripped with a dragline scraper or bulldozer and dumped below the quarry. A quarry face from 25 to 30 feet high may be maintained throughout the length of the deposit and drainage effected by gravity. The clay could be trammed to a bunker built on the steep slope below the quarry floor, the bunker intake at elevation 450 feet, and the chute gates at 425 feet, where the foundations would rest on basalt. A 1,400 foot tram line would deliver the mined clay either to the railroad or to boats on the Columbia river. (See fig.11.)

Underground mining will require some conventional type of underground equipment suitable for such material.

The P. C. E. tests indicate that the entire mass, 25 to 30 feet thick, can deliver a product averaging above cone 30. Should the sand lens become thicker than 4 feet, it would be necessary to make some segregation; however, there might be a market for the sand as molding sand.

Transportation:

Cheap transportation is one of the more favorable features connected with the Fransen deposit, for the clay can be moved either by barges, deep-draft vessels, or by rail. The tram line (see figs. 9 and 11) is laid out so that it crosses the railroad, and clay may be dumped into bunkers at a railway sidetrack or carried to the tram terminus and dumped into bunkers built over deep water.

A channel with a minimum depth of 30 feet extends northwestward into the main channel of the Columbia River, except for a 700 foot shoal area at the downstream end of Walker Island. This shoal is covered with 12 feet of water at high tide, and dredging will permit deep-draft vessels to dock at the proposed bunker. It is estimated that the clay could be delivered on board the ship for 75¢ to $1.00 per ton.

Rail shipment from the tram-line locality would require the construction of a sidetrack and bunkers. The rail distance to Portland is 50 miles.

The clay can also be delivered by trucks over 3.5 miles of graveled county road to the railway siding at Mayger. The rail distance to Portland is 56 miles. An alternate route is to Rainier; 2.5 miles by county graveled road and 6 miles of hard-surfaced state highway, with only about 1 mile of adverse grade. From Rainier to Portland the rail distance is 46 miles.

Back Pit.

The "Back Pit" is 1,400 feet west of and 125 feet lower in elevation than the Fransen house and lies in a tributary valley of Green Creek. (See fig. 9.) It was discovered and worked before the Front Pit was opened, and clay from it was shipped to the Pacific Stoneware Co. It has been idle for a number of years.

The clay-soil overburden seems to grade into refractory clay, and auger-hole data imply that the top of the refractory clay is about at the present pit floor level. The clay is greenish-gray but contains no softened pebbles, and pieces of thoroughly weathered vesicular lava are mixed in the mass. Five feet below the pit floor a thin layer of metamorphic pebbles and cobbles occurs in a manner that suggests deposition on an uneven surface. Then, ponding became effective and reworked clay was deposited. It is assumed, therefore, that the deposit is a pocket covering an area of some 200 feet by 100 feet, and that the thickness is not much over 5 feet between the pit floor and the layer of metamorphic pebbles. Additional pockets may be located by core drilling.

Quality:

Slumping of surface material undoubtedly caused the variation in fusion of the preliminary samples 1-b, cone 16-minus, and 1-c, cone 32- plus. The latter probably represents the material formerly mined for stoneware, and showed 37.6 percent alumina and 43.6 percent silica with 5.3 percent iron oxide. The ignition loss was high, indicating high fired shrinkages. No large samples were obtained for the bar tests. The clay, when free of overburden, apparently is similar in refractory properties to the clay in the front pit.

Transportation:

There is a graded but ungraveled road from the pit to the county highway, and usable clay could be trucked to the proposed bunker below the Front Pit. It is recommended that such clay as can be economically salvaged, be so handled and added to the tonnage from the Front Pit.

Summary of the Fransen Locality.

The clay in the Fransen Front Pit fuses at cone 30, requires grog to reduce shrinkage, has a spotted fired color, and an available tonnage of 430,000 to 1,720,000 short tons. Low transportation costs are possible by construction of a tram line from the pit to deep-water or railside bunkers. The tests indicate that further investigation of this deposit is worth while.

P. M. West Locality No. 2

Clay is reported about 2 miles south of Seaside, Clatsop County, and half a mile west of the Seaside-Tillamook road. (See fig. 5.) A sample was submitted by the owner, who reported that it had been used in pottery manufacture at Warrenton, Oreg. This light, cream-colored, soft material is buff-firing clay of low refractory value, giving light-gray, vesicular, glassy fusions below cone 16. The analysis showed 23.4 percent alumina, 63.2 percent silica, only 1.86 percent iron oxide, but also contained comparatively large quantities of alkalies (by difference) and alkaline earths. It is therefore more valuable for the light colored pottery and structural wares than for refractories.

Willett and Rudolph Clay, Locality No. 3

George Willett and H. Rudolph submitted three samples from Washington County, northwest of Cherry Grove (see fig.5.) "A" sample was a light-gray clay of weak plasticity, which gave a white, glassy, slightly vesicular fusion at cone 20-minus. Further study may show that it has a value for the light-colored structural wares or pottery, but it is not refractory enough for firebrick. Flintlike sample "B" was divided into three portions, according to color, but all gave gray glassy fusions below cone 16, indicating low refractoriness, a high flux content with low iron oxide, and light fired colors. Gray, flintlike sample "C" also had a fusion below cone 16, but gave a brown glassy melt that indicated dark fired colors if made into clay products.

Willamina Clay Products Co. Locality No. 4

The Willamina property is located in Yamhill County, in the $SW\frac{1}{4}SE\frac{1}{4}$ sec.36, T.5 S., R.7 W., on Willamina Creek, 0.8 mile north of the town of Willamina. (See fig.5.)

This deposit is not considered as a source of high refractory fireclay, although the clay has been blended with various refractory clays to produce a good grade of firebrick. The only light-colored face brick manufactured in the State is made from these clays at the local plant. An unusual feature of the clay is that although its original color is black, it fires white, and at common brick temperatures.

A casual examination of the property was made, and no detailed work was done. Washburne 1/ reported on the geology of the area, as follows:

> "The next exposure *** is in the deep cut of the Pacific Coast Face Brick Co., half a mile west of Willamina post office, where there is about 70 feet of shale, mostly dark clay shale but of variable character. Some layers are black and carbonaceous and turn white when burned, and some are dark green (glauconitic?) and burn red. There is also a little light-gray or white shale, with soapy feel, which is mixed with the black carbonaceous shale to make brick. Calcareous concretions from this excavation furnished a small collection of fossils, which were not specifically determinable but which indicate probably an Oligocene or lower Miocene age. The structure is irregular, probably from creeping movements downhill, a sort of slow landslide, which is common in the clay rocks of western Oregon during the wet season. The shale is slickensided on most of the joints and bedding planes, and the dip is irregular and in various directions, so that in spite of the excellent exposure the normal inclination of the rock could not be determined."

1/ Washburne, Chester W., Geology and Oil prospects of northwestern Oregon: U. S. Geological Survey, Bull. 590, pp.84-85, 1914.

It is believed that the unusual character of the clay - its origin- and fired color, its low fusing point, its use with fireclay grog - together with the fact that there are few published data on the property, justify the following quotation from Wilcox: 1/

"The clay deposit and plant of the Willamina Clay Products Co. is located one mile north of Willamina. Clays are obtained with fired colors ranging from a pure white, through the creams and buffs, to a dark brown. The only light-colored face brick in the State is produced at this plant. The unburned colors of the light-firing clays are white, mottled-gray, gray, and black. The black color is due to the high carbon content. It appears as if these clays were originally all light firing, as the tan and brown color is due to the presence in the clay of finely disseminated iron pyrite. The white and gray-colored clays do not carry any appreciable amount of pyrite, and some of the carbonaceous clay also is free from pyrite. The heavy pyrite is in carbonaceous clay only, which might indicate that the clay was deposited in water containing iron sulphate and that the sulphate was reduced to sulphide by the organic material in the clay. Some of the clay carries a small amount of limestone in the finely disseminated condition, and there are some places where calcite crystals are of sufficient size to cause trouble in the fired ware. Most of the clay from this pit is quite plastic; two different types of clay that occur in the upper part are only slightly plastic and do not break down readily in water. The clay that carries heavy pyrite has a fusion at cones 3 to 5; the plastic white-firing clay has a fusion at cones 8 to 9; a slightly less plastic clay has a fusion at cone 12; the hard, slightly plastic black clay has a fusion at cone 16; and a slightly plastic, mottled-gray clay has a cone-26 fusion. The drying shrinkage ranges from 4 to 5 percent and the total fired shrinkage from 9 to 11 percent".

"The light-firing plastic clay is used in making face brick and a bond for the nonplastic slightly weathered basalt in making common brick; it is also shipped to Portland and used in the manufacture of stoneware by the Pacific Stoneware Co. The light- and dark-burning clays are used for a bond in a firebrick mix."

"The clay measures in the pit are at least 50 feet thick but have been so mixed by slides that their true relationships are not shown. The underground workings show the beds to have a dip of about 10 degrees to the northeast. The beds are on the east limb of a gently dipping anticline, the crest of which is about half a mile west of the plant. The beds are overlain by a greenish-colored tuffaceous sandstone, which is covered, in turn, by a brownish-gray shale and a basalt flow."

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, pp. 25-31, 1935. (unpublished)

Tests.

Two samples from the Willamina pit were tested by Wilson 1/ in 1922, and since these tests are more complete than any of this study, they will be quoted:

> "No. 228. - A light-gray sample of soft clay from the Pacific Face Brick Co., Willamina, Oreg. Wet tensile strength was 2.4 pounds per square inch. Fired colors: Pink-gray cone 012-1/2, light-cream cone 07 to 3-4, light-gray cone 5 to 8. Steel hardness is found at cone 02-01, a vesicular structure at cone 8, and fusion at cone 8. Best firing range, from cones 06 to 4. Samples fired to cones 012-1/2 and 07 disintegrated in water, owing to lime content. An unusual clay material because of the combination of light fired colors and low fusion. Now used for a high quality of face brick."

> "No. 229. - A soft, dark, carbonaceous sample of ball-claylike material from the Pacific Face Brick Co., Willamina, Oreg. Wet tensile strength was 3.2 pounds per square inch. Strong dry strength. Fired colors: Very light gray, cones 012-1/2 to 02, light-gray cones 1 to 3 plus, light blue-gray cones 5 to 8. Steel hardness was found at cone 06-05, a vesicular structure at cone 5 and fusion at cone 8. Best firing range cone 08 to 01. This material is used for a portion of a stoneware body (Pacific Stoneware Co., Portland, Oreg.) and mixed with No. 228 for a high quality of buff face brick. A remarkable light color for the low temperature of firing."

At the present time the soft, carbonaceous, plastic Willamina clay is used at the Potlatch Pottery of Seattle, Wash., as a portion of their single-fired, white, semivitreous, art-pottery body, being mixed with English clays, feldspar, and flint. Some difficulty was experienced at first when the clays were dispersed in water by blunging or stirring only; but the particles of hardened clay and the small amount of calcite inclusions are now thoroughly incorporated by ball-mill grinding in water. Such commercial tests, which thus include white face brick, stoneware, and art pottery, are far better indications of the quality and properties of the clay than any laboratory tests.

Chemical properties:

The chemical analysis of the Willamina clay gives a clue to the cause of the white fired color produced at remarkably low temperature in comparison with the usual china clay or kaolin, the common representatives of white clays. Many of the latter are soft, open, and porous as high as cone 15 (2,615° F.), and vitrify only at cone 20 (2,786° F.). The plastic English ball clay is closer in physical properties to the Willamina black clay and

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1/ Wilson, Hewitt, The clays and shales of Washington: University of Washington, Engineering Experiment Station, bull. no. 18, p. 204, 1923.

likewise is found often in a similar dark carbonaceous condition. The English ball clay may vitrify at cone 5 with a gray or dark-cream color, and maintain this condition without vesicular development to high temperatures. However, its shrinkage is so great that it cannot be used without other clays and nonplastic materials. Its composition is similar to that of an impure kaolin. The Willamina clay and the Hobart Butte clay analyses are given in figure 17 for comparison with typical commercial kaolins and feldspars now in use for whiteware bodies.

Figure 17.

Chemical analyses of Oregon clays in comparison with commercial white ware and feldspars 1/

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Ignition	Calculated alkalic feldspar
*Willamina soft black clay	65.6	18.5	0.4	1.4	1.0	3.0	3.1	5.0	43.2
*Hobart Butte flint clay	46.3	35.7	0.3	0.3	0.3	None	1.4	13.4	11.8
English ball clay	46.4	35.5	0.8	0.2	0.4	1.0	0.1	15.1	6.8
English china clay	47.0	37.7	0.9	0.2	0.2	1.6	0.2	12.4	11.2
Kentucky ball clay	49.9	31.4	0.6	0.2	0.3	1.2	0.2	14.7	8.8
Tennessee ball clay	50.3	31.5	0.6	0.2	0.3	2.0	0.3	13.6	14.4
Florida kaolin	46.3	37.7	0.8	0.5	Tr.	0.2	0.0	13.7	1.2
Georgia kaolin	45.7	38.7	0.3	0.2	Tr.	0.0	Tr.	13.7	Trace
North Carolina kaolin	47.9	37.4	0.4	0.1	Tr.	1.0	0.1	13.2	6.8
Maine feldspar	72.7	15.1	0.1	0.3	Tr.	8.3	3.1	0.3	75.2
Canadian feldspar	66.5	18.2	0.1	0.2	0.1	12.4	2.0	0.3	90.2

1/ Meyer, W. W., and Klinefelter, T. A., Substitution of domestic for imported clays in whiteware bodies: National Bureau of Standards, Research Paper 1011, 15 pp., 1937.

* Analyses by Crowell and Murray, Inc., Cleveland, Ohio.

The soft Willamina black clay showed a calculated mineral composition of 43.2 percent alkalic feldspar, 26.2 percent kaolinite, and 24.4 percent free silica, with 6 or 7 percent of alkaline earth and volatile matter. It corresponds to a whiteware body of very high feldspar content which, if compounded by mixing commercial feldspar, clay, and flint would have a fusion near cone 15. This natural clay combination with a fusion near cone 18 gives the physical properties of a mixture of very soft feldspar, ball clay, and silica in a finer state of subdivision than the ordinary potter's flint.

The high content of K_2O in a district of low potassium rocks is unusual. Its low softening temperature gives trouble when the carbonaceous material is not completely removed during the oxidation period or by fast firing, causing the clay to bloat like a carbonaceous red brick shale. However, since no special precautions are necessary with the slowly heated commercial kilns in the firing of brick and tile, trouble from this direction is not expected with the thin-walled pottery wares. This clay is recommended for further research in low-temperature whiteware bodies where a plastic flux can be used.

Grand Ronde Clay Locality no. 5

The Grand Ronde locality mentioned by Wilcox 1/ is in Yamhill County in the SE$\frac{1}{4}$ sec. 5, T.6 S., R.7 W., and is reached as follows (see fig.5.): from the Grand Ronde Agency one travels easterly a distance of 2.3 miles on hard-surfaced highway to a sharp corner where the highway turns south. Walk easterly to the creek, and follow the creek northeasterly to a private bridge, cross bridge, and up a slope in an easterly direction to a rail fence. Cross fence, and continue east-southeast to an abandoned road; up this road to the forks, and turn south. The clay is below (west) of the road. The distance walked is one-quarter to one-half mile. Aneroid elevation at the pits was about 575 feet.

Several pits were worked 25 years ago but are now full of water and slumped clay. In order to secure samples of value, it would be necessary to drain the pits and clean out some of the slump or else do some core drilling. Wilcox describes the locality on page 31 of his thesis, as follows:

> "About four or five miles west of the Willamina clay pits, and north of the Tillamook road, near Grand Ronde, the same type of clay is encountered. This clay was shipped to Portland and used in the manufacture of firebrick a number of years ago . Now the pit is full of water and the surface of the clay is covered by broken material, making it impossible to determine the strike and dip. This exposure lies at a higher altitude than the Willamina clay and indicates that the beds must have been elevated by folding or faulting."

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, 54 pp., 1935 (unpublished)

MOLALLA AND SALEM DISTRICTS

Location

The Molalla-Salem districts are in northwestern Oregon, in southwestern Clackamas, and northwestern Marion Counties, in the general vicinity southeast of Molalla, and east and northeast of Salem. (See fig. 5.)

Topography

These districts are situated in what is called the Western Cascades 1/, a portion of the Cascade Mountain physiographic province that terminates at the west, adjacent to the Willamette Valley, in a rather steep slope of 300 feet within one mile. This slope may represent an erosional scarp, and the amount of deepening the Willamette Valley has had since the latest deformative movement.

East of the erosional scarp the general surface rises at the rate of 100 feet per mile over a distance of 12 miles, with gentle, rolling hills characteristic of late mature topography. It is deeply incised by head ward-cutting streams adjusted to the Willamette Valley as a temporary base level. Figure 30 is an east-west profile across the Stayton quadrangle to show the sloping surface, and a north-south profile at right angles to it to illustrate the deeply incised streams, which have a common 300-foot elevation.

Some of the streams, as Drift Creek and Silver Creek, have a series of structurally controlled waterfalls; the streams have cut through the soft overlying rocks, to become temporarily base-leveled on harder basalt. The underlying softer sediments have been eroded, and the waterfalls tend to retreat by a process of sapping. The larger valleys are flanked by terraces 25 to 50 feet above the stream and a suggestion of older terraces above the flood-plain terraces.

Virtually all of the land of the Western Cascades in these districts is tillable. The soil is fertile and, according to agriculturists, is excellent for raising stone fruits. Timber is chiefly fir, with the usual salal, alder, and devil's club underbrush. Logged-off land soon reproduces alder and soft wood if the land is not cleared for agriculture, and if fire is kept out.

1/ Callaghan, Eugene, Some features of the volcanic sequence in the Cascade Range in Oregon: Am. Geophysical Union, Trans., 14th Ann. meeting, pp. 243-249, 1933.

Thayer, Thomas P., Structure of the north Santiam River section of the Cascade Mountains in Oregon: Journal of Geology, v. 44, no. 6, pp. 701-716, August-September 1936.

---------------- The general geology of the north Santiam River section of the Oregon Cascades: California Inst. Tech., Division of Geol. and Paleo., Ph.D. thesis, 91 pp., 18 pls., 1934 (unpublished)

Climate

The climate is typical of the Willamette Valley; the winters are mild and rainy, the summers cool, dry, and comfortable. The "rainy season" extends from October to May, inclusive, and accounts for 85 percent of the total precipitation of 45 inches per year. The mean annual temperature is about 52°; the absolute maximum is about 100°, and the absolute minimum is about -10°. The winters are open, with very little snowfall, and working conditions are favorable the year round.

General Geology

Oligocene sediments are identified in the lower Santiam River area south and west of the Salem district. The marine Illahe formation is exposed at the west and grades eastward into the Mehama formation, which is composed of terrestrial pyroclastics. Sediments of supposed Oligocene age are exposed in the bed of Silver Creek some distance below the Falls. 1/ In the Marquam area, between the Molalla and Salem districts, is an impure limestone that contains quantities of shell fragments. This material may be of Oligocene age. Miocene volcanics, presumably Stayton lavas, unconformably overlie the Oligocene rocks, and are, in turn, conformably overlain by Fern Ridge pyroclastics. More recent mud flows and volcanics of High Cascade type are found in some of the larger stream valleys, capped with gravels resulting from Pleistocene glaciation.

The clay of these districts appears to lie at or near the base of the Fern Ridge tuffs and above the Stayton lavas, and to have been altered from the tuffs. The contact of clay and tuff is usually quite distinct and the gradation affected within narrow limits. This may indicate that the clay was altered and then buried by subsequent tuffs. Other possibilities might include alteration below a stable water table or a type of alteration confined to certain strata.

Structure

Thayer 2/ suggested that there is a series of folds, trending northeast-southwest and correlating with folds exposed in the Columbia Gorge. The northwest flank of the Mehama anticline would cover the Molalla-Salem districts, and our brief field studies confirm his hypothesis in that there seems to be a general west or northwest dip to the strata.

Molalla District

The Molalla district is located in southwestern Clackamas County, southeast and east of Molalla, within the Molalla River drainage basin,

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1/ Mackay, Donald K., personal communication.

2/ Thayer, Thomas P., Structure of the north Santiam River section of the Cascade Mountains in Oregon: Journal of Geology, v. 44, no. 6, pp. 701-716, August-September 1936.

--------------- The general geology of the north Santiam River section of the Oregon Cascades: California Inst. Tech., Division of Geol. and Paleo., Ph.D., thesis, 91 pp., 18 pls., 1934 (unpublished).

in T.5 and 6 S., R.2 and 3 E.W.M. (See fig.18.) Topographic and geologic conditions have been outlined previously, except that a basalt-porphyry containing feldspar crystals up to a quarter of an inch in length overlies the tuff series at the Ellis and Dibble localities. Mud flow or agglomerate is exposed along the Molalla River and may have been associated with late volcanism. A heavy conglomerate or boulder bed, probably of glacial origin, is the uppermost formation.

Ellis Clay Locality no. 6

Location:

The Ellis clay is adjacent to the Molalla River in the northeast corner of the $NE\frac{1}{4}NE\frac{1}{4}$ sec. 27, T.5 S., R.2 E. (See fig.18.) The nearest town is Molalla, and details of the highway route are: south through Molalla on the Silverton paved road; after crossing railroad tracks take first left turn onto pavement, then next left turn onto graveled road; thence east to the Ellis ranch, through barnyard and down a private road toward the river, total distance 4.3 miles, of which 2 miles is graveled and 2.3 is hard-surfaced. The clay mine is above the road near the bottom of the private road. The Molalla River enters sec.27, as the section corner is on the northeast bank. All clay at this locality is owned by Mr. L. L. Ellis, of Molalla, Oreg.

Topography:

The Molalla River occupies a valley a quarter of a mile wide, flanked by a 30-foot flood plain terrace and a persistent, 150-foot terrace from bedrock. This upper terrace is deeply dissected by a tributary stream that heads near the Ellis house (see fig. 19), and the clay is exposed on the flanks of this tributary.

History:

Small amounts of clay from the Ellis property were used by the Willamina Clay Products Co. for experimental purposes and also by the Denny-Renton Clay & Coal Co. A rumor that this clay had been used for pottery manufacture could not be confirmed.

A road was built to the clay deposit by the owner from the county road at the quarter-corner secs. 27 and 22, on an approximate grade of 10 percent. An adit was started in the upper portion of the clay seam 50 feet above the road and continued to a total length of 33 feet. A wide chamber was excavated just inside the portal and is just to the left of the portion illustrated in figure 21. Clay and tuff have caved from the roof and partially blocked the portal, and the original height of the adit is estimated at 11 feet. No clay has been mined in recent years.

Description of the Clay:

The clay is bluish-gray to purplish-green when fresh and brown after exposure, and assumes a hard, hornlike mass when dried. Certain portions

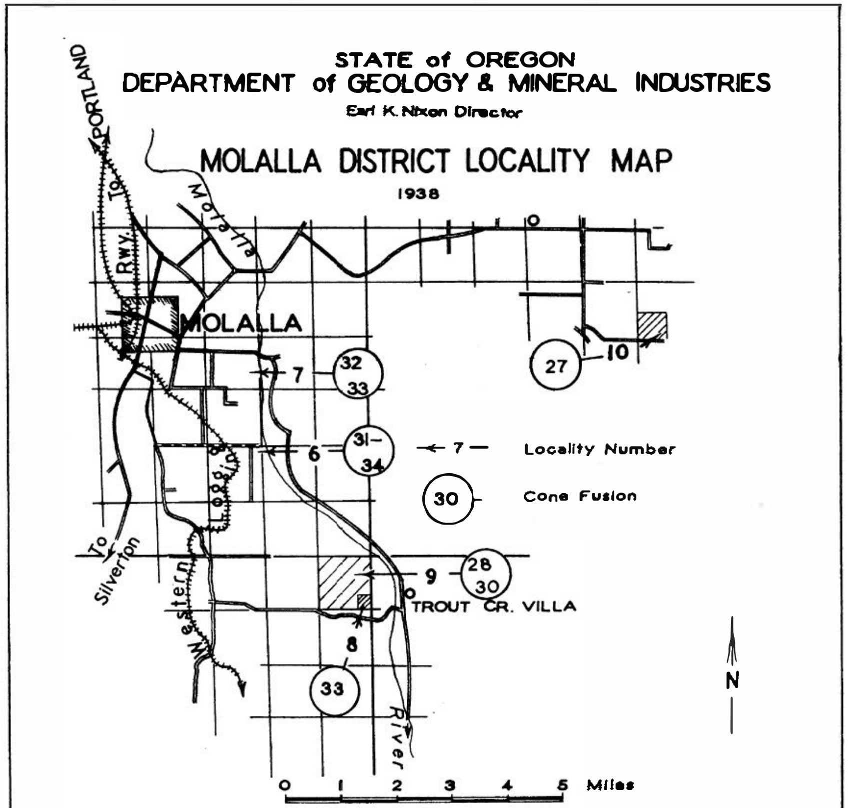


Figure 18

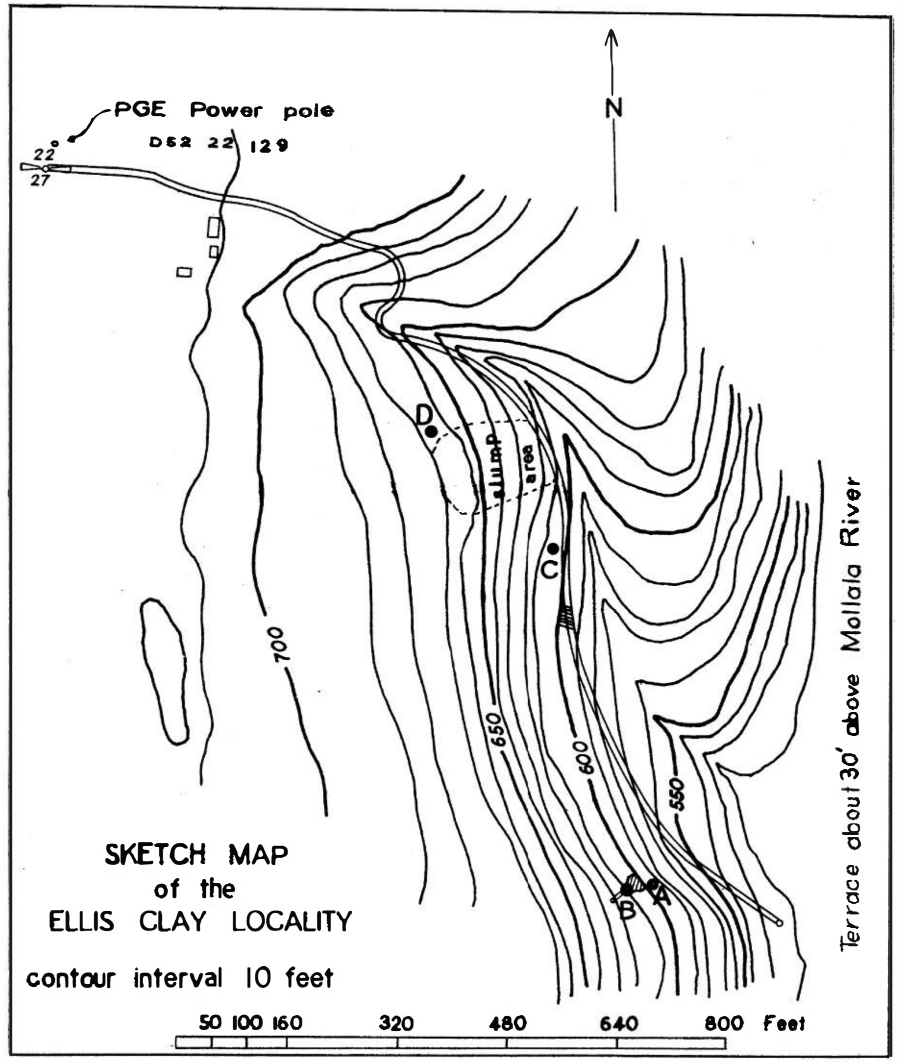


Figure 19

Hand level and brunton traverse

have white "porphyritic" inclusions that may be kaolin; otherwise it exhibits no textural differences discernible in megascopic examination. It could well be an altered tuff, and there is virtually no evidence of ferromagnesian minerals. It is a fire clay with an unusually high iron content, and in some cases contains an equal percentage of alumina and silica, which indicates weathering and dissociation beyond that of the kaolinite stage. Joints, striking N. 45° W., dipping 56° N.E., break the mass into layers from 1 to 6 inches thick.

Above the clay, a tuffaceous sandstone shows rude banding or bedding, that is practically horizontal in attitude, and has a P.C.E. of cone 27. The thickness of the tuff stratum is estimated to be 70 feet plus, and it is overlain with soil and clay. Basalt-porphyry was found at an elevation of 825 to 1,000 feet, or 125 to 300 feet above the tuff, on a hill east of the Ellis property.

The clay was sampled by channel and auger methods, and the location of the holes is indicated in figure 19. A channel sample, representing the upper 11 feet of clay, was taken inside the adit; hole A was drilled vertically downward at the mouth of the adit from the floor elevation to a total depth of clay of 24.7 feet, or 13.7 feet of auger hole (see fig. 13). Hole B was drilled 20 feet horizontally at the breast of the adit (fig. 14). This clay is very hard; it took two men six hours to drill the 20-foot hole with a 1-3/4-inch hard-pan auger. Hole C is about 300 feet north of A (see fig. 15); the sample represents clay that has been exposed to the weather for a long time, and it is possible that better results would have been obtained had it been possible to get back into the hill several feet before drilling. Hole D was drilled through the soil and clay on top of the terrace and on top of the tuff stratum overlying the fire clay (see fig. 16). This clay is not of refractory grade and was taken to show the alteration that had taken place on top of the tuff.

Quality:

Ellis clay tests: The numerous samples from the Ellis mine were similar in color, ranging from a light bluish-gray, greenish-gray, to brown, with a variable amount of iron staining in the conchoidal fractures. The blue and green colors change to brown on weathering. The light-gray weakly plastic tuff overlying the clay showed a fair refractoriness with a P.C.E. of cone 27, and various samples from the adit walls and floor gave fusions from cone 30 to 33. The channel sample in the mine gave the remarkable analysis of 39.0 percent alumina, 39.0 percent silica, 4.5 percent iron oxide, and 0.8 percent lime. An analysis of sample D-30 from the horizontal hole B, showed 39.2 percent alumina, 36.4 percent silica, 5.9 percent iron oxide, and 0.7 percent lime, and another analysis indicated 1.9 percent sodium oxide and no potassium oxide. But at the bottom of hole A, 23.5 feet from the top of the clay, sample D-28 was taken and analyzed only 31.7 percent alumina, 43.7 percent silica, 7.9 percent iron oxide, and 3.6 percent lime. This more siliceous clay with high iron and lime fluxes gave a fusion of only cone 17, and apparently represents the bottom of the refractory clay. The weighted cone fusion for 23.5 feet of clay in hole A, including the clay in the mine, was cone 31-plus. (See columnar section, figs. 13 to 16.)

The dried samples ground in the laboratory gave some resistance to dispersion on first working by hand; but when thoroughly tempered, a remarkable degree of sticky plasticity was developed. Over 58 percent of water was required, the highest of all the clays in the special tests. The shrinkage-water to pore-water ratio was normal, 1.1, but with a dry linear shrinkage of 14.6 percent the bars cracked in drying or early firing. Therefore, a continuous series of firing tests was not made on D-42 and D-43, the channel samples from the mine. One set of tests fired to cone 20 gave the following results: Linear shrinkage, 12.9 percent, weight loss 17.7 percent, absorption 4.4 percent. A black, vitreous, slightly vesicular body was developed at this high temperature, but the vesicules resembled the cavities formed by the early removal of volatiles rather than the swelling due to fusion. Owing to the great shrinkage, this clay could not be used alone or without the admixture of grog, flint clay, or sandy clay.

A complete firing series of a grogged body was made, consisting of equal portions of the most refractory sections of hole B, samples B-29, D-30, D-31. Eighty percent of the same mixture was calcined to cone 16, ground finer than 28-mesh, and made plastic with 20-percent raw clay. While weakly plastic, the mass had sufficient working properties for refractories and required a normal amount of tempering water, 26.5 percent. The drying shrinkage was low, 2.5 percent, and the shrinkage-water-to-pore-water ratio was only 0.2 The firing shrinkage remained low beyond cone 15, but since the grog was calcined to only cone 16, 6.3 percent linear shrinkage was found at cone 20 and 13.6 percent at cone 29. The absorption remained near 20 percent to beyond cone 15, was 13.4 at cone 20, and 1.1 percent at cone 29. At low temperatures, such as cone 02, the body was very soft and colored brown to purple, which changed to a raw umber color at cone 10, a burnt umber at cone 15, a chocolate brown at cone 20, and black at cone 29. Steel hardness did not develop until above cone 20, but at cone 29 a vesicular structure was found in the interior, although the test bars were not badly deformed.

Conclusions: This clay has been tried in commercial lots for fireclay brick by two clay manufacturers and abandoned because of the troubles with high shrinkage. At that time, competition had not forced the use of as large quantities of grog in refractories as is the practice at present. But it is very questionable if a successful firebrick manufacture could be developed with the use of the Molalla plastics combined with their own grog, in competition with better-acting fireclays from other local districts.

The problems for future investigation include the following: 1. The cost of mining 23.5 feet or less of the fire clay under the roof of tuff; 2. The amount of clay having a P.C.E. as close to cone 33 as possible; 3. The uniformity of the clay seam, whose dependability has been questioned by the commercial operators. While the colloidal plastic nature of this clay interferes with its commercial development when used alone, this property can be made of service in developing the workability of the flint clays deficient in plasticity from other localities. The quantities used will not be large in the latter case, but they would provide a very valuable accessory to other refractory materials without materially lowering the P.C.E. values of the final product. Plastic refractories, ramming mixtures requiring the minimum of plastic material and the maximum bonding power, are other possible outlets for these clays. Any refractory requiring the minimum of silica, the absence of free quartz, and high plasticity may be able to use the Molalla fireclays.

Quantity:

Considering the length of the clay exposure along the bluff as 800 feet(see fig. 19) and the depth as 11 feet (exposed in the adit) and the width as 53 feet (33 feet of adit and 20 feet of auger hole), the deposit will contain about 500,000 cubic feet, or 31,000 tons. If the depth is considered as 25 feet (adit plus hole A), the amount would be one million cubic feet, or 62,000 tons. There is reason to believe that the clay has a greater width than 53 feet, which can be proved by core drilling.

Transportation:

Under existing conditions, it is necessary to truck the clay to the railroad siding at Molalla. The route covers a quarter of a mile of private dirt road with an adverse 10 percent grade, 2 miles of county graveled road, and 2.3 miles of county hard-surfaced road, a total of 4.5 miles of truck haul. Rail transportation to Portland, via Southern Pacific Railroad, is 35 miles; via Willamette Valley Southern Electric it is 31.5 miles.

William Vincent Deposit.

There is another adit in clay in the vicinity of the Ellis deposit from which N. W. L. Brown, Wenatchee, Wash., reports having secured a carload sample at one time for the Denny-Renton Clay & Coal Co. in Seattle. No other data were available.

Dewey Miller.

Mr. Dewey Miller, Route 1, Molalla, Oreg., who owns land in the NW$\frac{1}{4}$ sec. 27, T. 5 S., R. 2 E., states that he has clay similar to Ellis' material underlying his place. It was exposed in a well excavation, from the grass roots to a depth of 50 feet. No specimens were seen, and the occurrence is mentioned here for future reference.

Molalla Reservoir, Locality no. 7

This deposit is in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 15, T. 5 S., R. 2 E., (see fig. 18). It is reached as follows: starting from the center of Molalla, follow the paved highway to the east line of the townsite, then turn south (right) for one-quarter mile, then left (east) for one-half mile, then right (south) onto graveled road about one-quarter mile, to the H. C. Robbins ranch, a total distance of 2.4 miles. From their house, walk to the Molalla reservoir, thence east to the bluff overlooking the Molalla River. Clay is exposed in a small cut about half-way down the bank, 40 feet below the top of the terrace.

Weathered tuffaceous sandstone overlies the clay; underlying rock is obscured by talus, and the clay thickness is estimated as 25 feet. It is similar to the Ellis clay, so its description is not repeated here. The land is owned by H. C. and D. H. Robbins.

It is stated that 50 acres were sold a number of years ago to the Cascade China Co. and the title was later regained by the Robbins brothers. Some clay must have been removed, but there is little evidence at present of any such operations.

Reservoir clay tests: This clay sample was similar to that from the Ellis property, showing a gray, compact clay with conchoidal fracture, some iron staining with the brown color developing on weathering. The preliminary samples showed the high P.C.E. values of cone 32-plus and cone 33 with tan and black-colored fusions. Analysis showed 36.7 percent alumina, 43.5 percent silica, 5.1 percent iron oxide, and 0.7 percent lime. High shrinkage and cracking accompanied drying and firing, and it is apparent that only small amounts of this material can be used in clay products without precalcination. It is not desirable for the light-colored wares because of the iron content and dark fired colors, and for general products because of the excessive plasticity and shrinkage.

It would be necessary to obtain right-of-way from the Robbins brothers and construct a road over a distance of about $\frac{1}{4}$ to $\frac{1}{2}$ mile. Truck haul to Molalla would be 2.4 miles, of which one-quarter of a mile would be over gravel and the remainder over pavement. Shipment from the railroad would be as for Ellis clay.

Dibble's Clay, Locality no. 8

The deposit lies in the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 1, T. 6 S., R. 2 E., southeast of Molalla and east of the postoffice of Trout Creek. Route shown on figure 18 is the most practical. Travel southward up the Molalla River, turn west across the covered bridge just beyond Trout Creek postoffice. Inquire at Dibble's house for further directions. The clay is about a quarter of a mile north of the county road.

Dibble's clay was the first of the Molalla series to be discovered. The occurrence is similar to that of the Ellis and Robbins deposits, except that the terrace is 450 feet above the river. The similarity of occurrence may indicate a northwestward dip to the rock formations of 500 feet in 4 to 5 miles, or about 100 feet to the mile.

The clay is overlain by a series beginning with tuffaceous sandstone, followed by a streak of limonitic material about 1 to 3 inches thick, then a lower grade of clay about four feet thick, and then the high-grade fire clay, in descending order. The limonitic seam is reported to carry gold. The clay is generally light-colored, nearly white, with a suggestion of blue and pink. It tends to have flintlike characteristics when dry but is highly colloidal. Down the slope, to the southeast, a bluish to violet-colored clay, 8-b, was sampled; it was quite gritty, and proved to be quite inferior in refractoriness. A rock quarry operated by Clackamas County is 165 feet above the Dibble clay and has a thickness of at least 50 feet. Megascopically, the rock is a basalt-porphyry with large feldspar phenocrysts.

At one time extensive workings were developed in the clay. According to Mr. Dibble, there were several adits and at least one shaft or raise that indicated a thickness of 150 feet for the clay with no change in quality. The adits are now caved completely and only surface indications exist, so it was not possible to check these statements. Commercial production was not indicated.

Preliminary samples showed two types of material from this property. That from the surface above the old mine, 9-a, was a smooth, gritless, light bluish-gray clay of excellent appearance and free from iron staining. It showed the usual compact structure with conchoidal fracturing and cracking common to the Molalla clays, a P.C.E. of cone 33, and the lowest iron-oxide content, 2.8 percent, found in the Molalla series. The alumina content was 38.8 percent, the silica 45.9 percent, and the lime was 0.7 percent. (9-b) from an adjoining deposit carried the highest iron-oxide content, 14.1 percent, found in any clay of this study and gave a fusion of only cone 23, probably due to the fluxing action of the iron, since the other oxide percentages were normal. It was a sandy, deep-blue clay when wet and brown when weathered.

A complete firing series of a grogged body was made, consisting of 17 percent raw Dibble clay, 9-a, with 83 percent grog, previously calcined to cone 15 of this same clay and ground finer than 20 mesh. This semi-plastic mass required 22 percent tempering water and shrank only 1.3 percent in drying. The bars remained soft beyond cone 20 but were steel hard at cone 29. There was no shrinkage to beyond cone 20 and only 7.8 percent linear shrinkage at cone 29. The bars remained porous, with between 16 and 17 percent absorption to beyond cone 20, but this dropped to 6.7 percent at cone 29. The color at cone 10 was a light-brown topaz matrix with many fine darker specks that spread on further heating until, at cone 20, a lightly mottled gold-brown was produced, which, in turn, changed at cone 29 to a chocolate brown with some vitreous black just beginning to form.

This sample, therefore, represented one of the best prospects for a high type of refractory material from the Molalla area, subject, of course, to the limitations and troubles in manufacturing, described for the Ellis clays. Great care should be exercised accurately to determine the quantity and uniformity of the material represented by sample 9-a in contrast to the inferior material 9-b.

The distance from Molalla is more than 10 miles by highway, plus one-quarter of a mile of dirt road badly in need of repair. While the upper portion of the clay seems to be of excellent quality, the deposit is handicapped by the fact that similar deposits are more advantageously situated.

Zahar Clay Locality no. 9

Krammerer Clay, Locality no. 10.

W. E. Krammerer, Route 1, Colton, Oreg., submitted a sample which he reports as occurring southeast of Colton in $SE\frac{1}{4}$ sec. 12, T.5 S., R.3 E., on his property (see fig. 18). The property is known as the old Hunter place. He states that similar material underlies a considerable portion of his ranch. The sample submitted was taken from the bed of a small creek and is undoubtedly contaminated with surface leaching. The P.C.E. was cone 27-plus, and no further tests were made.

Reported Localities.

N. W. L. Brown reports that samples similar to Dibble's were taken from the Hall Brothers property near Dibble's. Other locations of Molalla clay are outcrops along road junction in north-central sec.14, in which the clay was irregular, and the Molalla Electric Co.'s property in the northwest corner of sec. 11, which is a small deposit.

Conclusions for Molalla Area.

Clay of no. 1 refractory grade occurs in an area south and east of Molalla. It tends to be bentonitic in nature, and fire to brown colors, has high shrinkage and bad cracking. The quantity found at any of the localities examined is sufficient to justify further studies for commercial operations. Transportation requires truck hauls of 2.5 to 12 miles to a railroad siding and thence 35 miles by rail to the Portland area. Should the clay be found commercially suitable for firebrick, conditions should justify detailed exploration by companies who intend to manufacture such products.

The distribution of the localities cited herein indicates a good possibility of other deposits being discovered. The clay underlies a tuff tentatively correlated with Upper Miocene Fern Ridge tuffs, and overlies basalt that is presumably Middle Miocene. Outcrops of clay would be expected in stream channels that cut into the basalt where the overlying tuffs have not been removed by erosion. An attempt should be made, in sampling, to secure specimens as far removed from the present zone of weathering as possible.

Salem District

The Salem district is roughly bounded by the towns of Salem, Silverton, and Sublimity, and, except for the more easterly localities, is covered by the Stayton quadrangle sheet. The topographic and geologic conditions have been outlined previously. The most important locality is that of R. E. King, locality no. 11, a quarter of a mile west of Union Hill schoolhouse; the area along the Victor Point road northward to Silverton was sampled extensively and may prove to be a continuation of locality no. 11.

King's Clay Locality no. 11.

Location:

The King's locality is a few miles northeast ofSublimity in the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 18, T. 8 S., R. 1 E. (see fig. 23), in a saucer-shaped valley bounded on the north and south by ridges 150 feet above the valley. Highway no. 214 parallels the base of the north ridge and clay is exposed in road cuts between highway stations 850 and 870. 1/. Wilcox 2/ first reported this clay as his Sublimity locality and in the fall of 1937 the Willamina Clay Products Co. removed several truckloads from the highway right-of-way for experimental purposes 3/. (see fig.35.) Sketch topography (see fig. 39) was controlled by aneroid elevations checked by highway profiles, and a few Brunton shots were taken for alignment. Contours represent the general shape of the topography but were not accurately scaled. A general view of the area is shown in figure 40.

Description of the clay:

The clay usually is chalky white, fine-grained, and contains small clear grains of quartz. Near the surface it is limonite-stained along joint planes that separate the mass into small blocks; deeper, the blocks are larger and the percentage of limonite is less; and in each case the clay itself is relatively free of stain. The overlying tuff, however, is heavily iron-stained in a manner that suggests the solutions originated near the surface and migrated downward through the voids without particular reference to joint cracks. Perhaps the clay was not formed by the same surface weathering that gave rise to iron-bearing solutions that stained the tuff.

1/ Oregon State Highway Alignment Map, 5 B - 12 - 5.

2/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, 54 pp., 1935 (unpublished).

3/ Edwards, O. K., personal communication, January, 1938.

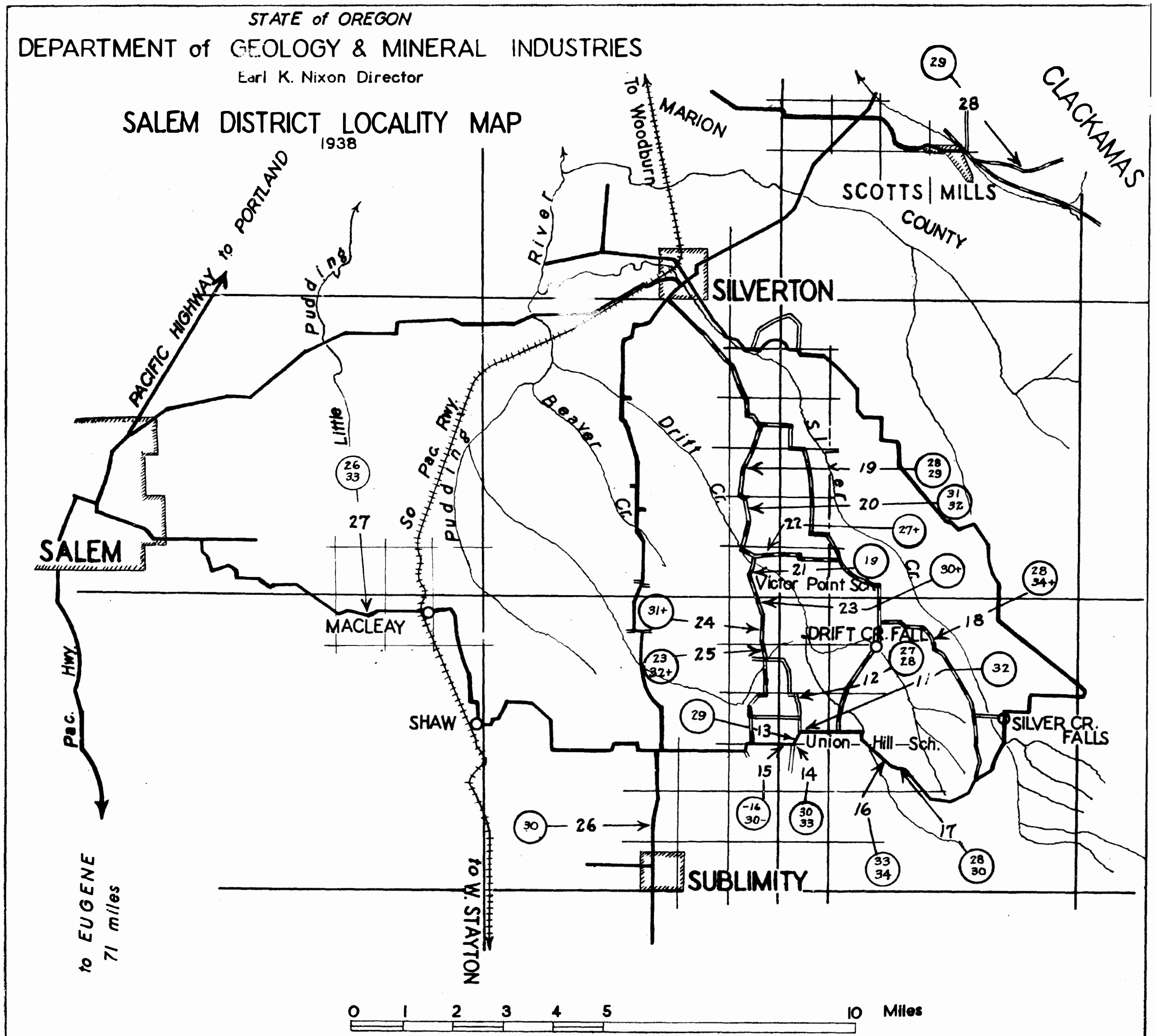

STATE of OREGON
DEPARTMENT of GEOLOGY & MINERAL INDUSTRIES
Earl K. Nixon Director
SALEM DISTRICT LOCALITY MAP
1938
PACIFIC HIGHWAY to PORTLAND
To Woodburn
MARION
CLACKAMAS
COUNTY
SCOTTS MILLS
SILVERTON
SALEM
MACLEAY
SHAW
SUBLIMITY
to EUGENE
71 miles
Pac. Hwy.
So. Pac. Rwy.
to W. STAYTON
Pudding
Little Pudding
River
Beaver Cr.
Drift Cr.
Silver Cr.
Victor Point Sch.
DRIFT CR. FALL
Union-Hill-Sch.
SILVER CR. FALLS
0 1 2 3 4 5 10 Miles

Figure 23

The tuff contains pumice fragments up to an inch in diameter, and many of these are altered to a skeletal system of planes suggestive of petrified wood. Petrified wood does occur; several twigs were recovered in which the structure of the original wood is excellently preserved. Tuff and clay have similar appearance, except for color; the tuff is grayish to brownish and the clay is dead white.

Basalt underlies the clay; it was found, in place, in a dug well on the Ralph W. Mollet ranch a few feet southwest of Hole D (see fig. 29) and in the valley of Drift Creek, a quarter of a mile to the east. The basalt and clay contact is not exposed but relationship of outcrops confirms such a contact and a general westward dip of a few degrees.

Quality:

The locality was sampled with one channel cut and several auger holes (see fig. 29), and columnar sections for the various holes are shown in figures 24 to 28.

A channel sample, no. 11, was taken in the cut made by the Willamina Clay Co. in 1937. It was a soft, white, but compact clay giving a fusion of cone 32.5, and an analysis showed 32.3 percent alumina, 46.2 percent silica, 3.8 percent ferric oxide, 1.9 percent soda, 12.4 percent ignition loss, with minor amounts of lime and magnesia. Another analysis showed 37 percent alumina, 45.2 percent silica, and 3.4 percent ferric oxide. The sample was dried, ground finer than 20 mesh, and tempered to produce a plastic mass having a high content of tempering water. While the dry shrinkage was not large, the pore space remained high, causing a rather high firing shrinkage even at cone 02. In general, the strongest, most plastic clays develop high drying shrinkages and form such dense, compact, though often cracked, dry masses that little pore space is left for the contraction in firing. A small number of shrinkage cracks developed in the King's clay bars during drying, but intense cubical cracking was found in firing. A light buff color was noted at cone 02, which changed to a dark cream with many fine specks and a brown, iron-stained surface at cone 10. At cone 14 the interior was a speckled light brown or raffia color with a dark-brown exterior. At cone 20 the interior was a speckled golden wheat or orange brown with a cinnamon surface. The black specks had spread throughout the clay mass, not as fused slag spots but merely as a deeper brown color without fusion. This is a different action to that of iron spots in the ordinary siliceous clays.

While the linear shrinkage remained between 11.4 and 12.4 percent from cones 10 to 20, 8.1 percent pore space (percent absorption) remained in the body at the latter temperature, indicating incomplete shrinkage. The unusual white original color, the deep brown fired color, the large amount of water required for plasticity, the large dry pore space, the cracking and high shrinkage in firing which is not complete at cone 20 indicate a peculiar clay with manufacturing troubles ahead. The fusion of cone 32.5 showed a refractoriness worthy of further experiment, possibly not alone but mixed with more stable clays of lower shrinkage.

Hole A was drilled at the cut made by the Willamina Clay Products Co. The first eight feet of clay was soft, white, and compact, containing darker pebbles of varying size in a partly decomposed condition, and giving a fusion of cone 32-minus. The 3 feet at the bottom of the hole was composed of buff earthy clay with tan and brown material, some small pebbles. Its fusion was only cone 27.

Hole B was started 150 feet to the east but was discontinued at a depth of six feet as the flow of water did not permit a sample to be recovered. An interesting side light on this spot concerns the flow of water. Water was discharging from cracks in the clay above the hole. Twelve hours later, discharge from the cracks had practically ceased and water was bubbling out of the auger hole. This would indicate that it was not surface drainage from directly over this spot; that the water must have entered the clay some distance away. The description of the clay from this hole is shown in figure 25.

Hole C was drilled across the road to give data expected from B. Hole D was drilled on land owned by Ralph W. Mollet. The well mentioned in a previous paragraph, in which basalt was exposed, is about 100 feet southwest of D, and basalt was reached at a depth of 35 feet, equivalent to 40 feet below the surface at D. Hole E was started in the stream valley just north of Mollet's house; the auger penetrated 6½ feet of rich black soil before clay was reached, but too much water made it impossible to recover a sample.

Hole F was started near the summit of the hill north of the valley and 150 feet higher in elevation. The first 12 feet consisted of a mixture of soil and clay and was not saved; the next 5 feet of clay had a P.C.E. value of cone 27. The surface was covered with small basalt boulders, but no basalt could be found at an elevation that would allow its deposition at this elevation. It was concluded that the rock is tuff containing basalt boulders; that this clay represents a higher stratum of clay than the one sampled in holes A, B, C, and D. Hole G was started on a terrace just above and 25 feet north of hole A, proving that the material over the clay is tuff.

Pyroclastics of Fern Ridge tuff age were laid down on Stayton lavas to a thickness of 200-plus feet at this vicinity, and that portion just above the basalt was completely altered to refractory clay. Therefore, it is assumed that this locality is underlain by the white refractory clay in the form of a bed or seam. Certain higher seams were locally altered but not as intensely. Conditions of alteration were probably similar to those described at the Ellis locality.

Quantity:

Drill holes did not prove a wide area and quantity is difficult to compute. Considering the length as 800 feet parallel to the highway, a width of 400 feet between holes A and D, a thickness of 15 feet, the quantity is 330,000 short tons. Should the assumption prove correct that the stratum is extensive, the tonnage estimates would be increased materially. Core drilling will be necessary to prove the body.

COLUMNAR SECTIONS

King's Locality No. 11

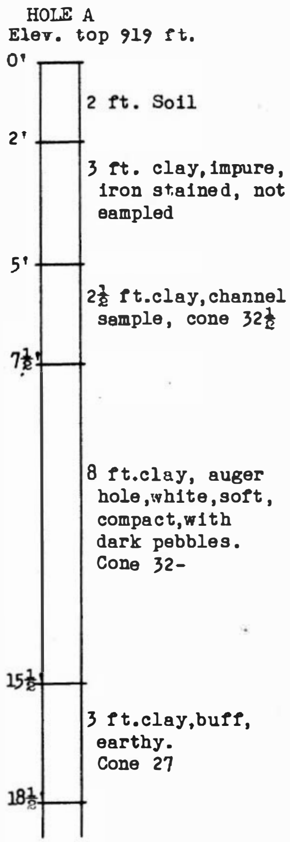


Fig. 24

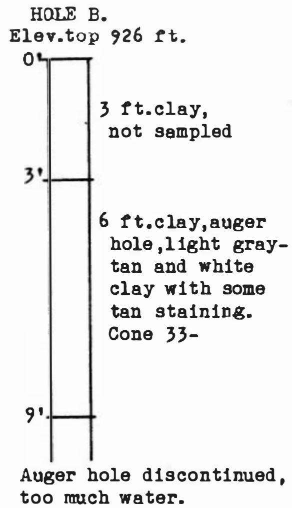


Fig. 25

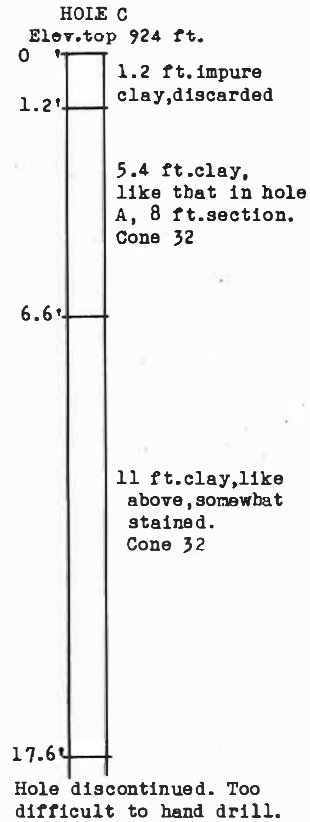


Fig. 26

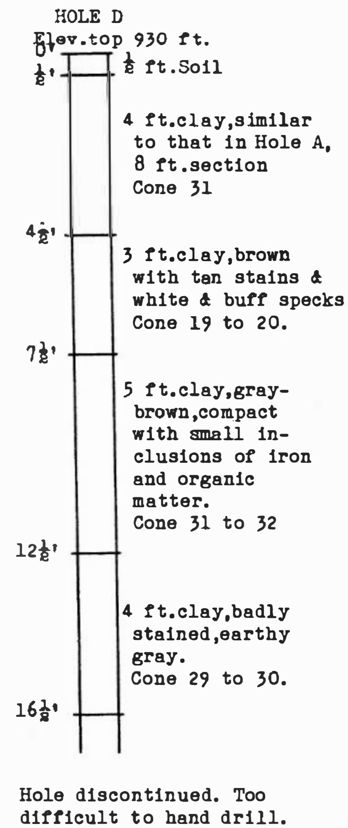


Fig. 27

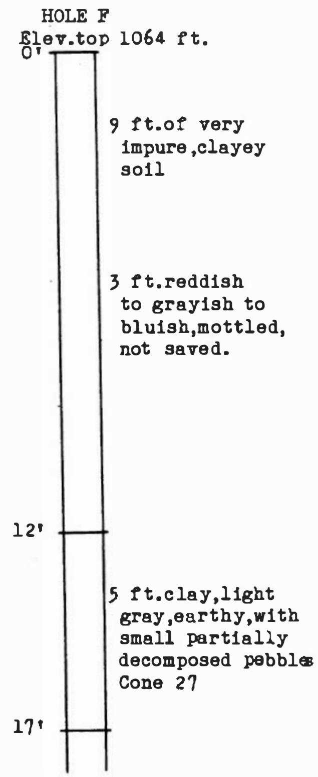


Fig. 28

Transportation:

Hard-surfaced roads connect the locality with the S. P. Railroad as shown in the following tabulation:

Truck haul via hard-surfaced roads		Railroad haul via S. P. R. R. to Portland	
To West Stayton	- 7.7 miles	From West Stayton	- 65.5 miles
To Aumsville	- 8.7 miles	From Aumsville	- 61.7 miles
To Shaw	- 9.9 miles	From Shaw	- 58.8 miles
To Salem	- 26 miles		

Locality no. 12 North of King's.

This clay exposure is 0.8 mile north of King's clay by graveled road in the NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 18, T. 8 S., R. 1 E. The road leaves highway no. 214 a hundred yards west of King's locality, in the south-center of sec. 18, and continues northward through sec. 18. Near the north line, the road dips into a small swale, and just after crossing the bridge the clay is exposed in a cut on the east side of the road.

The clay appears to be altered tuff; it is white to pinkish, with a mottled appearance. Material near the surface gave a P.C.E. of cone 20-minus. An auger-hole sample (see fig. 33) gave P.C.E. cone 27-28. These samples of necessity came from close to surfaces that have been exposed to the weather for considerable periods, and the quality should improve as one gets away from such surfaces. It is recommended as secondary in importance.

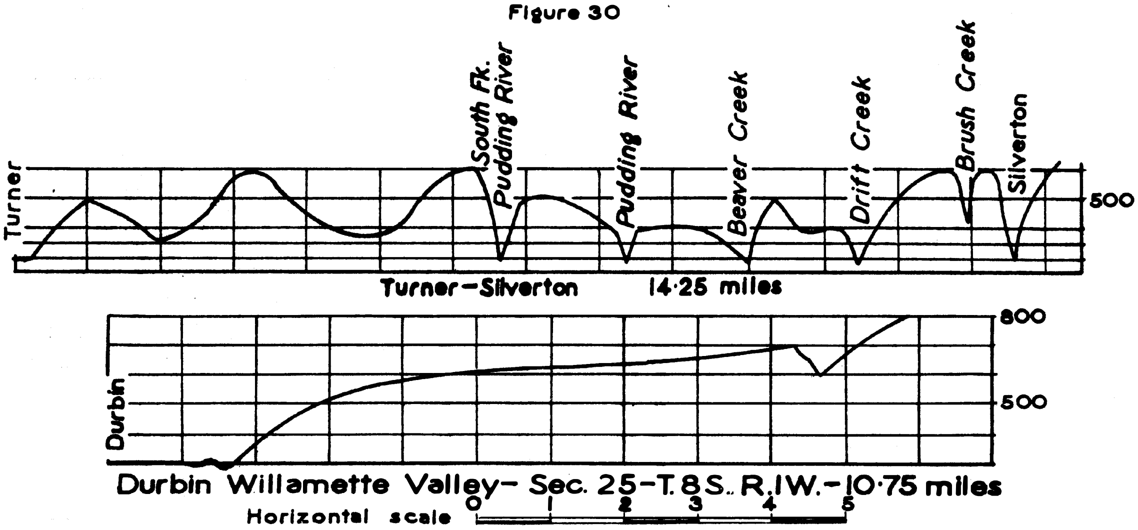
Locality no. 13, South of King's.

This locality is south of King's clay on the same highway where it turns north from the north line of sec. 19 into sec. 18. (See fig. 23.) The locality is therefore in the SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 18, T. 8 S., R. 1 E., in a deep road cut.

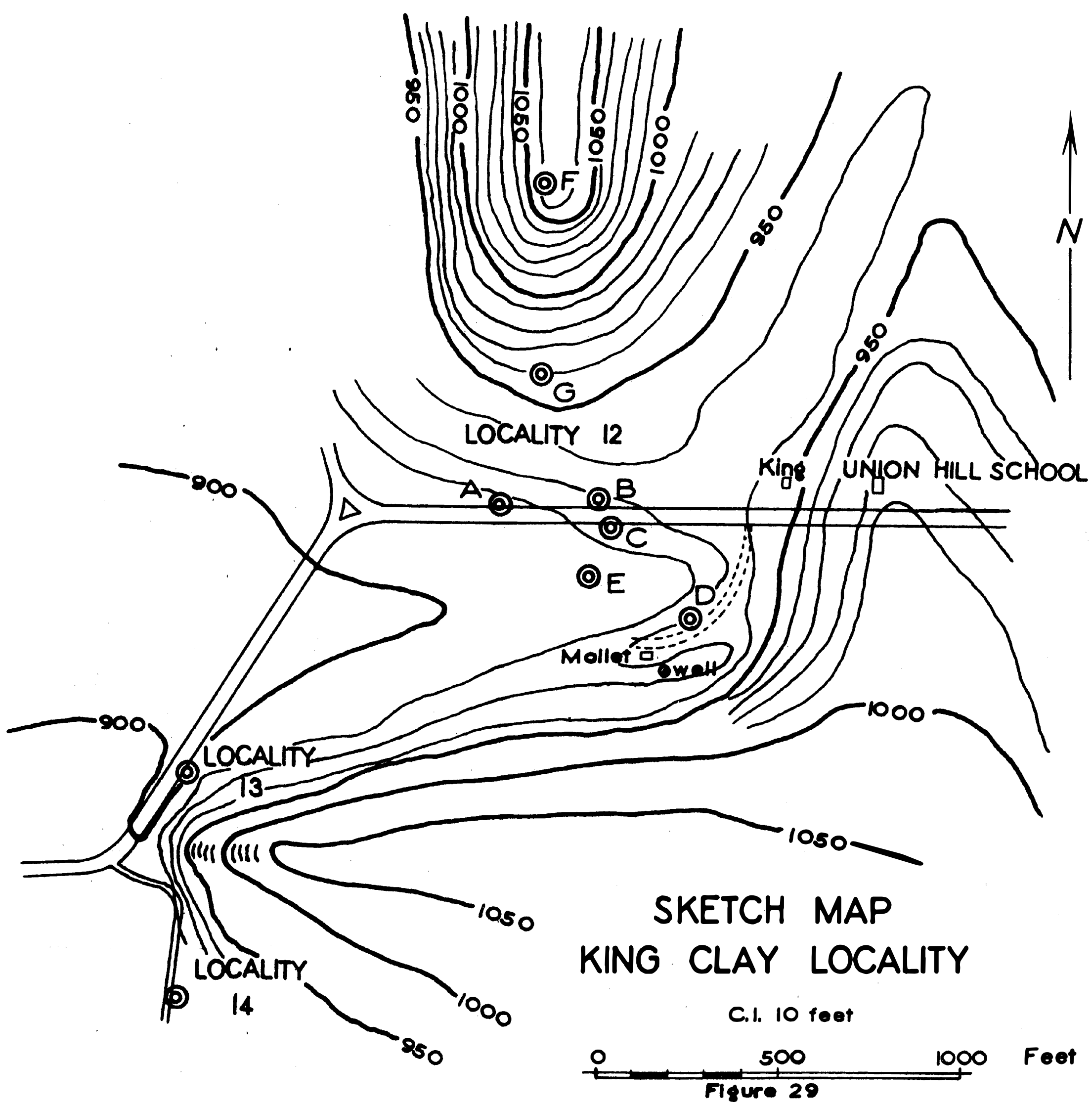
A thick body of weathered conglomerate is exposed here, but it is not as completely weathered as the Fransen conglomerate. Cross-bedded tuff lenses are common. It is similar to the upper part of the Fern Ridge tuffs.

Tests of No. 13: This sample was divided into four parts, according to appearance, and each was tested separately. The gray portion, containing nodules of white clay, showed a brown glassy fusion at cone 30-31; when this type was iron-stained the fusion dropped to cone 18; another portion similar to the first showed a surprising low fusion below cone 19 and some of the light-colored portions surrounding the only partially altered rock fragments fused to cream-colored melts below cone 16. The hard, partially altered rock fragments still contained enough fluxes to soften below cone 16 with light-tan glassy fusions. This location contains too much unkaolinized material for refractory purposes, but some of the low iron portions may have some service in the light-colored vitrifying structural wares.

Figure 30



STAYTON QUADRANGLE



SKETCH MAP
KING CLAY LOCALITY

C.I. 10 feet

Figure 29

Locality No. 14.

This locality is south of locality no. 13 along a graveled road, as shown in figure 23, in the NW$\frac{1}{4}$ sec. 19, T. 8 S., R. 1 E. The clay was sampled with an auger and is very similar to King's clay - it is chalky white and contains small, clear grains of silica. It is exposed for 20 feet through an elevation difference of 8 feet. Above the clay the soil is covered with small pumice pebbles, which were probably derived from the overlying tuffs. An auger hole was drilled and the results are diagrammed in figure 32; the P.C.E. cone fusions are 30-plus to 33.

A small flow of water was struck at a depth of 11.5 feet just above a hard, purplish-blue clay, and some difficulty was experienced in recovering the sample. Below this point the clay was hard and compact.

The area is recommended for further prospecting with a core drill. There is a good possibility that this locality and the King locality are part of the same clay seam.

Locality no. 15.

Clay occurs on the north side of the highway no. 214, half a mile west of locality no. 13, on the south line of the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 13, T. 8 S., R. 1 W., by highway station 795 1/ (see fig.23). The clay is more iron-stained than at King's; the upper 2$\frac{1}{2}$ feet of auger-hole sample gave a P.C.E. of cone 30-, and the lower portion cone 16-. Contact with overlying tuff is rather well defined, and at the west end of the cut the clay grades laterally into tuff. As the deposit is underlain by tuff instead of basalt, it is concluded that it represents one of the seams stratigraphically higher than King's. A columnar section is given in figure 31.

Locality no. 16.

This clay deposit is 1.2 miles east of the intersection of highway no. 214 and the Drift Creek Falls road, near highway station no. 63 2/, in the NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 21, T. 8 S., R. 1 E.

The clay is a white, soft, compact material containing dark inclusions of varying size, some being partly decomposed, and may represent a portion of the stratum at King's. Tuff with approximately horizontal attitude overlies the clay, and the contact is irregular. The P.C.E. is cone 33-34.

Locality no. 17.

A sizeable stratum of clay is exposed in a road cut 2 miles east of the intersection of the Drift Creek Falls road and highway no. 214, in the NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 21, T. 8 S., R. 1 E., near highway station 109. 3/

1/ State Highway Alignment Map, 5 B - 12 - 5.
2/ State Highway Alignment Map, 5 B - 3 - 10.
3/ State Highway Alignment Map, 5 B - 3 - 10.

COLUMNAR SECTIONS

Locality #15

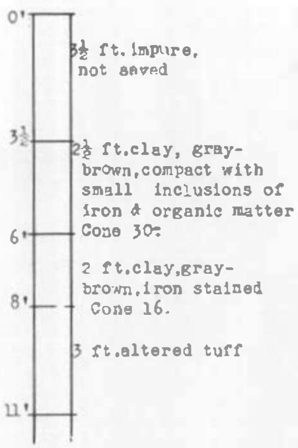


Fig. 31

Locality #17

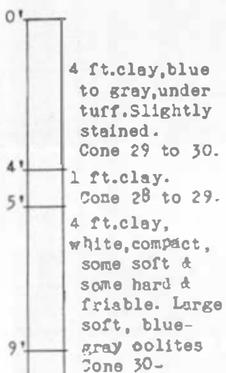
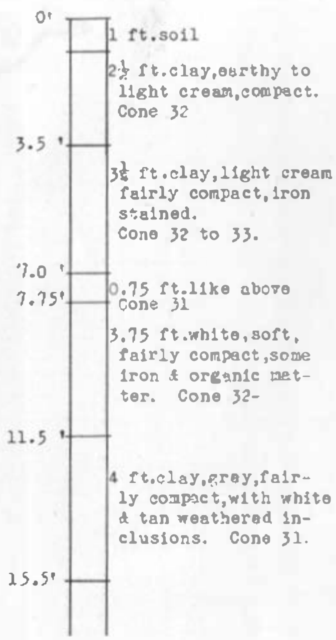


Fig. 34

Locality #14



Hole discontinued. Too difficult to hand drill.

Fig. 32

Locality #12

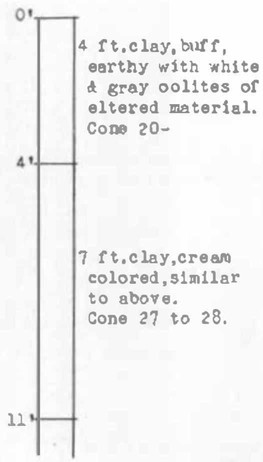


Fig. 33

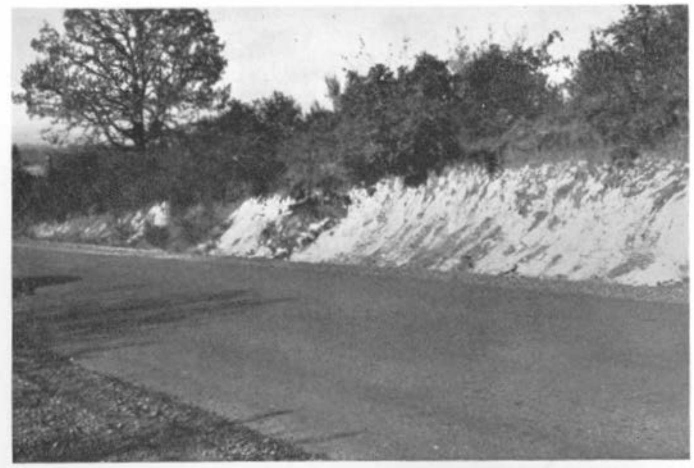


Figure 35. King's Clay in Road-cut

Figure 36. Locality No. 18, Clay Dike

Figure 40. King's Clay Locality, Looking South

Figure 41. Hobart Butte Quarry

Figure 42. Carbonized Log in Clay at Hobart Butte. This log shows at right-center of Figure 41

Five feet of clay is exposed in the lower portion of the road cut and four feet more in a culvert ditch. It is overlain by 25 feet of Fern Ridge tuff similar to that at King's. The tuff is quite massive, but there are a few planes that may represent bedding. If such is the case, the tuff has a low angle dip to the west. Two or three seams of impure clay occur above the seam samples and may be equivalent to the upper, impure seams at King's.

There are three phases of the clay - an upper 4 feet of bluish clay, 1 foot of yellowish blocky clay that has a bluish color at the center, and 4 feet of yellowish-cream to white clay. This lower portion has some black stain like manganese and contains weathered felsite pebbles similar to those in the weathered conglomerate at Fransen's. The bottom is not exposed. A columnar section, figure 34, shows P.C.E. of cone 28-30, the lower phase running cone 30-. The locality might well justify further exploration by core drilling.

Locality No. 18.

Samples of this clay were collected west of Silver Creek Falls on the ridge road between Silver and Drift Creeks in the SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 3, T. 8 S., R. 1 E., in a road cut. (see fig. 23.) It is the most northerly and the lowest of a series in which red soil, tuff, and clay are exposed.

Four distinct zones are represented, beginning with a clayey red soil at the top. Fresh, unaltered tuff lies below the soil and on weathered tuff in a manner that suggests it is a younger pyroclastic. Clay underlies the weathered tuff and grades into it. Two clay "dikes" cut the clay and older ? tuff, but not the unaltered material above. (See fig.36.) The dikes are composed of very fine-grained, hard clay with a cone fusion of 34-35, which approaches that of pure kaolinite. It is possible that the agents of alteration passed through them and produced kaolinite in a manner suggested by Goodspeed and Weymouth 1/, for the alteration of pegmatite to kaolinite.

Sample "A" of no. 18 was divided into three parts. The first, showing a gray-tan clay with small weathered white oolites gave a dark chocolate brown melt at only cone 28. The iron-stained buff portion rose to cone 32.5 while the clean buff part showed cone 34-plus with a speckled brown fusion. The composite sample of "A" had a P.C.E. of cone 32-minus and a light cream-colored fusion.

Sample "B" or that below the roadside ditch was uniform in appearance and gave a fusion of cone 33-34. A mixture of half portions of "A" and "B" showed an alumina content of 36.1 percent, silica 43.2 percent, and ferric oxide of 4.5 percent.

Sample "C" from the small "clay dikes" was very refractory, with a fusion of cone 34; the one portion of gray clay without iron-staining showed cone 34 to 35, while the stained portion dropped to cone 32.5.

1/ Goodspeed, George E., and Weymouth, A. A., Mineral constituents and origin of a certain kaolin deposit near Spokane, Washington: Am. Ceram. Soc., Jour., vol. 11, pp. 687-695, 1928.

The predominance of high fusing material from this locality under the stained overburden indicated a source of high refractory material worthy of further investigation.

Victor Point Road Localities.

Wilcox 1/ records a number of clay localities sampled south of Silverton along a road known locally as the Victor Point Road. Almost every cut along this road contains some kind of clay materials. The better of these were sampled in a reconnaissance manner and are briefly described. (See fig. 23.)

Speedometer readings, miles	
0.0	Silverton, intersection of Water and Main Streets. Go south on Sublimity highway.
0.4	Turn east (left) onto Victor Point graveled road.
3.9	Continue ahead. Left hand (east) road leads to Drift Creek Falls and locality no. 18.
4.9	Locality no. 19.
6.0	Locality no. 20.
7.4	Locality no. 21.
7.9	Locality no. 23.
8.5	Locality no. 24.
9.1	Locality no. 25. Continue south on this road, and intersect highway no. 214 about 100 yards west of locality no. 15.

Locality no. 19 is 4.9 miles south of Silverton in the SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 24, T. 7 S., R. 1 W., near the bottom of a minor swale. Clay is exposed in the highway ditch. The upper portion is heavily iron stained, P.C.E. fusion of cone 30-31; a foot lower it is more gritty, with a P.C.E. fusion of cone 28-29.

Locality no. 20 is 6.0 miles south of Silverton in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 25, T. 7 S., R. 1 W., a road cut. The deposit is overlain by weathered arkose or tuff. The clay is very fine grained, somewhat plastic but heavily iron stained. The sample represents material one foot below the highway ditch which is equivalent to 8 feet below the surface. The P.C.E. cone fusion was 31-32. Analysis showed 31.1 percent alumina, 51.7 percent silica, and 2.9 percent ferric oxide. Further investigation should be made for larger quantities below this depth.

Locality no. 21 is 7.4 miles south of Silverton in the NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 36, T. 7 S., R. 1 W., a road cut immediately north of Victor Point School, and 0.2 mile south of Krenz ranch house. The material seems to be an arkose or tuff with a cone fusion of 19, and therefore represented only partially altered clay containing too high a content of fluxes.

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, 54 pp., 1935 (unpublished)

Locality no. 22 is located on a side road, east of the Victor Point road in the NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 36, T. 7 S., R. 1 W. The material appears to be a badly weathered, iron-stained arkose or grit conglomerate. Many of the small pebbles can be crushed to fine clay and a few of the gritty particles seem to be quartz. The sample produced a speckled-gray glassy fusion at cone 27-plus.

Locality no. 23 is 7.9 miles south of Silverton in the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 1, T. 8 S., R. 1 W., a road-cut on the west side of the road. The clay is very plastic and heavily iron-stained and gave a dark-brown fusion at cone 30 plus.

Locality no. 24 is 8.5 miles south of Silverton in the SE$\frac{1}{4}$ sec. 1, T. 8 S. R. 1 W., a road cut. The clay is gray, plastic, and somewhat iron-stained on joint cracks with brown clay, and is so plastic that it had to be cut from the tools with a knife. The P.C.E. was cone 31 plus.

Analysis showed 29.1 percent alumina, 57.2 percent silica, and 3.6 percent ferric oxide. The excess silica above the kaolin ratio may be present as free quartz, amorphous silica, or some clay mineral with a molecular alumina-silica ratio of 1 to 3.4.

Locality no. 25 is 9.1 miles from Silverton just north of cross roads on the west line of NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 12, T. 8 S., R. 1 W. The clay is white to red, intermixed so that it presents a "marble-cake" appearance. Less altered material in the cut is either arkose or tuff, and the cone fusions are 23 and 32 plus for the different clays, with an average for the composite sample of cone 27-plus. There are several cuts between localities 24 and 25 that expose similar clay.

Sublimity Weathered Gravel, Locality no. 26.

This weathered gravel is exposed in road cuts 0.8 mile north of Sublimity on a paved road on the west line of the NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 27, T. 8 S., R. 1 W. The easterly road cut shows blue-gray throughout its entire length that has a fusion of cone 30. Analysis showed 30.4 percent alumina, 54.9 percent silica, and 4.4 percent iron oxide. A 1-foot layer of white clay, saucer-shaped and about 20 feet long, occurs near the middle of the cut and is underlain by a similar, only vari-colored seam. The limited extent of this material did not justify sampling.

A road cut 0.2 mile south shows weathered gravel that looks like hand-laid rubble masonry. It has the same degree of alteration as the Fransen gravel but not the high refractory fusion. This area is covered Salkum soil 1/ and is underlain by the weathered gravel. Basalt is exposed in the channel of upper Beaver Creek 0.2 miles north of locality no. 26. Apparently, the weathered gravel overlies the basalt, and in turn is overlain by the blue clay.

1/ Torgerson, E. F., and Glassey, T. W., Soil survey of Marion County, Oregon: U. S. Dept. of Agriculture, Bureau of Chemistry and Soils, no. 32, p. 23, series 1927.

Macleay Area, Locality no. 27.

This occurrence is cited by Wilcox 1/ as being of exceptional importance. It is located 1.1 miles west of Macleay and is reached from Salem as follows (see fig. 19):

Speedometer reading, miles	
0.0	S. P. R.R. crossing of State St., Salem; take highway no. 222 east.
3.1	Turn left (east) on paved road to Macleay.
7.1	Locality no. 27.

In the $SE\frac{1}{4}NE\frac{1}{4}$ sec. 3, T. 8 S., R. 2 W., clay overlain by typical purplish-red soil is exposed in road cuts. It is light greenish to brown, contains a small amount of grit, and most of the samples are mixed with soil and rock fragments. The parent rock of the lower fusing clays is basalt, probably Stayton lava, and occasionally the weathered product retains the original vesicular voids.

Tests: "A" sample was a mixture of soft, fine-grained, white, gray and yellow-brown clay with the white predominating. It gave a P.C.E. value of cone 33 and dark-colored fusions. The alumina content was 41.3 percent, the silica 42.2 percent, and the ferric oxide content was 2.9 percent. "B" sample was divided into two parts - no. 1, or the iron-stained portion, gave a fusion below cone 16, and no. 2, or the clean buff clay, showed cone 30-plus. The mixture as received fused at cone 28-minus. The fusions were brown, brownish-tan, or black, depending on the iron content. "C" sample from a different location consisted of a light yellow-brown clay and was not as refractory as the others, giving a fusion of only cone 26. A gray clay predominated in the "D" sample from another location, and its fusion was cone 27-28. The Macleay clay varied in composition and refractory properties with the lightest color the best. The thickness, acreage, and uniformity of the most refractory portion should be studied for commercial purposes.

Alteration apparently has been effected by descending surface waters acting on basic igneous rocks. The refractory clay is of limited extent. It is considered a non-commercial deposit.

Scotts Mills Locality no. 28.

Wilcox 1/ mentions the occurrence of clay having a cone fusion of 28-29 on the Scotts Mills road near Scotts Mills. Similar clay was found in the $NE\frac{1}{4}$ sec. 23, T. 6 S., R. 1 E., along this road, where the clay is exposed at the surface or "Grass roots". Its P.C.E. was only cone 29 and the melt was a speckled cream-colored glass. Analysis showed only

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, p. 23, 1935 (unpublished)

22.5 percent alumina, with 65.1 percent silica and 2.5 percent iron oxide. The high silica content, in comparison with the clays south of Silverton, indicates a difference in origin and less shrinkage in the manufacture of clay products.

Buena Vista Clay.

This sample was submitted, after the plates were prepared for publication, by W. B. Sullivan of Portland, Oregon, acting for the owner, Albert Taylor, of Buena Vista, Oregon.

The clay is found on the east bank of the Willamette River at the Buena Vista ferry, south of Salem, in the SW$\frac{1}{4}$ sec. 23, T. 9 S., R. 4 W., Marion County, and is four miles from a Southern Pacific Railroad siding. The sample represents a 4-foot channel across 15 feet of clay.

It proved to be a light-buff gritty clay that developed good plasticity after grinding finer than 20-mesh and tempering in water. The bars did not crack in drying and firing, although the water of plasticity and the shrinkage were high. A vanilla color developed at cone 02, which changed to a light brown at cone 10, a dark brown (Lido) at cone 15, and a gray-centered, brown-surfaced, vesicular mass at cone 20. Iron spots showed at cone 10 and were magnified at cone 15. The clay is one of the buff-firing structural ware clays not suitable for stoneware unless the iron spots are removed by washing and not refractory enough for firebrick.

EUGENE DISTRICT.

Location.

The Eugene district is at the head of the Willamette Valley (see fig. 5) in west-central Oregon, and is covered in part by the Eugene, Elmira, and southeastern Monroe quadrangles.

Topography and Geology.

General topographic and geologic relationships have been discussed in a prior section.

The Willamette River flows inside natural levees, and local drainage tends to be away from the master stream into parallel-flowing tributaries. Consequently, large areas are flooded during the rainy season and conditions are ideal for surface water leaching. Eugene formation sandstone of Oligocene age is the principal bedrock, intruded and covered in part by Miocene volcanics.

Bellfountain Locality no. 29

Location.

The postoffice of Bellfountain is south of Corvallis and northwest of Monroe in the southwest corner of the Monroe quadrangle. The highway log is as follows:

Speedometer reading, miles	
0.0	Center of town of Monroe, northward on Highway no. 99 W.
3.3	Turn west to Bellfountain.
6.8	Town of Bellfountain, west on Dawson Mill graveled road.
7.7	Turn north at top of small hill; continue in a northerly direction.
8.4	End of road at Bystrom ranch in SW$\frac{1}{4}$ sec. 2, T. 14 S., R. 6 W.

The locality is near the west side of the Willamette Valley and the east side of the Coast Range foothills. Gentle, rolling hills, which are characteristic of the borders of the Willamette Valley, form the surface at a general elevation of 400 feet. Reese Creek drains the locality and is flanked by a 75-foot terrace.

The owner, A. Bystrom, states that in pioneer days people from the surrounding area obtained this clay for local use as a refractory material. Clay was dug from the base of the 75-foot terrace, and within 24 hours the pit would again be filled. Apparently the clay was forced up from the bottom, as Mr. Bystrom said that it was not a case of slump from the sides. The pit is now a quaking bog filled with soil and brush.

The Bellfountain clay undoubtedly is slump material and its quality is not uniform. Certain portions are intermixed with soil, and it might be difficult to mine for that reason. The sample taken from a small spring near the prune drier was gray and sandy, with some iron staining, and gave a cream-colored fusion at cone 31 minus. It, therefore, is one of the second-grade buff fireclays, which would bear investigation if the mining and transportation costs were not too high in comparison with commercial clays found farther north. Analysis showed 24.3 percent alumina, 64.1 percent silica, and 2.3 percent ferric oxide. Buff-colored structural wares may be possible from this material.

It can be trucked 1.6 miles to Bellfountain and 104 miles to Portland by Southern Pacific Railroad, via Alpine Junction and Corvallis. The area should be prospected by core drilling to determine whether clay can be found, in place, under the terrace.

Junction City, Locality no. 30

Location.

Clay was reported west of Junction City and was reached by the following route: leave Junction City on highway no. 36, traveling north for 0.9 mile; turn left onto graveled road, and continue past Bear Creek station to a total distance of 8.1 miles from Junction City. The clay occurs in the SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 31, T. 15 S., R. 5 W., in a road cut just beyond the junction with the Ferguson Creek road (see fig. 5).

Description of the Locality.

Clay was found to be exposed in an excavation north of the road. It was fine-grained, contained some very fine grit, had a slightly "sour" taste, and was quite plastic at the surface. A few inches below the surface the clay became more gritty and probably represented an altered arkose in which the feldspathic material has weathered to clay. Unfortunately, th sample was misplaced and no P.C.E. was run. However, Wilcox 1/ reports as follows:

> "The Eugene Brick & Tile Plant reported that they had obtained a white firing clay about 6 miles east of Junction City on the Triangle Lake road. This clay was obtained from a pocket about 50 feet in diameter. In the same locality, a gray clay mixed with yellow, which was similar in appearance to the Bellfountain clay, had been found. Light-firing clays in this section come from an area classified as of Eocene age, and the red firing clay at Monroe has been assigned to the Miocene".

Apparently, the occurrence is quite local in extent. The general relationships are somewhat similar to those south of Eugene, and from data presented by Schenck, the age of the strata is assumed to be Oligocene.

Eugene Fire Clay Products Co., Locality no. 31.

Location.

The deposit is west of Eugene, 3.1 miles from the Southern Pacific R.R. depot on land owned by M. H. Rice in the NW$\frac{1}{4}$ sec. 36, T. 17 S., R. 4 W. (See fig. 5).

History.

Brick of various kinds have been produced here for a number of years and several attempts were made to market firebrick. At present the clay is shipped to Portland as a molding sand.

Description of the Locality.

The clay is removed from a pit several hundred square feet in area, and while hand labor is used at present, it could be obtained easily by means of a dragline scraper.

Two samples of sandy clay were taken from the company's pit near the barn on the northeast side of the bank, and another sample from the storage pile in the shed. Analysis of the latter gave only 15.6 percent alumina and 79.5 percent silica, with 0.74 percent ferric oxide. The clay contain

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, p. 26, 1935 (unpublished too much quartz sand to produce a strong plastic mass, but a low grade of siliceous refractory material was indicated by the P.C.E. values of cone 28 to cone 30-minus for the three samples. The calculated free quartz content from the analysis was close to 60 percent, and it is possible that a greater commercial value could be obtained from this material by washing the sand free of clay and using it for the purer forms of silica sand, which are not abundant in this part of Oregon. More permeable foundry sands for larger castings could be made with smaller clay contents, and it is possible that the washed quartz will have sufficient purity for steel foundry service. Tests for particle size, particle shape, and resistance to abrasion and thermal shock should be continued.

Hawkins Clay, Locality no. 32

The Hawkins clay is found about half a mile south of locality no. 31 and is reached from 11th Street in Eugene. At the airport, turn south for half a mile, then west for half a mile to the Hawkins place in the NE¼NW¼ sec. 2, T. 18 S., R. 4 W. (see fig.5). The material examined was similar to that at locality 31 and no sample was taken for tests.

Mabel Area Locality no. 33

Location.

The Mabel clay area is located northeast of the town of Mabel, which is northeast of Springfield (see fig. 5). The highway log is:

Speedometer reading, miles	
0.0	Center of Springfield: take hard-surfaced road to Marcola.
13.6	Marcola. Take graveled road to Mabel.
18.3	Mabel. Take graveled road to Holley.
23.4	Carl Marks' house. Continue on road.
23.9	Clay area is 100 yards west of road.

Description of the Locality.

The clay is concealed by soil overburden and no sample was secured. Wilcox 1/ reported on the area as follows:

> "Samples of a hard, white fireclay with a cone-32 fusion were obtained about 4 miles northeast of Mabel and 100 yards west of the Mabel-Holley road. This was the whitest clay encountered in Oregon. The extent of the deposit could not be determined, as it was covered with soil and brush."

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick; Univ. of Washington Library, Engineer of Mines thesis, p. 23, 1935 (unpublished)

Carl Marks, who owns the property, submitted some samples to Wilcox, who tested them and reported to Marks by letter as follows: "Three samples from ravine one-half mile above your house were subjected to a high-temperature test. The hard, white clay taken farthest up the stream ran cone 32 (about 3,100° F.). The sample from the bottom of the auger hole farther down the stream ran cone 31 (3,056° F.). The sample from the place where you ran your tunnel did not stand up. Apparently, the most likely place to dig is near the hard white clay. The same material would seem to be in the bottom of your auger hole." 1/

A quarry just west of the town of Mabel shows clay underlying basalt. The clay is light brown in color and semi-flintlike, with light-colored spots like phenocrysts, and is probably quite siliceous. Below the brown clay is a softer, greenish-colored clay. The overlying columnar basalt has been quarried for road metal. Some of the clay has been used for road patching.

Transportation of Marks' clay will involve trucking 10.3 miles to Marcola, a railroad haul of 141 miles to Portland by Southern Pacific Railroad via Springfield, or 14 miles to Eugene. This clay might have economic value if refractory material were manufactured in Eugene.

Fall Creek Ranch Locality no. 34

Location.

A deposit of clay was reported by Wilcox 2/ in the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 31, T. 18 S., R. 1 E. The deposit is reached from Springfield. Follow out the McKenzie highway 2.8 miles; turn south on Jasper graveled road; at mile 14.3 turn right, cross Fall Creek, to Lowell, at mile 16.8 turn east, at Fall Creek bridge; at mile 19.3 is Henry Page place, large sign labeled "Fall Creek Ranch".

Description of the Locality.

The clay is across the creek from the highway and the nearest bridge is half a mile west. This bridge is privately owned and carefully guarded by "No Trespass" signs. According to Mr. Page, the clay lies along the side of a 75-foot stream terrace, concealed by soil and rock overburden, and extends westward onto adjoining land. Wilcox 3/ states:

> "A hard, rather white, number 2 fireclay was obtained about 4 miles east of Lowell. This deposit was examined by O.K.Edwards, of the Willamina Clay Products Co., who reported that the material occurs on the side of a bluff and is covered by talus. The extent of the deposit was not determined. The color of the samples varied from white to a yellow with chocolate-colored streaks, and the cone fusion ranged from cone 30 to cone 23."

1/ Letter courtesy of Carl Marks.

2/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, p. 23, 1935 (unpublished)

3/ Wilcox, Howard Glen, op. cit., p. 24.

The locality should justify further exploratory work when a need for refractory clay arises in this area. It is 145 miles to Portland from Lowell, via Eugene, by Southern Pacific Railroad.

HOBART BUTTE DISTRICT.

Location.

The Hobart Butte district is in south-central Lane County and northeastern Douglas County about 20 miles south of the town of Cottage Grove (see fig. 5).

Topography.

The district lies across the boundaries of the Willamette Valley and Coast Range physiographic provinces. The valleys are narrow and V-shaped, and the ridges are sharp and serrated. The Coast Fork of the Willamette River, which flows northward, heads on the north side; Elk Creek heads near Hobart Butte and flows westward. Relief averages 1500 feet.

Climate

The 17-year record of the Black Butte meteorological station, at an elevation of 1,200 feet, is summarized as follows 1/:

Annual snowfall	20 inches
Average precipitation	49.27 inches
Days with 0.01 plus inches precipitation	110.
Average temperature	49.2°
Average maximum temperature	60.4°
Average minimum temperature	38.2°
Highest temperature	100°
Lowest temperature	5°
Prevailing wind	Northwest

Conditions at the summit of Hobart Butte are more severe, as it is 1400 feet higher, but not enough to handicap operations seriously for more than a few days in January.

Geology. 2/

The rocks of this district are chiefly Eocene in age; Hobart Butte is composed of the lower sedimentary facies of the Calapooya (upper Eocene), Black Butte by upper igneous facies of the Calapooya; and the Elkhead mine area by Umpqua (lower Eocene) rocks. Faulting is normal, with a general northeast-southwest strike, and usually small throw, although faults at Black Butte are displaced several hundred feet. The last

1/ Martin, R. J. and Corbin, E., Climatic summary of the United States, Section 3, Western Oregon: U. S. Dept. of Agriculture, Weather Bureau, 1930.

2/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bull. 850, pp.11-34, 1934.

major deformative period occurred between the deposition of Umpqua and Calapooya formations, producing northeast-southwest trending folds.

Hydrothermal solutions have altered the rocks profoundly wherever the solutions have had free circulation through rock fractures. Cinnabar was introduced by some of the solutions, although many of them were not mercury-bearing, or at least not capable of depositing cinnabar. The altered rocks are frequently cut by hard, silica-carbonate veinlets, which stand out as ribs when oxidized; these are known as iron ribs.

A characteristic of the lower Calapooya formation is the unusual depth and remarkable completeness of its decomposition by surface waters. Commonly nothing but decomposed conglomerate of about the consistency of cheese is to be seen in many cuts, yet there has been no large volume change and the original structure of the once resistant conglomerate is well preserved. In well cemented conglomerate gypsum is the cementing material and it is readily dissolved by surface waters making the andesitic fragments more easily accessible to these waters.

Three main areas of altered rocks have formed in this district as follows: Hobart Butte, the Black Butte, and the Elkhead areas, and refractory grade clays sometimes are associated with them.

Hobart Butte Area, Locality no. 35.

Location.

Hobart Butte is located south of Cottage Grove in the SE$\frac{1}{4}$ sec. 36, T. 22 S., R. 4 W.; the NE$\frac{1}{4}$ sec. 1, T. 23 S., R. 4 W.; The SW$\frac{1}{4}$ sec. 31, T. 22 S., R. 3 W.; and the NW$\frac{1}{4}$ sec. 6, T. 23 S., R. 3 W. The highway log is as follows (see fig. 37):

Speedometer reading, miles	
0.0	Center of Cottage Grove, on Pacific Highway no. 99; turn south on London-Black Butte hard-surfaced road.
12.3	Store at London; take left hand turn onto graveled road.
13.4	Turn right onto private road, cross cattle guard, and thence to the Butte.
16.2	Bunkers at Hobart Butte, 200 feet below the crest and 50 feet below the clay quarry.

The elevation difference between mile 13.4 and mile 16.2 is 1,300 feet; the road is graveled and has a 9-percent average grade.

History.

Robert Phillips discovered the clay in the latter part of 1930 while prospecting for cinnabar. Samples were submitted to Hewitt Wilson

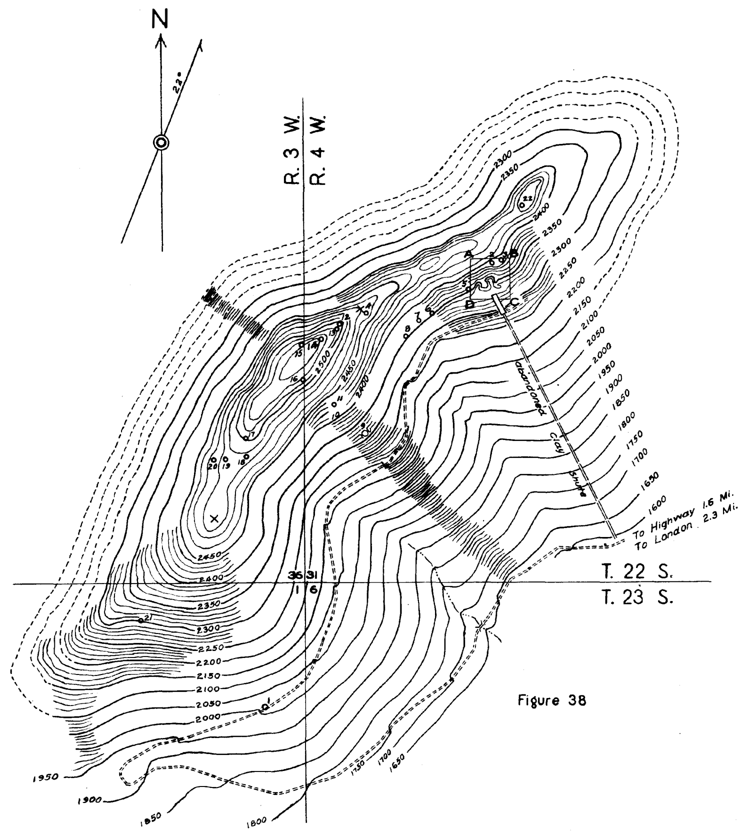


Figure 38

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
Earl K. Nixon, Director

HOBART BUTTE AREA
LANE COUNTY

Scale
0 500 1000 Feet
Contour Interval 10 Feet
Datum by Aneroid

LEGEND

ABCD	Willamina Clay Products Co. Hobart Butte Quarry
o	Test pits
X	Quartz claim corners

Topography by C.O. Greenwood & J.A. Ross, Jan. 1938

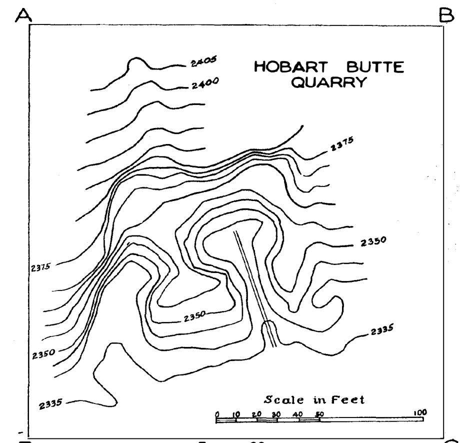


Figure 39

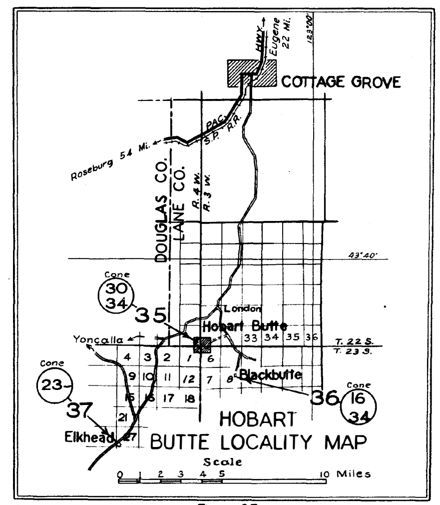


Figure 37

and proved to be a high-grade refractory clay. The attention of O. K. Edwards, president, Willamina Clay Products Co., was called to the deposit, and in the spring of 1933 an agreement was reached with Phillips to lease the property on a 5-cent-per-ton royalty basis for 25 years; but later this was changed to outright purchase. The property is now held by Edwards for seven associates.

In the fall of 1933 a road was built part way to the clay quarry and clay mining was begun. The clay was dropped from the quarry to the road in a chute, the elevation difference being 825 feet. In 1936 the road was completed to the quarry, and the clay is now trucked 16 miles to Cottage Grove and shipped 136 miles by rail via Salem, Gerlinger, and Whiteson to the plant at Willamina.

A series of test pits and physical tests have proved that the 140 acres owned by Edwards, et al., is underlain by high refractory clay.

Description of the Clay.

There are three phases of the clay, each having different physical appearances; (1) one at the top of the quarry face is a ligh-gray, hard, flinty mass with a hardness of 3 and conchoidal fracture, and contains white bodies that look like altered feldspars; (2) below is similar clay, except that it has a slight brownish cast; (3) at the bottom of the quarry is darker-gray, softer clay with hackly fracture and a higher percentage of "white bodies" that are frequently elongated in a parallel direction. This gray clay contains small fragments of carbonized and silicified wood in addition to some realgar, cinnabar, and stibnite. The gray color is due to finely divided carbon that burned out in firing and showed a slightly higher loss on ignition. Realgar, cinnabar, and stibnite volatilize in the physical tests and do not affect the refractoriness.

Small fragments, twigs, and even 10-foot logs of carbonized and silicified wood are found in the gray clay (see fig. 42). Some of the logs appear to have been flattened by pressure. The presence of small fragments of wood indicates that the altered rock was originally a pyroclastic instead of a flow. To the westward, the clay grades into more impure material of various colors; some is brick red, grading to dark tan but otherwise having many of the characteristics of the clay in the quarry. The zones of colored clay appear to have vertical extent like strata dipping at steep angles.

The extent of fractures in the clay mass was not determined, and although slickensides occur frequently, they could properly develop in such a mass with very little displacement. In some cases, either realgar or cinnabar, or both, was deposited prior to the fracturing, as these minerals may be smeared along the slickensides.

An iron rib similar to those described by Wells and Waters 1/ on

1/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bull. 850, pp. 29-30, 1934.

Black Butte lies in the saddle at the north end of the Butte about 400 feet northwest of the clay quarry. It strikes transversely to the trend of the Butte and dipping S. 45° E., 85°. This rib was traced for 60 feet, is 6 inches wide, and has deep, black, botryoidal incrustations.

In general, the clay appears to be an altered pyroclastic of andesitic or rhyolitic composition in which some fault breccia has a cement of colloidal clay (see fig. 41).

Wells and Waters 1/ state that Hobart Butte is composed of a coarse conglomerate in the lower and dominately sedimentary facies of the Calapooya formation, with silica-carbonate material oxidized to deep brown, which forms a cement to bind the altered andesite cobbles together, - that no cinnabar has been found in it; but the outcrops show evidence of rock alteration similar to those at Black Butte.

The coarse conglomerate was not identified during the present investigation in the upper 200 feet of clay, but cinnabar, realgar, and stibnite mineralization were identified. However, the large exposure offered by the Willamina quarry was not available at the time of the U. S. Geological Survey study, and furthermore, the soil cover is sufficient to mask most outcrops. These observations do not reflect on the quality of the previous work, but merely add more information toward the solution of a complicated problem.

When certain portions of the clay are removed from the quarry face, the odor of arsenic is strong enough to be repulsive, and occasionally hinders operations. The mineralization certainly indicates the action of hydrothermal solutions, and there is justification for the statement that at least a portion of the alteration was due to hydrothermal action. The effect of descending meteoric waters on the clay body has not been determined, but, as stated by Wells and Waters, the iron ribs and the staining of the clay west of the quarry indicate that undoubtedly they had some effect.

1/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bull. 850, p. 34, 1934.

Quality.

Fig. 43. A series of P.C.E. tests on hand samples of Hobart Butte clay illustrating all possible variations in the present working face gave the following results:

Cone fusion	Location	Description
	Top pit	
27 - 28	"	White, granular material, at grass roots.
32½	"	Hard, flinty, white clay with gray stringers.
33 plus	"	Gray clay with white "oolites".
31 plus	"	Gray clay with white "oolites", vesicular structure.
32	"	Darker gray with more "oolites" and some red material (realgar).
34	"	Lighter gray with fewer and smaller "Oolites".
32½	Top pit, east side	Cream-colored flinty material.
32½	West pit	Light gray with white "oolites".
33 - 34	"	Darker gray with white "oolites".
33	"	Cream-colored, waxy clay having a semiconchoidal fracture.
32½	"	Light-gray clay with sparse distribution of larger white "oolites".
32½	"	Dark gray with white "oolites".
31 - 32	"	Lighter gray than the one above, but similar to first sample in West Pit.
30 plus	Center, lower pit	Light-gray clay with large number of white "oolites".

Traces of green, secondary, chertlike incrustations were found, which fused below cone 16.

The tabulation shows the comparatively uniform quality of the clay from this quarry. Chemical analyses shown in figure 45 also indicate the uniformity of the clay.

This flintlike material developed but weak plasticity, even though ground wet in a ball mill to pass a 200-mesh sieve. The sample was taken from the lower portion of the quarry and showed a very light gray color from carbonaceous matter and was not as white as the upper portions of the working face. The tests shown in figure 47 gave a low drying shrinkage and a comparatively high dry pore space. The bars, on firing, developed a fine cubical surface cracking characteristic of many commercial kaolins, but the color remained white, without specks, until cone 20, where a very light cream tint appeared with a very few light-brown specks. A uniform light-gray color and a vitrified texture developed at cone 29. Steel hardness was found at cone 10, and the absorption dropped below 10 percent between cones 10 and 15.

The analysis shown in figure 17 indicates a clay of high purity, with the exception of the large alkali content, 1.40 Na_2O. The ferric-oxide content is less than all of the other kaolins or china clays except the Georgia kaolin sample of figure 17. The alumina content was low, but the silica content was not correspondingly high. The calculated alkalic feldspar, based on the soda, is similar to that of the ball clays rather than the kaolins, and this flux is undoubtedly the cause of the lower P.C.E. value, averaging for the best portions between cones 33 and 34 and from one to two cones lower than the best kaolins.

Experience at the Willamina Clay Products Co. has shown that while sufficient plasticity can be developed by wet-pan grinding for the molding of firebrick in the auger machine, a better article can be produced more easily when a plastic bond clay is added. A high temperature calcination of the flintlike lumps of clay from the bank for grog, likewise has been found to give a refractory mixture with less volume changes in the original firing as well as less trouble in shrinkage and spalling in the consumer's furnace. Such a procedure requires a highly refractory bond clay for plasticity, and such materials are found in commercial quantities in the Molalla River district and near Silverton and Sublimity east of Salem. Therefore, by proper treatment a no. 1 firebrick is undoubtedly assured for western Oregon. 1/

Preliminary tests at the University of Washington indicate that the Hobart Butte clay can be used as the kaolin content of a whiteware pottery body consisting of the ball-milled flint clay, the Willamina black plastic for bonding, and feldspar from Deer Harbor, Wash. This would produce a whiteware mixture from west of the Cascade Mountains. It is also believed that the whitest clay at the top of the Hobart Butte quarry can be used as a paint filler and possibly for paper filling.

Quantity.

(prepared by John A. Ross).

Cone fusion tests indicate that the 140 acres controlled by Edwards and his associates are underlain by clay of refractory quality. The quarry floor is 200 feet below the top of the hill which shows a minimum of 200 feet for the thickness of the clay. The average specific gravity of the clay was determined as 2.4; therefore, 13.3 cubic feet of the material weighs one ton. On the basis of the above figures, there is an estimated quantity of 46,200,000 short tons.

This tonnage indicates that there is a supply of refractory clay to satisfy the needs of industry for many years.

1/ Bell, J. W., Refractories from Hobart Butte, Oregon, fireclay; University of Washington, thesis, 1938.

Quarrying.

(prepared by John A. Ross)

The topography of the quarry is shown on figure 39. (See also fig. 41). Two benches are maintained in the quarry, the lower bench being divided into an east and a west pit. The clay is drilled by hand and broken with low-strength dynamite. Sorting, other than the throwing out of heavily iron-stained material, is unnecessary, as the gray, white, and cream-colored clay all behave similarly in the kiln. The clay is hand-trammed about 50 feet to a chute, which discharges into a bunker. Trucks are loaded by gravity directly from the bunker. The haul to Cottage Grove is 16 miles. Rail distance, via Southern Pacific Railroad to Portland, is 144 miles.

Should as much as 250 tons a day be quarried, it might be advisable to erect an aerial tramway from the quarry to the base of the hill. The horizontal distance is about 1 mile, the vertical distance is 1300 feet, and the tram length would be about 6,000 feet. Allowing for cable-sag and minor irregularities, the cable length would be about 7,000 feet. Against the present truck-haul of 2.8 miles from the quarry to the base of the hill, the saving would be about 10 cents per ton on transportation charges.

Black Butte Area, Locality no. 36

Location.

Black Butte is about 2½ miles southeast of Hobart Butte in the NW¼ sec. 16, T. 23 S., R. 3 W. It is reached from Cottage Grove by a route similar to that for the Hobart Butte; but instead of turning onto the private road at mile 13.4, continues on the main graveled road to the mine. It has a sharp crested butte, the summit of which is 1,450 feet above the valley. The mine buildings and reduction plant are in the valley. The lowest mining level during October 1937 was the 900 level, from which ore was delivered to the mill by aerial tram.

Geology 1/

Black Butte is composed of andesitic lavas and breccias of the upper facies of the Calapooya formation which have been so profoundly whitened and bleached by hydrothermal solutions that the original character of the rock is almost unrecognizable in the field. These altered rocks are cut by silica-carbonate veins related to faulting. The leaching action of surface waters has converted the silica-carbonate veins into iron ribs, one of which forms the crest of the Butte.

Although hydrothermal alteration has thoroughly altered the andesites

1/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bull. 850, pp. 29-33, 1934.

and breccias, the outlines of altered phenocrysts of feldspar or hypersthene are still visible. Occasionally, however, volume changes have completely destroyed this texture. Oxidation and leaching by surface waters have penetrated to a depth of nearly 1,000 feet.

Zones of folding and faulting have influenced the location of the altered zones, but instead of being long and narrow, the zone at Black Butte is 2 miles long by 1 mile wide. The permeable nature of the andesites may account for the widespread alteration.

Description of the Clay Formations.

The Black Butte mine was visited to ascertain possible relationships that might help to explain the alteration on Hobart Butte, and to determine if fireclay similar to that found at Hobart Butte occurs in this operating mine. The rocks are severely altered and stained by meteoric waters carrying iron solutions. One characteristic of this altered rock is that it can stand in openings like stopes and drifts for indefinite periods without requiring timber and with no apparent spalling. The 1100 stope is an excellent example; it has been open for many years, its size is breath-taking, but not a stick of timber is in sight. This competency was noted in all the cinnabar mines visited.

All levels are numbered as being so many feet below the surface or hilltop level. Clay is here associated with cinnabar and probably has some relation to faulting, as the ore body at this point is somewhat controlled by a major fault. The stopes from the surface are open throughout, and it gives one a most peculiar feeling to prowl around the upper level and realize that a slip will mean that the next stop is 900 feet down. Actually, however, the slope of the stope walls changes so that one would not skid over 50 feet before coming to a stop.

Tests of clay from the Black Butte Mine: Hand samples were taken from the upper surface workings, the 200-foot level, the 900-foot level, and the 1,100-foot level.

Upper level, top of mountain: A tan-colored plastic clay, sample A, taken from the hanging wall, gave a P.C.E. value of cone 31-minus and a tan-colored, speckled melt. But two other samples from the same vicinity gave very low refractory values. Sample B, consisting of light-gray, partially altered rock, fused to a brown slag below cone 16. This likewise was true of a pink sample of another partially altered rock, sample C, from the footwall near the upper surface. Analysis of A showed a high alumina content, 35.4 percent; low silica, 50.1 percent; and low iron oxide, 2.2 percent.

Sample H was taken from a surface outcrop near the mine entrance of the 200-foot level. It consisted of a pink to white flintlike clay having a conchoidal fracture and weak plasticity, and which produced a spotted, tan-colored fusion at cone 30. Sample H3, consisting of bluish-gray matrix mottled with white inclusions, gave an ivory-colored fusion at cone 32-plus, and analysis showed 27.4 percent alumina, 62.1 percent silica, and 1.5 percent iron oxide.

A number of hard, rocklike, weakly plastic clay samples were taken from the side walls and roof of the West Tunnel of the 900-foot level, but all showed low refractoriness. The best, consisting of white nodules surrounded by gray clay, gave a speckled, nearly white fusion at cone 28, but the cream-colored, tan, and purplish varieties fused to dark-colored melts below cone 18. Several large inclusions or balllike masses from 6 inches to 2 feet in diameter of white very plastic, kaolinlike clay were found in the matrix of hard country rock in the Copenhagen tunnel. These proved to be very refractory, giving a P.C.E. of cone 34 plus and a melt nearly white in color. The indications were not favorable for producing commercial tonnage in this location, but such valuable material may be found concentrated at other places in the mine. Other samples of the soft white clay mixed with light-colored rock found in the Copenhagen tunnel gave chocolate-brown fusions below cone 26.

A sample of light-colored, flintlike clay stained by iron compounds was taken from no. 2 chute on the 1,100-foot level. This gave a plastic mass when tempered with water and a P.C.E. of cone 32. The melt was a speckled buff. The analysis showed 30.0 percent alumina, 58.1 percent silica, and 1.8 percent ferric oxide. A large pile of waste material from the calciners has accumulated in a stock pile near the plant. This represents a mixture from all parts of the mine and is used by the country for road-surfacing. The predominating color is a dark pink or red-brown, but the material proved of low refractory value, cone 16, and poor fired color.

Conclusions: Kaolinlike clay was found in the Black Butte mine, but the samples taken on the preliminary inspection indicated considerable variation in refractoriness and difficulty in obtaining commercial quantities of high-grade fireclay equal to that in Hobart Butte.

Although alteration at Hobart Butte is more complete and more uniform, the presence of iron ribs and mineralization indicated a similar hydrothermal origin.

P.C.E. data are given in figure 44. Chemical tests are shown in figure 45.

Mining.

As Black Butte is being operated as a quicksilver mine, clay mining would probably be incidental to the "stoping of ore", and its mining would depend on the demands made by cinnabar mining.

Fig. 44 Refractory tests of Black Butte clays.

P.C.E.	Location	Description
31-	Upper Level, hanging wall	Yellow, plastic clay.
16-	" " near surface	Gray clay with white "oolites".
16-	" " under footwall	Reddish-brown rock with white specks scattered throughout.
34 plus	200 level	Large "oolites" of white, flinty clay in pinkish rock.
32	" "	Purple rock with small, white specks.
27-28	" "	Same as above, but with tan iron stains.
26-27	" "	Altered rock, purple, similar to above.
*34 plus	Copenhagen tunnel	White, soft, kaolinitic clay.
32	" "	White clay and light-pink rock with black specks throughout.
16-	" "	Light-pink rock with tan surface weathering.
16-	" "	Similar to above, but with "oolites" of white clay.
16-	900 west tunnel	Tan, earthy material.
16-	" "	Purplish-colored, hard material with included white nodules.
18-	" "	Light-cream, rocklike material.
28	" "	Gray clay surrounding white nodules.
33	1,100 stope, no. 2 chute	White, flintlike clay.
32-	" "	Light-purple clay with small white nodules.
16	Miscellaneous road material and waste rock from retort after mercury is removed.	

*Cone 34 plus and a white cone indicate that the clay must be near the composition of pure kaolin.

Elkhead Mine Area, Locality no. 37

Location.

The Elkhead mine is 6 miles east of Yoncalla, which is on the Pacific Highway no. 99 and the main line of the Southern Pacific Railroad. The mine is in the NE$\frac{1}{4}$ sec. 21, T. 23 S., R. 4 W., and was originally worked as a cinnabar property. It has not been operated in recent years.

Geology 1/

The ore body at the Elkhead mine is situated in altered tuffs, which lie between upper Umpqua tuffaceous sandstone and lower Umpqua amygdaloidal basalt. The conditions of alteration and the formation of iron ribs are similar to those at Black Butte and Hobart Butte.

Description of the Locality.

The mine has been abandoned for a number of years (exact date unknown); rails have been pulled from tunnels and drifts, and the workings are in bad condition, characteristic of abandoned workings. Extensive sampling was not attempted, as it was considered unwise and unsafe to attempt entry with the crew available.

The altered rock exposed at the portals of the tunnels is similar to that found at the 200 level at Black Butte. A sample gave a P.C.E. fusion of cone 23 minus, with a light-green fusion that contained a few specks. The result of this test did not warrant further investigation at this time.

Conclusions for Hobart Butte District.

The quarry at Hobart Butte is the most promising of all the localities visited during this investigation. Certain portions of the Black Butte quicksilver might be used to produce refractory clays of high quality.

Field and laboratory work indicate that the areas of altered rock identified by Wells and Waters 2/ offer very good prospecting possibilities for refractory clay. It is recommended that their maps be used to guide future field parties in these areas, and that careful sampling and laboratory work be done for each of them. Where new workings have been opened since their quicksilver study, a careful investigation of the geologic relationships should be made. Additional areas include the Bonanza-Nonpareil and the Tiller-Trail districts.

1/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bull. 850, pp. 34-35, 1934.
2/ - - - - - - - - - - - - - - - - op. cit., pls. 7, 14.

SOUTHWESTERN OREGON DISTRICT.

A brief reconnaissance trip was made into southwestern Oregon to check several localities. The limited time and budget allowances did not permit other than a hurried collection of samples.

Trail Area.

Gaines Property, Locality no. 38.

Wilcox 1/ describes a clay deposit northwest of Trail, for which a search was made. His location is given as the SW$\frac{1}{4}$ sec. 28, T. 33 S., R. 1 W. This deposit could not be found, but as a result of the search clay was found in the SW$\frac{1}{4}$ sec. 20, T. 33 S., R. 1 W., on the Gaines property (see fig.5).

The country rock appears to be altered tuff or rhyolite. The clay is exposed near the west fork of Trail Creek and was sampled in a road cut adjacent to the stream bed. The P.C.E. of cone 27-plus is not satisfactory for a high refractory fireclay, although the laboratory test indicated a possibility of its use as face brick. Refractory clay occurrences in T. 33 S., R. 2 W. are reported, but confirmation could not be obtained.

Rogers' Cinnabar Properties, Locality no. 39

The Rogers cinnabar claims are reported by Wells and Waters 2/ as the Poole Prospect in the SE$\frac{1}{4}$ sec. 25 and NE$\frac{1}{4}$ sec. 36, T. 33 S., R. 1 W. A. G. Rogers, of Jennings Lodge, Portland, Oreg., is the present owner (see fig. 5). The claims are reached from the store at Rogue-Elk with the aid of a guide.

The cinnabar claims are on the southwest, south, and southeast flanks of a conical-shaped hill about $\frac{1}{2}$ mile northwest of Rogue-Elk. Production of mercury is evidenced by ore taken from the 75-foot adit on the southwest side of the hill and a very crude retort which is still there. The rock is altered, very resistant, and stands without timbering as it does at Elkhead and the Black Butte mines. A few grab samples were taken inside the adit, and a P.C.E. of cone 28 to 29 plus was obtained. The analysis showed 19.8 percent alumina, 71.5 percent silica, and 2.3 percent iron oxide.

Wells and Waters 3/ reported on this property as follows:

> "The country rock contiguous to the vein has been altered to a white friable mass cut by a network of narrow limonite ribs. The alteration fades out in a short distance, the white friable rock grading into a gray-purple rock, somewhat iron-stained, which in turn grades into the fresh basalt."

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon, and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, p. 25, 1935 (unpublished)
2/ Wells, Francis G., and Waters, Aaron C., Quicksilver deposits of southwestern Oregon: U. S. Geol. Survey, Bull. 850, pp. 48-49, 1934.
3/ - - - - - - - - - - - - - - op. cit., pp. 48-49.

On the basis of the examination and the above statement, it is doubtful if this clay will have value as fireclay or other clay products in competition with purer materials closer to the markets.

Rogers' Tiller-Trail, Locality no. 40.

A. G. Rogers submitted samples of material taken from a tunnel near the summit of the Tiller-Trail road, but this was not visited by the field party. An apple-green, hard, fine-grained clay, some of which was mineralized and some unmineralized, gave a P.C.E. of cone 16 and black fusions; however, some siliceous chert, tinted blue and red, from this same location showed cone 33.

Brownsboro Locality no. 41.

Advice received from O. K. Edwards indicated that the deposit sought at the Gaines locality in reality is in the vicinity of Brownsboro, which is 6 miles east of Eagle Point in Sec. 3 or 4, T. 36 S., R. 1 E. Wilcox's description 1/ is as follows:

> "A short drift with two crosscuts has been driven in the clay, and a shaft has been sunk 20 feet below the tunnel level. . . . . . This clay was not uniform in character throughout the tunnel. Small light-colored patches, yellow iron-stained areas, and hard iron-cemented patches were so mixed as to make mining of the best material extremely difficult. A sample from nineteen sacks of the light, iron-stained material fused at cone -32. The heavy iron-bearing clay was below fireclay specifications. The clay from this deposit is fairly plastic and has a drying shrinkage of 4 percent and a total fired shrinkage of 7 percent."

Medford Area, Locality no. 42.

Clay was reported east of Medford, but it was not found. In the NE$\frac{1}{4}$ sec. 25, T. 37 S., R. 1 W., the soil has a peculiar spongy appearance and a purplish-red color. A sample of this material fused below cone 16 and was not satisfactory for ceramic ware.

W. C. Hurst Clay, Grants Pass, Locality no. 43.

A sample of clay was submitted by the owner, W. C. Hurst, 521 West L. Street, Grants Pass, Oreg. The clay was taken from the head of Waters Creek in Josephine County, in T. 36 S., R. 7 W., but no more accurate location could be obtained. Its P. C. E. was minus 16, with tan to buff and black fusions. The material appeared to be an altered tuff or rhyolite but was not refractory.

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, p. 25, 1935 (unpublished)

Dead Indian Deposits, Localities nos. 44, 45, 46.

Location.

The area is at the extreme eastern side of the Medford quadrangle in Jackson County, east of Ashland. The best material was found one-eighth of a mile south of the summit on the Dead Indian road, in the south central part of sec. 19, T. 38 S., R. 3 E.

Description of the locality.

Wilcox 1/ refers to this locality as follows:

> "There is a broken mass of no. 2 fireclay on the Dead Indian road about eight miles east of Ashland. This clay is a hard, nonplastic material, rather porous. At one time it was shipped to Portland and used in making firebrick. About a mile beyond the mass just mentioned, near the crest of the ridge, this material is found in place as an outcrop. The ledge is 15 to 20 feet high and has the appearance of a flow. The characteristics of the clay and the position of the outcrop indicate an altered rhyolite. The material has a cone -28 fusion, a 2-percent drying shrinkage, and a total fired shrinkage of 4 percent. It would be classified as a semiflint clay, and though it cannot be made into brick by itself, it is a suitable nonplastic for a number 2 brick."

The outcrop trends S. 30° W. for a length of 1,000 feet west of (below) the Dead Indian road. A white porcelainic material that gave a P.C.E. test of cone 31-plus occurs at its northeast end. East of the road the material, if present, is covered by a fresh, comparatively unaltered, amygdaloidal felsite.

Quality.

Tests of the Dead Indian materials: Sample no. 44, taken from the upper end of the outcrop, was an impure flint or chert. Analysis showed only 3.4 percent alumina, 89.5 percent silica, and 2.3 percent ferric oxide. It is, thus, too siliceous to be classed as a clay and does not contain sufficient silica for the highest type of silica brick, whose requirement has been tentatively set at about 94 percent silica. The hard, conchoidal, nonplastic mass was stained to a deep cream with iron oxide and fused to a glassy, light-gray, speckled melt at cone 31-plus. The P.C.E. test, therefore, indicated that if there were a market for silica brick, and if commercial quantities of uniform chert could be found, attempts should be made to use this material in view of the lack of high-grade quartzites in western Oregon and Washington.

1/ Wilcox, Howard Glen, Fireclays and light-colored clays of western Oregon and the commercial development of number 1 firebrick: Univ. of Washington Library, Engineer of Mines thesis, p. 32, 1935 (unpublished)

Sample no. 45, taken to represent the entire outcrop, did not indicate uniform material. The first portion of cream color gave a high fusion of cone 31-plus; the mottled purple colors showed only cones 26-27; the white material dropped to cone 23, and the brown and maroon porous samples gave a chocolate-brown fusion below cone 16. The porous vesicular portion contained too great a quantity of fluxing materials, and their presence in this outcrop presents too much variation for safe and economical industrial service.

Sample no. 46, taken from a roadcut a mile below no. 45, was divided into three parts: non-mineralized white clay, mineralized blue-gray material, and a mixture of white and iron-stained clay. The separate portions and the composite sample gave black to brown fusions at cones 19 to below cone 16. The material, therefore, is worthless for the purposes of this investigation.

SUMMARY.

Western Oregon presents a most unusual variety of clays. Those studied, in the order of their importance are:

(1) High refractory semi-flint clays, as at Hobart Butte, where it occurs as a 200-foot camp rock for the Butte. The clay has high fusion, low shrinkage, light to moderately dark fired colors, and an estimated tonnage of 35,000,000 short tons. It is being operated for the Willamina Clay Products Co.

(2) High refractory plastic clays, as the Fransen clay near Mayger. This clay is a weathered gravel that has been altered until all the water-worn aluminum silicate pebbles have softened to plastic clay without movement. It has high fusion, moderate shrinkage, moderately dark fired colors, an estimated tonnage of 430,000 short tons. Transportation facilities are particularly favorable, especially with reference to deep water shipping.

(3) High refractory bentonitoid clays of the Molalla area. These clays have high-iron content, brown-firing colors, bentonitoid plasticity, silica-alumina ratios of 1:1, and alumina contents of 36 to 28 percent. Shrinkage is great but can be overcome to a certain extent by pre-calcination. The available tonnage is great and transportation is favorable.

(4) Pottery and stoneware clays as at Willamina where a white-firing, plastic, carbonaceous clay occurs that vitrifies at cone 1 (2,120° F.). It has a calculated mineral composition corresponding to 43 percent feldspar, 26 percent kaolin, and 24 percent free silica.

Lateritic weathering has been pronounced in certain areas producing low silica clays as well as low-grade iron ores. Free quartz is practically absent in large areas now covered by weathered red clay which has formed from the Tertiary basalt flows. The underlying andesitic, tuffaceous materials have also altered to refractory clays with a minimum of free silica.

The study indicates that there is an abundant supply of raw materials to supply a refractory clay products industry in the lower Columbia River area.

Fig. 45 CHEMICAL ANALYSES WESTERN OREGON CLAYS

Field Number	Locality Description	Alumina Al_2O_3	Silica SiO_2	Ferric Oxide Fe_2O_3	Titanium Oxide TiO	Lime CaO	Magnesia MgO	Ignition Loss	TOTAL
1 C	Fransen, Back Pit	37.56	43.62	5.31	1.07	0.39	0.22	12.63	100.80
1 D	Fransen, Front Pit	25.58	63.58	2.55	0.13	0.47	0.29	8.00	100.60
1 F	Fransen, Front Pit	39.82	39.40	6.68	0.32	0.21	0.14	13.88	99.85
1 G	Fransen, Front Pit	40.10	38.10	8.82	0.47	0.35	0.15	12.20	100.19
2	P. M. West	23.36	63.20	1.86	0.34	0.92	1.07	4.64	95.39
5 A	Willamina	22.86	63.46	0.56	0.13	1.39	1.47	8.72	98.59
5 B	Willamina	20.27	69.40	0.46	0.14	1.58	0.59	5.10	97.54
6 D 30	Ellis	39.22	36.38	5.85	0.28	0.67	0.31	17.36	100.07
6 D 28	Ellis	31.72	43.74	7.85	0.27	3.60	0.42	12.61	100.21
6 X 1	Ellis	39.04	38.96	4.54	0.17	0.84	0.34	16.28	100.17
7	Molalla Reservoir	36.72	43.52	5.10	0.66	0.65	0.21	13.10	99.96
8 A	Dibble	38.78	45.86	2.79	0.21	0.70	0.24	12.40	100.98
8 B	Dibble	32.50	35.84	14.10	0.20	0.61	0.26	17.46	100.97
9 B	Zahar	30.38	54.14	3.90	0.27	0.52	0.28	11.35	100.84
11	King	36.96	45.20	3.43	0.16	0.79	0.31	13.13	99.98
14	South of King's no. 11	35.87	46.58	5.06	0.10	0.76	0.28	11.78	100.43
15	West of Kings, Hwy Sta. 795	34.71	44.88	7.71	0.28	0.23	0.28	12.74	100.83
16	East of Kings, Hwy Sta. 63	37.95	44.80	3.62	0.29	0.42	0.18	13.10	100.36
17	East of Kings, Hwy. Sta. 109	33.89	46.04	7.34	0.33	0.64	0.27	11.95	100.46
18	Near Silver Creek Falls	36.12	43.20	4.46	0.43	0.41	0.37	15.02	100.01
20	Victor Point Road	31.08	51.72	2.87	0.14	0.47	0.66	12.46	99.40
24	Victor Point Road	29.06	57.16	3.62	0.17	0.56	0.33	9.23	100.13
26	Sublimity	30.38	54.86	4.36	0.15	0.44	0.56	9.73	100.48
27	Macleay	41.30	42.16	2.87	0.55	0.26	0.30	13.37	100.81
28	Scotts Mills	22.53	65.10	2.50	0.25	0.65	0.46	8.08	99.57
29	Bystrom	24.33	64.12	2.31	0.13	0.34	0.36	8.49	100.08
31 C	Eugene Fire Clay Products Co.	15.63	79.54	0.74	0.13	0.32	0.31	3.23	99.90
35 C 1	Hobart Butte	39.86	46.98	0.46	0.17	0.47	0.19	12.46	100.59
35 C 2	Hobart Butte	39.20	48.40	0.74	0.19	0.50	0.22	10.92	100.17
35 F 2	Hobart Butte	40.20	46.98	0.37	0.50	0.47	0.17	11.38	100.07
35 G	Hobart Butte	38.42	49.68	0.56	0.13	0.44	0.15	11.18	100.56
35 H 2	Hobart Butte	38.75	45.60	0.57	0.34	0.37	0.19	14.90	100.72
35 I 1	Hobart Butte	39.82	47.20	0.47	0.25	0.43	0.16	12.40	100.73
36 A	Blackbutte	35.43	50.12	2.23	0.22	0.37	0.15	11.52	100.04
36 H 3	Blackbutte	27.44	62.06	1.48	0.22	0.40	0.17	8.83	100.60
36 G	Blackbutte	29.68	58.10	1.76	0.44	0.21	0.20	9.61	100.00
38	Gaines	19.45	68.02	3.90	0.13	1.91	0.40	6.26	100.07
39	Rogers	19.77	71.48	2.27	0.30	0.70	0.18	5.64	100.34
44	Dead Indian	3.40	89.46	2.31	0.71	0.38	0.33	3.32	99.91

Analyses by Lerch Brothers, Incorporated, Hibbing, Minnesota.

Fig. 46

FIRED TEST DATA, AMERICAN CERAMIC SOCIETY'S METHODS

Temperatures	cone 02 (2057°F)		cone 10 (2381°F)		cone 15 (2615°F)		cone 20 (2786°F)		cone 29 (2984°F)	
Shrinkage 1/	Volume 1/ percent	Linear 2/ percent	Volume 1/ percent	Linear 2/ percent	Volume 1/ percent	Linear 2/ percent	Volume 1/ percent	Linear 2/ percent	Volume 1/ percent	Linear 2/ percent
Buena Vista	5.7	1.9	18.1	6.4	21.2	7.6	Fused	Fused	Fused	Fused
Hobart Butte	11.6	4.0	28.3	10.5	29.0	10.8	35.0	13.3	41.3	16.3
King's Clay	16.3	5.8	30.5	11.4	31.6	11.9	32.8	12.4	42.5	16.9
Dibble, grogged	1.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	21.7	7.8
Fransen, top	4.8	1.5	10.5	3.6	10.5	3.6	18.7	6.7	30.6	11.4
Ellis, grogged	1.9	0.4	2.4	0.8	2.9	1.0	17.8	6.3	35.6	13.6
Absorption 3/	percent									
Buena Vista	12.8		5.3		2.1		Fused		Fused	
Hobart Butte	17.0		11.2		9.4		6.4		0.6	
King's Clay	19.5		12.8		10.8		8.1		0.7	
Dibble, grogged	17.2		16.8		17.4		16.8		6.7	
Fransen, top	21.1		16.1		15.4		10.2		1.6	
Ellis, grogged	22.0		20.5		20.4		13.4		1.1	

1/percent dry volume 2/percent dry length 3/percent fired weight

Fig. 47. Plastic and dry test data, American Ceramic Society's methods.

Clay Samples	[1]Water of plasticity, percent	[1]Shrinkage water, percent	[1]Pore water, percent	[2]Dry Volume shrinkage, percent	[3]Dry linear shrinkage, percent
Buena Vista	38.1	19.4	18.7	35.1	10.6
Hobart Butte	27.8	6.2	21.6	10.7	3.4
King's clay	39.6	11.7	27.9	16.3	5.3
Dibble, grogged	21.9	-	-	4.0	1.3
Willamina, hard	47.4	33.0	14.4	67.6	18.8
Willamina, soft	56.6	39.4	17.2	73.9	20.3
Ellis, raw	58.5	31.1	27.4	49.2	14.8
Ellis, grogged	26.5	4.4	22.1	7.6	2.5
Fransen, upper	43.2	21.9	21.3	37.9	11.4
Fransen, lower	40.3	16.1	24.2	26.9	8.3

[1]Percent dry weight.

[2]Percent dry volume.

[3]Percent dry length.

Figure 48

KEY TO ABBREVIATIONS USED IN TABLES.

COLOR OF FUSED CONES:

Symbol	Color*	Color Designation*
W	Pure White	
Wb	White with brownish cast	
LG	Light gray	
LGT	Light gray-tan	
LD	Light drab	14 C-D 2-3.
LI	Pale Ivory	10 A 1
I	Ivory	10 B-C 1-3
PB	Polar bear	9 B 2-3
EBe	Ecru beige	11 B-C 2-3
RBe	Rose beige	5 A-B 9-10
T	Tan	12 L 11
Bz	Bronze	14 G-L 6-9
S	Sepia	8 A-E 10-12
CBr	Chocolate Brown	8 C-H 2-4
Bl	Black	
SO	Slate olive	23 A 3

* "Dictionary of Color". Maerz & Paul, McGraw-Hill Book Company, New York, 1930.

TEXTURE OF FUSED CONES:

G	Glassy
Sa	Satin
D	Dull

DEGREE OF PLASTICITY:

N	Non-plastic
W	Weakly plastic
M	Moderately plastic
P	Plastic
S	Sticky

AMOUNT OF SPOTS IN FIRED CONES:

f	Very few
F	Few
m	Moderate
M	Many

CHARACTER OF POWDER:

G	Gritty
g	Slightly gritty

DEGREE OF FIRING SHRINKAGE:

Low	Low
Med	Medium
Hi	High

DEGREE OF BLOATING:

Sl	Slight
Se	Severe

- indicates absence of property
? indicates lack of data.

Figure 48.

DATA OBTAINED FROM CONE FUSION, P. C. E.								
Locality Number	P.C.E.	Color	Texture	Spots	Shrinkage	Bloating	Workability	Grittiness
Fransen								
1-A-1	32_2	S	Sa	?	Hi	-	P	g
1-A-2	32	EBe	Sa	F	Low	-	M	g
1-A-3	32_2-	LG	G	f	Low	-	N	G
1-B	-16	I	G	f	?	Se	M	g
I-C	32	Bz	D	?	Low	-	P	g
I-D	30	EBe	Sa	m	Med	-	P	G
1-E	30	LI	G	f	Low	-	W	G
1-F	31-	SO	D	f	Hi	-	M	g
1-G	29-30	SO	D	?	Hi	-	M	g
I-J	30-	Bl	D	?	Med	-	P	g
1-K	18-	I	G	m	Low	-	M	G
West								
2	-16	LG	G	-		Se	M	g
Willett & Rudolph								
3	-16	?	G	?	?	?	W	G
3-A	20-	LG	G	f	Low	-	W	g
3-B	-16	LG	G	f	Low	-	W	G
3-C	-16	LG	G	-		Se	W	G
Willamina								
5	-16	Bl	G	?	Med	-	M	-
Ellis								
6-A-1	34	T	Sa	F	Hi	-	S	-
6-A-2	31-	T	Sa	G	Med	-	SM	-
6-B	27	S	Sa	?	Low	-	M	-
Drill Holes								
6-D-24	29	Bl	Sa	?	Hi	-	M	g
6-D-25	30-	Bl	D	?	Med	-	P	-
6-D-26	33-	Bz	Sa	F	Hi	-	P	-
6-D-27	31	Bz	Sa	F	Med	-	P	g
6-D-28	17	Bz	Sa	M	Med	Sl	M	g
6-D-29	32	Bl	D	?	Hi	-	P	g
6-D-30	33	S	Sa	?	Hi	-	P	g
6-D-31	31-32	Bl	D	?	Hi	-	S	g
6-D-32	30	S	Sa	?	Med	-	P	g
6-D-33	28	S	Sa	F	Hi	-	S	g
6-D-34	28-	S	Sa	?	Med	Sl	S	g
6-D-35	20	Bl	Sa	?	Hi	-	S	g
6-D-36	15	Bl	G	?	Med	-	S	g
6-D-37	23	S	Sa	?	Med	Sl	S	g

Locality Number	P.C.E.	Color	Texture	Spots	Shrinkage	Bloating	Workability	Grittiness
6-D-38	23+	Bl	Sa	?	Hi	-	S	g
6-D-39	28-29	Bl	D	?	Hi	Sl	S	g
6-D-40	18-	Bl	Sa	?	Hi	Sl	S	g
6-D-41	18-	S	Sa	?	Med	Sl	S	g
6-D-42	33+	Bz	Sa	F	Hi	-	S	g
6-D-43	30	Bl	Sa	?	Hi	Sl	S	G
Molalla Reservoir								
7-A	32+	Bl	D	?	Hi	-	M	g
7-B	33	T	Sa	-	Med	-	S	g
Dibble								
8-A	33	EBe	Sa	F	Hi	-	S	-
8-B	23	CBr	Sa	?	Hi	-	S	G
Zahar								
Krammerer								
10	27+	Bz	Sa	?	Med	-	M	-
King's								
11	32$_2$	LD	D	M	Med	-	P	G
11-A	32$_2$	T	D	m	Med	-	S	G
11-B	-16	?	?	?	?	Se	W	G
11-D-8	32-	Bz	Sa	m	Med	-	P	G
11-D-9	27	Bl	Sa	?	Med	-	P	G
11-D-10	33-	EBe	Sa	F	Med	-	M	G
11-D-11	32	Bz	Sa	F	Hi	-	M	g
11-D-12	32	T	Sa	m			P	G
11-D-13	31+	Bz	Sa	m	Hi	-	M	G
11-D-14	19-20	Bl	Sa	?	Med	-	W	G
11-D-15	31-32	Bl	Sa	m	Med	-	W	G
11-D-16	29-30	Bl	Sa	?	Med	-	M	g
11-D-17	27	Bl	Sa	?	Med	-	S	g
North of King's								
12-A	28-	Bl	Sa	?	Low	-	W	G
12-B	20-	CBr	D	?	Med	Sl	W	G
12-D-1	27	Bl	Sa	?	Hi	-	W	G
12-D-2	27	Bl	Sa	?	Hi	-	W	g

Locality Number	P.C.E.	Color	Texture	Spots	Shrinkage	Bloating	Workability	Grittiness
Big Cut, South of King's								
13-1	30-31	T	Sa	m	Low	-	M	g
13-2	18	CBr	Sa	?	Low	Sl	W	G
13-3	-19	Bz	G	M	Med	-	W	G
13-4	16-	I	G	F	Med	-	W	G
13-5	-16	Bz	G	F	Hi	-	W	G
South of King's Hi grade								
14	34+	EBe	D	m	Hi	-	P	G
14-D-3	32	Bz	D	m	Hi	-	M	G
14-D-4	32-33	Bz	Sa	m	Hi	-	P	G
14-D-5	31+	Bz	Sa	m	Hi	-	M	G
14-D-6	30+	S	Sa	?	Med	-	M	G
14-D-7	32-	T	Sa	m			P	G
14-D-7½	31	Bz	Sa	F	Hi	-	S	G
W. of King's sta. 63								
15-A	30-	Bl	Sa	?	Med	-	M	-
15-B	-16	Bl	D	?	Med	-	M	
E. of King's sta. 63								
16	33-34	EBe	E	m	hi	-	M	g
E. of King's Big Cut								
17-A	29-30	Bz	Sa	F	Hi	-	W	-
17-B	28-29	Bl	Sa	?	Hi	-	P	g
17-C	30-	S	Sa	?	Low	-	S	g
Between Silver & Drift Creeks								
18-A	32-	S	Sa	?	Med	-	W	G
18-A-1	28	Bl	Sa	?	Hi	-	W	g
18-A-2	32_2	Bz	Sa	F	Med	-	W	g
18-A-3	34+	T	Sa	F	Hi	-	W	G
18-B	33-34	Bz	D	F	Hi	-	W	-
18-C	34	EBe	D	-	Hi	-	P	-
18-C-1	34-35	I	D	-	Hi	-	S	-
18-C-2	32+	T	Sa	-	Hi	-	M	-
Victor Point Road								
19	28-	Bz	G	?	Hi	-	W	G
19-1	30-31	T	Sa	F	Hi	-	M	-
19-2	28-29	T	G	m	Med	-	W	G

Locality Number	P.C.E.	Color	Texture	Spots	Shrinkage	Bloating	Workability	Grittiness
Victor Point Road								
20	31-32	I	Sa	-	Med		W	G
Victor Point Road								
21	19	T	G	M	Med	-	W	G
Victor Point Road								
22	27+	LD	G	m	Med	-	W	G
Victor Point Road								
23	30+	S	Sa	m	Med	-	P	G
Victor Point Road								
24	31+	EBe	Sa	m	Low	-	P	G
Victor Point Road								
25	27+	S	G	F	Low	-	M	G
25-1	32+	I	Sa	F	Med	-	P	G
25-2	23	S	G	F	Low	-	W	G
Sublimity, N. of								
26	30	Bz	Sa	M	Med	-	P	G
Macleay								
27-A	33	Bl	D	?	Med	-	M	-
27-B	28-	Bl	Sa	?	Med	-	S	G
27-B-1	23	S	Sa	?	Med	-	S	G
27-B-2	30+	SO	D	?	Hi	-	P	-
27-C	26	S	Sa	?	Med	-	W	g
27-D	27-28	Bl	Sa	?	Med	-	W	g
Bystrom								
29	31	I	Sa	F	Low	-	P	G
Eugene Fire Clay								
31-A	28	I	G	m	Med	-	M	G
31-B	28	LI	G	-	Med	-	M	G
31-C	30-	W	G	-	Low	-	M	G

Locality Number	P.C.E.	Color	Texture	Spots	Shrinkage	Bloating	Workability	Grittiness
Hobart Butte								
35-H-1	32_2	PB	D	m	Low	-	W	g
35-H-2	33-34	PBe	D	M	Low	-	W	G
35-H-3	33	PB	D	m	Low	-	W	G
35-H-4	32_2	PB	Sa	F	Low	-	W	G
35-I-1	32	Wb	D	F	Med	-	M	g
35-I-2	31-32	PB	Sa	m	Low	-	M	G
35-J	30+	Wb	Sa	m	Med	-	M	g
35-A-1	-16	?	G	?	?	?	N	G
35-A-2	31	Bz	Sa	M	Low	-	M	G
35-B	27-28	Wb	G	m	Hi	-	W	G
35-C-1	32_2	PB	D	F	Med	-	W	g
35-C-2	33+	PB	D	F	Med	-	M	g
35-D	31+	RBe	D	M	Med	-	M	g
35-E	29+	RBe	Sa	M	Low	-	M	g
35-F-1	32	PB	D	M	Low	-	M	G
35-F-2	34+	WB	D	-	Low	-	W	G
35-G	32_2^+	Wb	D	f	Med	-	W	-
Black Butte								
36-A	31-	EBe	Sa	M	Med	-	W	G
36-B	-16	Br	G	F	-	Sl	M	G
36-C	16	Br	G	?	Low	-	W	G
36-D-2	34+	I	D	F	Med	-	P	g
36-D-3	32	I	Sa	F	Low	-	P	G
36-D-4	-16	?	?	?	?	?	P	-
36-D-5	-16	?	?	?	?	?	P	
36-E-1	-16	Br	?	?	?	Se	W	G
36-E-2	-16	Br	?	?	?	?	W	G
36-E-3	18-	CBr	Sa	?	Med	-	P	-
36-E-4	28	Wb	G	F	?	-	N	G
36-F-2	33	EBe	D	f	Med	-	P	-
36-F-3	32-	I	G	f	Hi	-	P	g
36-G	16	Br	G	?	Low	-	N	G
36-H-2	34+	EBe	Sa	m	Med	-	M	?
36-H-3	32+	I	Sa	F	Med	-	P	-
36-H-4	27-28	CBr	Sa	?	Med	-	W	G
36-H-5	27-28	CBr	Sa	?	Med	-	W	G
Elkhead								
37	23-	EBe	G	M	Low	-	W	g
Gaines								
38-A	27+	I	G	F	Low	Sl	S	G
38-B	-16	?	?	?	?	Se	S	G
Rogers', Tiller-Trail								
39-1	28	LI	G	F	Low	-	M	G
39-2	29+	LI	G	F	Low	-	M	G

Locality Number	P.C.E.	Color	Texture	Spots	Shrinkage	Bloating	Workability	Grittiness
Rogers', Poole								
40-1	16+	Bl	G	?	?	-	W	g
40-2	-16	?	?	?	?	?	W	g
40-3	33-	Wb	G	F	Med	-	N	G
Medford								
42	16-	Br	G	?		Sl	P	-
Hurst, Grants Pass								
43	16-	Bz	G	Med	Med	Sl	M	G
Dead Indian								
44	31+	LGT	G	M	Med	-	N	G
Dead Indian								
45-1	31	LG	G	f	Med	-	N	G
45-2	26-27	LGT	G	m	Low	-	N	G
45-3	23	LI	G	-	Med	-	N	G
45-4	-16	Br	G	?	Med	-	N	G
45-5	16-	Br	G	?	Med	-	N	G
45-6	26	LI	G	m	Med	-	W	G
45-7	16	Br	?	?	?	?	N	G
Dead Indian								
46-1	19-20	LI	G	f	Low	Sl	M	G
46-2	-16	Bl	G	?		Sl	M	G
46-3	-16	Bl	G	?		Sl	M	G

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*V. 1, #1 What is the Matter with the Mining Industry: A. M. Swartley; The Occurrence of Coal in Squaw Creek Basin; I. A. Williams; Something Ever New in Coal Annals; I. A. Williams.
*V. 1, #2 Essential to Oregon's Development: H. N. Lawrie; Preliminary Report on Building Stone in Oregon: H. M. Parks.
*V. 1, #3 Geology and Mineral Resources of the John Day Region: Arthur J. Collier.
*V. 1, #4 Drainage of Farm Lands in the Willamette and Tributary Valleys: I. A. Williams.
*V. 1, #5 Petrology and Mineral Resources of Jackson and Josephine Counties: A. N. Winchell.
*V. 1, #6 Geology and Mineral Resources of Sumpter Quadrangle: J. F. Pardee and D. F. Hewett; Preliminary Report on the General and Economic Geology of the Baker District of Eastern Oregon: U. S. Grant and G. H. Cady.
*V. 1, #7 Construction and use of Relief Map: S. Shedd; Tests of Building Brick, Hollow Blocks, and Drain Tile: I. A. Williams.
V. 1, #8 Ore Deposits of Northeastern Oregon: A. M. Swartley, 229 pp., 97 illus. incl. maps, Dec. 1914 . . . . $0.50
*V. 2, #1 Some Little Known Scenic Pleasure Places in the Cascade Range of Oregon: I. A. Williams.
*V. 2, #2 Preliminary Survey of the Geology and Mineral Resources of Curry County, Oregon: G. M. Butler and G. J. Mitchell.
*V. 2, #3 The Columbia River Gorge: Its Geologic History Interpreted from the Columbia River Highway: I. A. Williams.
*V. 2, #4 Handbook of the Mining Industry of Oregon: H. M. Parks and A.M.Swartley.
*V. 3, #1 Oil and Gas Possibilities of Western Oregon: Harrison and Eaton.
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*The Nitrate Deposits of Southeastern Oregon: Ira A. Williams, (typescript) May 1918

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Sampling of Small Prospects and New Discoveries: (typescript) 6 pp., 1937 $0.06
Monthly Press Bulletin, issued the 8th of each month . . . . free
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Bull. #2 Progress Report on Coos Bay Coal Field: F. W. Libbey, 14 pp., 3 maps, 2 illus. (typescript) 1938 . . . . $0.10
Bull. #3 The Geology of Part of the Wallowa Mountains: C. P. Ross, in cooperation with U. S. Geol.Survey, 74 pp., 6 pls., 2 figs., 1928 . $0.50
Bull. #4 Quicksilver in Oregon: C. N. Schuette, 1938. . . . . $1.15
Bull. #5 Geological Report of a part of the Clarno Basin, Wheeler and Wasco Counties: Donald K. Mackay, (typescript) 1938. . . . . . . $0.25

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Bull. #6	A Preliminary Report on Some of the Refractory Clays of Western Oregon: Hewitt Wilson and Ray C. Treasher, in coop. with U. S. Bureau of Mines and the Univ. of Wash. (typescript)	$0.45
Bull. #7	The Gem Minerals of Oregon: Dr. H. C. Dake (typescript)	$0.10
Bull. #8	Feasibility of a Steel Plant in Columbia River Area near Portland, Oregon: R. M. Miller (typescript), available about July 15th.	
Bull. #9	Chromite Deposits in Oregon: John Eliot Allen (typescript), available about Aug. 1st.	