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FIGS. 1–3, APRIL, 1945

CLAY-PELLET CONGLOMERATES AT HOBART BUTTE, LANE COUNTY, OREGON[1]

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ABSTRACT

Ovate pellets of kaolinite from .05 to 15 millimeters in length occur in conglomerates interbedded with pyroclastic materials and waterlaid sediments in the Eocene Calapooya formation at Hobart Butte, Oregon. Although Miocene hydrothermal solutions invaded these rocks, altered welded tuffs to clay, and deposited kaolin minerals together with realgar, stibnite, pyrite, quartz, and other minerals, a hydrothermal or a volcanic origin for the pellets is considered unlikely. The sizes and shapes of the pellets, the presence of pellets and lithic fragments within pellets, the lack of radial and concentric structures, the presence of charcoal, lignitic material, and diatoms in the matrix suggest fluvial deposition of clay flakes, broken from thin clay layers that had dried on Eocene flood plains. The arrangement of the long axes of the pellets parallel to the bedding and the molding of pellets against quartz, lithic fragments, and pellets support the interpretation of a sedimentary origin for the pellets and the clays containing them.

INTRODUCTION

Hobart Butte is in Lane and Douglas Counties, Oregon, approximately 14 miles south of Cottage Grove and about 1 mile from the town of London. During 1943 Hobart Butte was prospected as a source of high-alumina clay by the United States Bureau of Mines in cooperation with the United States Geological Survey. The diamond drilling showed it to be one of the best high-alumina clay deposits in the Northwest. More than 10 million tons of ore with approximately 29 per cent available Al_2O_3 were proved.

The rocks of Hobart Butte are composed of pyroclastic materials and high-alumina water-laid sediments belonging to the Calapooya formation of Eocene age (Wells and Waters, 1934). These rocks were invaded by hydrothermal solutions, probably in late Miocene time (Wells and Waters, 1934, p. 25; Callaghan and Buddington, 1938), and realgar, stibnite, arsenates, pyrite, quartz, dickite, and other minerals were deposited.

Wilson and Treasher (1938, p. 18), as well as others, were impressed with the presence of the hydrothermal minerals and concluded that the kaolinite was also of hydrothermal origin. The presence of dickite and of welded tuffs which are now altered to high-alumina rocks indicates that some of the clay did result from hydrothermal activity. One of the most interesting and abundant rock types on the Butte contains ovate clay-pellets. Because these present significant evidence of the genesis of much of the high-alumina clay of Hobart Butte, they will be described and various theories for their origin will be considered.

DESCRIPTION OF PELLETS

Clay-pellet rocks are well exposed at Hobart Butte. They have been briefly described by Wilson and Treasher (1938, pp. 71 and 73), who called the pellets "white bodies" and white "oolites." These pellets are, in general, irregular spheroids with elliptical cross-sections. The long axes are parallel to the bedding and they range in length from 15 millimeters to less than .05 millimeter (fig. 1). Based on the measurement of 47 pellets, the average ratio of the long axes to the

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[1] Published by permission of the Director, Geological Survey, United States Department of the Interior.

morillonite could not be definitely established as a minor constituent of the Hobart Butte clay by either optical or chemical methods. According to the determinations of J. M. Axelrod of the Geological Survey kaolinite is the only clay mineral recorded in the X-ray patterns of ground samples representing both the pellets and the matrix. Also, the X-ray determinations reveal that the red color of the matrix surrounding the white pellets is caused by hematite in some samples and goethite in others. X-ray diffraction lines representing quartz are present in the patterns of nearly all the Hobart Butte clays examined. On the basis of thermal analyses Dr. Joseph A. Pask of the Federal Bureau of Mines finds that the pellets are kaolinite and in general are purer than the matrix.

The best place to see these pellets is in the main part of the quarry, about half way up the face (fig. 2). Here there is a 10 foot layer of rock in which they are abundant. Clay-pellet rocks occur elsewhere on the Butte and they are important constituents of the diamond drill cores.

ORIGIN OF PELLETS

Before it was established that organic material forms an essential part of the matrix surrounding the pellets, many theories of origin for these structures were proposed or considered by geologists who had visited Hobart Butte. The presence of organic matter in the matrix is regarded by the writers as convincing evidence for the rejection of all theories except those involving sedimentation. However, to avoid repetition only those arguments based on other evidence than the presence of organic matter will be briefly stated in reviewing the theories which follow.

It has been suggested that the rock in which the pellets are found was originally vesicular, that the clay pellets are filled vesicular cavities, and that the high kaolinitic composition is due to hydrothermal alteration (Wilson and Treasher, 1938, p. 73). It is unlikely, however, that this is an altered amygdaloidal rock because: 1. No relict igneous textures are present in the matrix. 2. There is no concentration of pellets at the top of the clay-pellet horizon such as would be expected if these were amygdules in an uneroded flow. 3. There is no disconformity at the top, which would be expected if the clay-pellet rock were an eroded lava flow. 4. The pellets are too regular and simple in shape.

The pellets are not hydrothermally altered spherulites, formed in lava or incorporated in a spherulitic tuff under some specially controlled conditions of crystallization and eruption, for the following reasons: 1. No relict spherulitic texture is apparent in the pellets. 2. No relict igneous textures can be seen in the matrix. 3. The presence of pellets and lithic fragments within pellets is left unexplained.

It has been suggested that the pellets are feldspar crystals altered by hydrothermal activity. This necessitates that the clay-pellet rock is either an altered porphyry, an altered crystal tuff, an altered reworked crystal tuff, or an altered arkose. The presence of pellets and lithic fragments within pellets, as well as the thickness of the clay-pellet rock, and the lack of relict igneous textures in the matrix all indicate that the rock is not an uneroded porphyry. Some modification in the shapes of phenocrysts might result from hydrothermal alteration, but it is unlikely that shapes similar to those of the pellets would be produced. Likewise, the shape and molding of the pellets and the presence of pellets and lithic fragments within pellets, exclude the derivation of the clay-pellet rock directly by alteration of a crystal tuff, a reworked crystal tuff or arkose. Moreover according to Harker (Harker, 1935) the long axes of some crystals in a crytal tuff may be roughly perpendicular to the bedding. The long axes of the pellets are parallel to the bedding, which is further evidence that the rock is not an altered crystal tuff.

The Hobart Butte pellets might be ac-

FIG. 2.—Hobart Butte quarry, Oregon. Bedding in the clay is shown at the left center, where pellets are abundant.

cretionary lapilli (volcanic pisolites) that have been hydrothermally altered to kaolinite (Wentworth and Williams, 1932). Accretionary lapilli have been found around active volcanoes; they have been described from the Triassic of New Zealand (Perret, 1924, 1913; Pratt, 1916; Richards and Bryan, 1927); and they have many characteristics that are similar to those of the pellets. Pellets within pellets, lithic fragments within pellets, the shape and orientation, the molding of pellets against pellets, and many other features could be explained if they were formed in this way. The general geologic setting seems favorable for such an origin because welded tuffs have been found stratigraphically only a few hundred feet above the clay-pellet rock and the Calapooya formation, in general, contains much volcanic material (Wells and Waters, 1934). It is thought, however, that the Hobart pellets were not formed in this way because the relict textures that might be expected in the matrix and within the pellets according to such a theory, are not present; furthermore, the Hobart pellets are not concentrically layered as are accretionary lapilli.

The shapes of these pellets of course eliminate the possibility that they are hydrothermally altered stream pebbles or lapilli.

Faecal pellets found in modern marine sediments have been illustrated and discussed by Moore (Moore, 1939) and they have been found in California oil shales of Miocene age (Galliher, 1932). Some of those illustrated by Moore (Moore, 1939, p. 520) are identical in shape with some of the pellets found at Hobart Butte. The pellets at Hobart Butte, however, are not faecal pellets as they are much too large, they are in continental rather than marine rocks, and they vary too much in shape and size.

The pellets under discussion are not syngenetic concretions formed by colloidal deposition because: 1. A study of the red beds on the Butte and elsewhere in the district indicates that the red color is original and is not the result of hydrothermal activity, which tends to remove ferric iron rather than to deposit it; as a matter of fact the hydrothermal solutions have in places bleached some of the red beds. If, therefore, the white pellets in the rock with the red matrix were formed by colloidal deposition, they should be red rather than white. 2. Pellets and lithic fragments within pellets, on the hypothesis of colloidal deposition, could be explained if the growing concretion is rotated. Conditions that would favor rotation, however, would be unfavorable for colloidal deposition. 3. The subangular outline of some of the pellets is not in harmony with the shapes resulting from settling from colloidal suspension. 4. In a discussion on mud pebbles Twenhofel (1939) states, "They are rarely, if ever, due to the union of suspended particles of mud."

The pellets are not epigenetic concretions formed after the deposition of the enclosed rock by substances derived from within or outside of the rock. It has been noted that the pellets and the matrix are both composed of kaolinite, but the pellets are purer and lighter in color than the matrix. If substances were removed from the pellets to increase the purity of the kaolinite comprising them, the permeability of the pellets should have increased in proportion to the amount of impurities removed. The effect of this action was slight, as the pellets are less permeable than the matrix. Moreover, since kaolinite has low solubility in ground water and since the deposition of any substance except kaolinite within the pellets to cause a contrast in color would decrease the purity of the pellets as compared with that of the matrix, the possibility of the formation of the pellets as a concretionary process by ground water action is remote.

The writers' interpretation is that these rocks were formed by processes of sedimentation similar to those described by Allen (1932), Fenton (1937) and others, for intraformational conglomerates, mud-conglomerates, mud-cake conglomerates, desiccation conglomerates, and flat-pebble conglomerates. The pellets are of intraformational origin and because most of them are small and round the name clay-pellet conglomerate or clay-pellet shale, depending upon the abundance of pellets, seems appropriate. They were probably formed somewhat as follows: Thin layers of clay were laid down on flood plains, the clay was dried out, and later the clay flakes, formed by the drying, were broken, picked up, and transported to their present position by running water. During transportation they were rounded by molding, sloughing, attrition, and perhaps also by accretion so that fragments of considerable initial angularity were changed into well rounded pellets. Finally the pellets were deposited together with clay, charcoal, organic material, and a small percentage of lithic and mineral fragments. That the pellets, in general, only slightly resemble the initial flakes indicates the effectiveness of these processes. Mud-flake breccias were seen in the drill cores and here the rounding processes were not so effective.

Some of the clay deposited at Hobart Butte apparently had a strong tendency to break up in water or crack in air on drying and yield ovate fragments which would require little or no modification during transportation to duplicate the shapes of the pellets. In the gray clays at the bottom of the quarry are many white kaolinite fragments that are separated from each other by clay containing organic matter and slightly more iron than that present in the white fragments. Many of these rudely ovate fragments fit together perfectly (fig. 3c) and suggest that they were broken apart in water and that fine clay with organic matter and appreciable iron washed into the cracks. It is conceivable that similar spalling

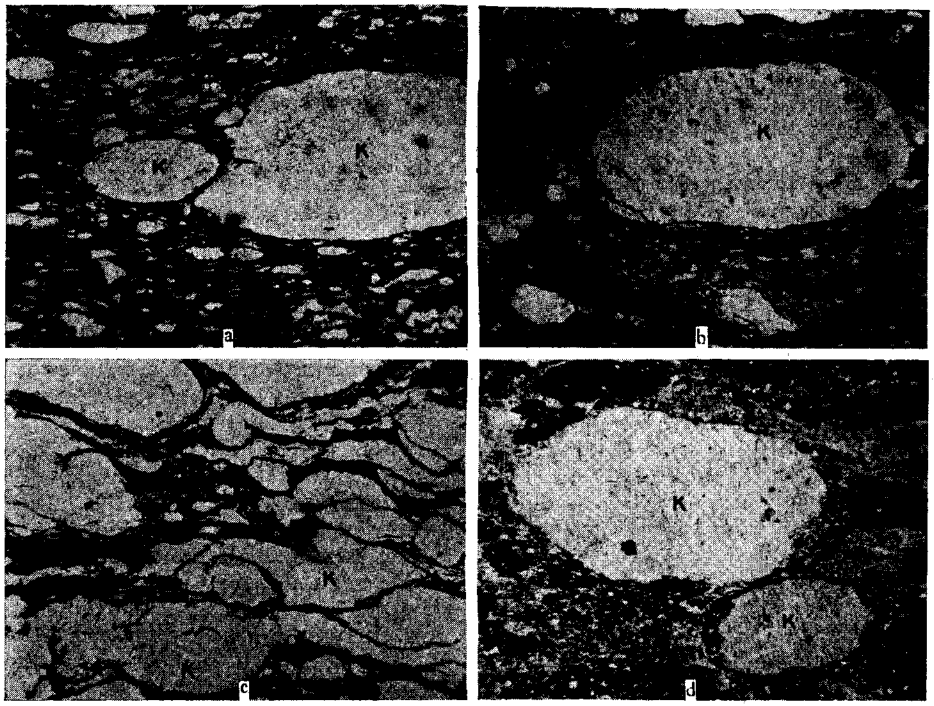

FIG. 3.—Photomicrographs of pellet structure in clay.

a—Kaolinite pellets (K) surrounded by clay and organic matter, Hobart Butte Quarry, Oregon. ×90.

b—Kaolinite pellets (K) surrounded by clay and organic material in a fire clay of the Pennsylvanian period. Fulton, Missouri. ×90.

c—White kaolinite fragments (K) with clay containing organic matter and appreciable iron filling cracks (C). Pellet shaped fragments have resulted from the breaking up of larger chips. Some fragments show evidence of molding around fragments to fit the space available. Hobart Butte Quarry, Oregon. ×90.

d—Kaolinite pellets (K) surrounded by clay and organic matter, Castle Rock, Washington. ×90.

took place on the Eocene flood plains of the Hobart Butte area, and furnished at the source many separated fragments of the required sizes and shapes to produce a clay-pellet conglomerate when they were deposited.

The flattened shape of the pellets may have been inherited from the clay flakes or may be due to the weight of the overlying sediments. The fact that almost all of the pellets are parallel to the bedding suggests that some pressure was involved. If the flattening were entirely inherited from the original flakes one would expect that a few of the pellets would be deposited edgewise. The range in the ratio of the long to the short axes of the pellets also suggests that pressure was effective in flattening the pellets. Pressure increased with the weight of the accumulating sediments, and rapid deposition permitted the molding of the pellets while they remained somewhat plastic.

While the molding of pellets affords ample evidence of their deposition as a clay with some plasticity, the question might well be asked if the clay had the composition of kaolinite when it was deposited or whether it was composed of another clay mineral which was later changed to kaolinite. On the southwest side of Hobart Butte about 200 feet below the summit kaolinite occurs as books in a leaf-bearing shale. This is the characteristic habit of kaolinite and suggests that a supply of kaolinite was available in the region during the deposition of the Calapooya formation. Fragments of pumice and welded tuffs now white kaolinite retaining original structures are enclosed in a red or purple iron-stained kaolinitic matrix at various levels throughout the Hobart Butte area. The alteration of volcanic glass to kaolinite must have been completed at the time of deposition because the alteration of the fragments to kaolinite could not have taken place after their deposition without bleaching ferric iron from the surrounding matrix. Finally, the lack of remnants of another clay mineral besides kaolinite in the pellets completes the reasons for concluding that the pellets had the composition of kaolinite when they were deposited.

The pellets containing lithic fragments may have been formed by the accretion of clay around these fragments or by having the lithic fragments included in the original clay flakes. Pellets within pellets may also have been formed by either of these mechanisms. That accretion was not the dominant process is suggested by: 1, the angularity of many of the pellets; 2, the lack of concentric layers; 3, the presence of white pellets surrounded by a red matrix; 4, the erosion of small pellets at the borders of large pellets; and 5, the presence of clay pellets in angular mud flakes. However, the one pellet that has a concentric structure may have grown by accretion.

Somewhat similar high-alumina clay-pellet rocks of sedimentary origin are found at widely separated localities—for example, in the Pennsylvanian rocks of the Eastern Coal fields, the Cretaceous and Eocene rocks of the Atlantic and Gulf Coasts, and the Cretaceous rocks of Colorado. At Castle Rock, Washington, they are interbedded in rocks of about the same age as those at Hobart Butte and in an area where there has been no hydrothermal activity. This fact, together with the fine-grained texture and kaolinitic composition of the pellets and matrix plus the lack of remnants of another clay mineral and the somewhat plastic condition of the pellets at the time of formation, indicates that the high-alumina content was original. This in turn suggests that a weathering profile was formed in this part of the Pacific Northwest, possibly sometime in the Eocene, that kaolinite was formed in the profile, and that it was concentrated into thin beds by selective erosion and deposition. This profile, like the source material of the widespread underclays of the Pennsylvanian series in Eastern North America, has not as yet been located with certainty. However, the presence of white pellets in a red matrix implies that the profile furnishing the Hobart Butte clays was in part high in iron and thus red and in part low in iron and probably nearly white.

SIGNIFICANCE

The initial kaolinitic composition of the pellets indicates that the matrix containing some plant materials or red iron oxides was also kaolinitic when it was deposited. The widespread distribution of these rocks testifies to the sedimentary origin of much of the clay on Hobart Butte. Later hydrothermal solutions altered non-kaolinitic to kaolinitic rocks thus increasing the tonnage of high-alumina material.

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HOBART BUTTE CLAY

Hobart Butte Clay

STATE DEPARTMENT OF GEOLOGY
AND MINERAL INDUSTRIES
702 WOODLARK BUILDING
PORTLAND 5, OREGON

General Laboratory Number P 3609 Date received May 19 1945

Spectrographic Laboratory Number 1217 Sample received from F. W. Libbey

QUALITATIVE SPECTROGRAPHIC ANALYSIS
(Quantities estimated to nearest power of ten)

1. Elements present in concentrations over 10%.

   Silicon, aluminum

2. Elements present in concentrations 10% - 1%.

   Titanium, strontium, sulphur

3. Elements present in concentrations 1% - 0.1%.

   Iron, calcium, barium

4. Elements present in concentrations 0.1% - .01%.

   Zirconium, chromium, vanadium, lithium, boron

5. Elements present in concentrations .01% - .001%.

   Magnesium, manganese

6. Elements present in concentrations below .001%.

~~Dr. H. S. Harrison, Spectroscopist~~

E. W. Miller

HOBART BUTTE HIGH-ALUMINA CLAY Lane County

Owners: Mineral claims held by O.K. Edwards, et al, c/o Willamina Clay Products Co., Willamina Oregon; now leased to Columbia Metals Corporation, Securities Building, Seattle, Washington.

Location: Hobart Butte is about 15 miles south of Cottage Grove, Oregon, and lies in the four sections around the corner of T. 22-23 S., R. 3-4 W. The portion of the property which has undergone developement, and includes the largest amount of the ore lies in sec. 31, T. 22 S., R. 3 W. The quarry is within 150 feet of the top of the butte, at an elevation of 2350 feet. It is reached by 16 miles of road from Cottage Grove.

History: According to Wilson and Treasher (38:69-71) the deposit was discovered in 1930 by Roberts Phillips, while prospecting for cinnebar. It was leased in 1933 by the Willamina Clay Products Company, who later purchased the land in section31. A road was completed to the mine, and 12,000 to 15,000 tons were mined and shipped to the ceramics plant at Willamina. In September, 1942, the Columbia Metals Corporation secured a lease on the property, with the object of using this clay for a source of alumina.

<u>Topography:</u> Hobart Butte rises more than 1500 feet from the valley of the Coast Fork of the Willamette River to an elevation of 2459 feet. It is elongated in a northeast-southwest direction, the crest ridge being about one half mile long. The sides are steep with 30° slopes. The quarry lies near the northeast end of the crest, on the southeast slope.

<u>Developement:</u> In the fall of 1933 a road was built part way to the quarry and clay mining was begun, the clay being dropped 885 feet by chute. In 1936 the road was completed to the quarry and by 1942 nearly 15,000 tons had been mined. During 1943 the U.S. Bureau of Mines drilled 24 diamond drill holes totalling 6896 feet, ~~which delimited 2 ore bodies, the first of which contains~~ ~~a total of~~ ~~10,700,000 tons of dry ore with~~ ~~the second~~ ~~a grade of 29.[illegible]% available Al_2O_3; and 6,500,000 tons of dry~~ ~~and 3% available Fe_2O_3. The maximum~~ ~~ore with an average grade of 29.3% Al_2O_3. Two other ore~~ ~~ratio of overburden to ore is 1 to 1; and there is~~ ~~bodies add substantially to the tonnage but are lower in gr~~ade. ~~6,500,000 tons of ore with no overburden.~~

<u>Geology:</u> The regional geology was sketched by Wells and Waters (34:26-28,34) who mapped (plate 7) the extent of the Eocene Umpqua marine sandstones and conglomerates with the underlying Eocene basalts; and the unconformably overlying Calapooya formation, consisting of a lower dominantly sedimentary facies and an upper, dominantly igneous facies. They also outlined the areas of altered rocks, which include Hobart Butte as well as the mineralized areas at the Elkhead and Black Butte Quicksilver mines. They report that Hobart Butte belongs to the lower sedimentary facies ~~volcanic conglomerate phase~~ of the Calapooya formation. According to Loofbourow (43:5), from whom a large

portion of this report is abstracted, these sedimentary rocks attain a thickness of at least 3500 feet in Hobart Butte, with the top not exposed. They are composed primarily of volcanic breccias, tuffs, conglomerates, lava flows, and mud flows, which do not vary greatly in composition but are strikingly dissimilar in appearance. East of the butte lavas predominate, to the west tuffs predominate. Wood and charcoal are common, and leaves date the formation as upper Eocene.

Ore deposits: The clays have been described in detail by Wilson and Treasher (38:71-72) and Loufbourow (43:6-11), and their account will only be summarized here.

The high alumina clay at Hobart Butte is non-plastic and homogeneous. It occupies fairly well defined horizons in the continental sedimentary series of volcanic origin, generally parallelwith the bedding. ~~Apparently~~ Hobart Butte appears to be ~~is~~ a gentle syncline pitching at a low angle to the northeast, ~~which [illegible]~~ broken by a northwest-trending fault. The altered rocks are~~xxxxx~~ mainly gray, in some places leached white. Red and reddish purple beds are common. Surface alteration changes the gray beds to a yellowish tint but does not affect the red beds. High grade material is characterized by a smooth conchoidal fracture, low grade breaks with an irregular rough surface. The lustre is porcellaneous, and although there are some areas of hard material, most of the clay can be easily scratched with a knife, often by the fingernail. ~~Mixxxxx~~ The only clay mineral is kaolinite, but there are several associated minerals in small amount, which may be listed as follows:

Realgar
orpiment
stibnite
pyrite
arsenopyrite
siderite
calcite
limonite
scorodite

The ore reserves as determined by the U.S. Bureau of Mines drilling in 1943 total 10,700,000 tons of dry ore, with a grade of 29% available Al_2O3 and 3% available Fe_2O_3. The maximum ratio of overburden to ore is 1 to 1, and there is 6,500,000 tons of ore with no overburden. The moisture content is 3%.

References: Loofbourow, 43
Wilson and Treasher, 38
U.S.Bureau of Mines War Minerals Report No. 175, 1943.
Nichols, 42
Wells and Waters, 34

CLAY FILE

CLAY FILE

R. I. 4449

MAY 1949

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
JAMES BOYD, DIRECTOR

REPORT OF INVESTIGATIONS

PRELIMINARY CERAMIC TESTS OF CLAYS FROM SEVEN PACIFIC NORTHWEST DEPOSITS

This paper presents the results of work done under a cooperative agreement between the Bureau of Mines, United States Department of the Interior, and the College of Mines, University of Washington

BY

KENNETH G. SKINNER AND HAL J. KELLY

R. I. 4449,
May 1949.

REPORT OF INVESTIGATIONS

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

PRELIMINARY CERAMIC TESTS OF CLAYS FROM SEVEN PACIFIC NORTHWEST DEPOSITS[1]

By Kenneth G. Skinner[2] and Hal J. Kelly[3]

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[1] Work on manuscript completed September 16, 1948. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Report of Investigations 4449."

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INTRODUCTION

Purpose of Investigation

The rapid growth of the metallurgical, chemical, and allied industries on the Pacific coast just prior to and during the war caused a sudden increase in the demand for refractories, which was the immediate cause of a revival in interest in refractory clays available on the Pacific coast, particularly in the Pacific Northwest. Population increases and shortage of shipping facilities caused an increase in the amount of various ceramic materials and products used and produced on the Pacific coast, with accompanying demand for information regarding sources of clay.

In an effort to supply part of this information, the Bureau of Mines, in cooperation with the College of Mines, University of Washington, started a program in 1944 to test the refractory and other properties of clays from seven Pacific Northwest deposits that had been drilled and sampled as part of the Bureau of Mines alumina-from-clay investigation. Figure 1 shows the location of these deposits.

By no means were all of the samples collected in the exploratory drilling campaign tested for their ceramic properties; instead, certain samples were selected on the basis of their available alumina and iron contents and on the basis of the location of the drill hole.

The results given in this report are based upon cone-fusion (pyrometric cone-equivalent) tests, plasticity tests, and preliminary firing tests at cone 04 (about 1,055° C.) and at cone 4 (about 1,175° C.).

A description of the drilling methods, general geology, and probable reserves of the Cowlitz, Wash., Molalla, Oreg., Hobart Butte, Oreg., and Olson, Idaho, deposits may be found in Wimmler's[4] report. His report is based upon

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[4] Wimmler, Norman L., Iverson, H. G., Lorain, S. H., Oscarson, P. E., and Ricker, S., Exploration of Five Western Clay Deposits: Am. Inst. Min. and Met. Eng. Tech. Paper 1739, 1944, 10 pp.

data as of November 1, 1943, and may be subject to some changes owing to subsequent information.

Acknowledgments

The writers wish to acknowledge the assistance of H. F. Yancey, supervising engineer, Northwest Experiment Station, Bureau of Mines, for supervision, suggestions, and corrections; Milnor Roberts, dean, College of Mines, University of Washington, for continued cooperative support; Norman L. Wimmler, mining engineer, Bureau of Mines, for aid in selecting and obtaining samples and field data; various project engineers, Mining Branch, Bureau of Mines, for samples and field data; Robert W. Fatzinger, associate metallurgical engineer, Bureau of Mines, for plasticity tests; and to the analytical laboratories of the Northwest Experiment Station and the Intermountain Experiment Station, Bureau of Mines, for chemical analyses.

TESTS

Test Methods

Ignition Loss, Available Al_2O_3, Available Fe_2O_3

Because of the enormous number of clay samples collected during the course of the alumina-from-clay investigation, some 12,000 were analyzed at the Northwest Experiment Station at Seattle, and it was necessary to use a rapid analytical procedure to evaluate them. As is well known, the calcination of clay, usually in the range between 600° and 800° C., renders the alumina present in the clay soluble in acid solutions. The following rapid analytical procedure was used for determining "available" alumina and iron oxides.

The samples to be tested were crushed to pass 4 mesh, reduced in quantity by riffling, ground to pass 100 mesh, and dried overnight at 130° C. Two 1/2-gram portions of each sample were calcined for 1 hour at 700° C., and the loss in weight was reported as ignition loss. A calcination temperature of 700° C. was chosen after considerable experimentation with its effect upon the solubilities of the various clay minerals.[5]

The soluble oxides in the calcined samples were extracted by boiling for 1 hour in 35 ml. of 20-percent solution (by weight) of H_2SO_4. Hot water was added as needed to maintain a constant volume. After the boiling period, the residue was filtered off and discarded. Ten ml. of 1:1 H_2SO_4 was added to the filtrate, and it was then evaporated to fumes, cooled, water added, and filtered. This second residue represented soluble SiO_2, which ranged from 0.5 to 2 percent. The silica-free filtrate from one of the 0.5-gram portions was used to determine the total acid-soluble R_2O_3, and the filtrate from the other portion was used for available Fe_2O_3. The difference between

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[5] Pask, J. A., and Davies, B., Acid Extraction of Alumina from and Thermal Analysis of Clays: Bureau of Mines Rept. of Investigations 3737, 1943, 28 pp.
Speil, Sidney, Berkelhamer, Louis H., Pask, Joseph A., and Davies, Ben, Differential Thermal Analysis; Its Application to Clays and Other Aluminous Minerals: Bureau of Mines Tech. Paper 664, 1945, pp. 68-71, 75.

he two determinations was reported as available Al_2O_3, although this would nclude some TiO_2 (usually less than 0.2 percent). If the samples contained ppreciable total TiO_2, corrections were made for the acid-soluble TiO_2 eported with the available alumina.

Comparison between total and available analyses. - The rapid analytical ethod was supplemented by standard analyses of certain key samples. Such ey samples included composites made up in the laboratory by mixing samples eighted according to the footages in a given drill hole for hole composites. rea and horizon samples were prepared in the same manner, with corrections or the "area of influence" for each hole. Total analyses were made for these omposites and reported by Wimmler.[6]

On the basis of the total and available analyses, the following relationhips were found, as observed in part by Pask:[7]

1. With minerals of the kaolinite group, except dickite, the available Al_2O_3 was 95 to 100 percent of the total Al_2O_3; for dickite it was about 65 percent.

2. With montmorillonite, the extraction was about 30 percent.

3. With beidellite, the extraction was about 90 percent.

4. With boshmite and gibbsite, the extraction was about 60 percent.

5. The available Fe_2O_3 represented about 70 percent of the total Fe_2O_3.

6. The available TiO_2 represented not more than 10 percent of the total TiO_2; therefore, it was included with the available Al_2O_3 for most clays.

The data in table 1 from Pask[8] shows the relationship between the available Al_2O_3, total Al_2O_3, and the percentage extraction of the total alumina r some selected Pacific Northwest clay samples. The clay minerals present, indicated by thermal analyses, also are given.

Work cited in footnote 4.
Work cited in footnote 5, second reference pp. 66-71.
Work cited in footnote 5, second reference, p. 75.

TABLE 1. - Results of extraction of alumina from selected Pacific Northwest clay samples with sulfuric acid after calcination at 800° C.

Deposit	Mineral composition		Total Al_2O_3	Available Al_2O_3	Extraction, percent
	Principal	Minor			
Cowlitz.....	Kaolinite-montmorillonite1/	Gibbsite	38.9	34.6	89
Do.	Halloysite................	-	37.3	36.9	99
Do.	Kaolinite.................	Gibbsite	42.3	39.1	92
Do.	Beidellitelike............	-	32.1	23.1	72
Hobart Butte	Kaolinite.................	Dickite (?)	39.1	34.0	87
Do.	do.	do.	42.7	35.9	84
Molalla.....	Montmorillonite...........	Illite	22.5	5.0	22
Do.	Kaolinite-montmorillonite1/	Gibbsite	38.2	33.3	87
Do.	Beidellitelike............		30.1	25.3	84

1/ This notation indicates a small amount of montmorillonite intergrowth.

Relationship between ratio of available oxides of aluminum and iron to P.C.E. - The possibility of estimating the approximate P.C.E. of any sample on the basis of its available alumina-to-ferric oxide ratio became evident when nearly 700 P.C.E. determinations were made. To test the reliability of these criteria, samples from the four largest deposits were plotted on the upper half of a triaxial diagram; thus, the lower left-hand apex of the triaxial diagram was considered 50 percent available alumina; the lower right apex was 50 available ferric oxide. The upper apex of the diagram was considered as 100 percent "undetermined." This value, for any given sample, is the difference between 100 percent and the sum of the available alumina and ferric oxides. The P.C.E. of every sample was plotted on the triaxial diagram. The location of a given sample on the diagram was noted by the use of a symbol indicative of its refractory classification. By plotting all of the samples from any one deposit, separate areas of maximum concentration of each refractory classification were noted. The size, shape, and location of these areas differed somewhat between deposits, but there still existed a remarkable similarity.

An attempt was made to reproduce these diagrams by using a mixture of electrically fused crystalline alumina and chemically pure ferric oxide, the "undetermined" constituent being represented by equal porportions of feldspar and silica. Cone-fusion tests were run on mixtures of various alumina and ferric oxide content through a range that simulated that of the clay samples tested. Little similarity existed between the triaxial diagrams of the artificial mixtures and those of the clay samples from any of the deposits. This evident discrepancy can be ascribed to the effects upon fusion of mineralogical entities as compared with the fusion of mechanical mixtures of similar chemical composition. Another known factor that affects this method of estimation is the presence or absence of clay minerals of low alumina availability.

As a general method of estimation of either probable fusion temperature of a sample of known available alumina-to-ferric oxide ratio or estimation of this ratio by determining the P.C.E., the results are satisfactory.

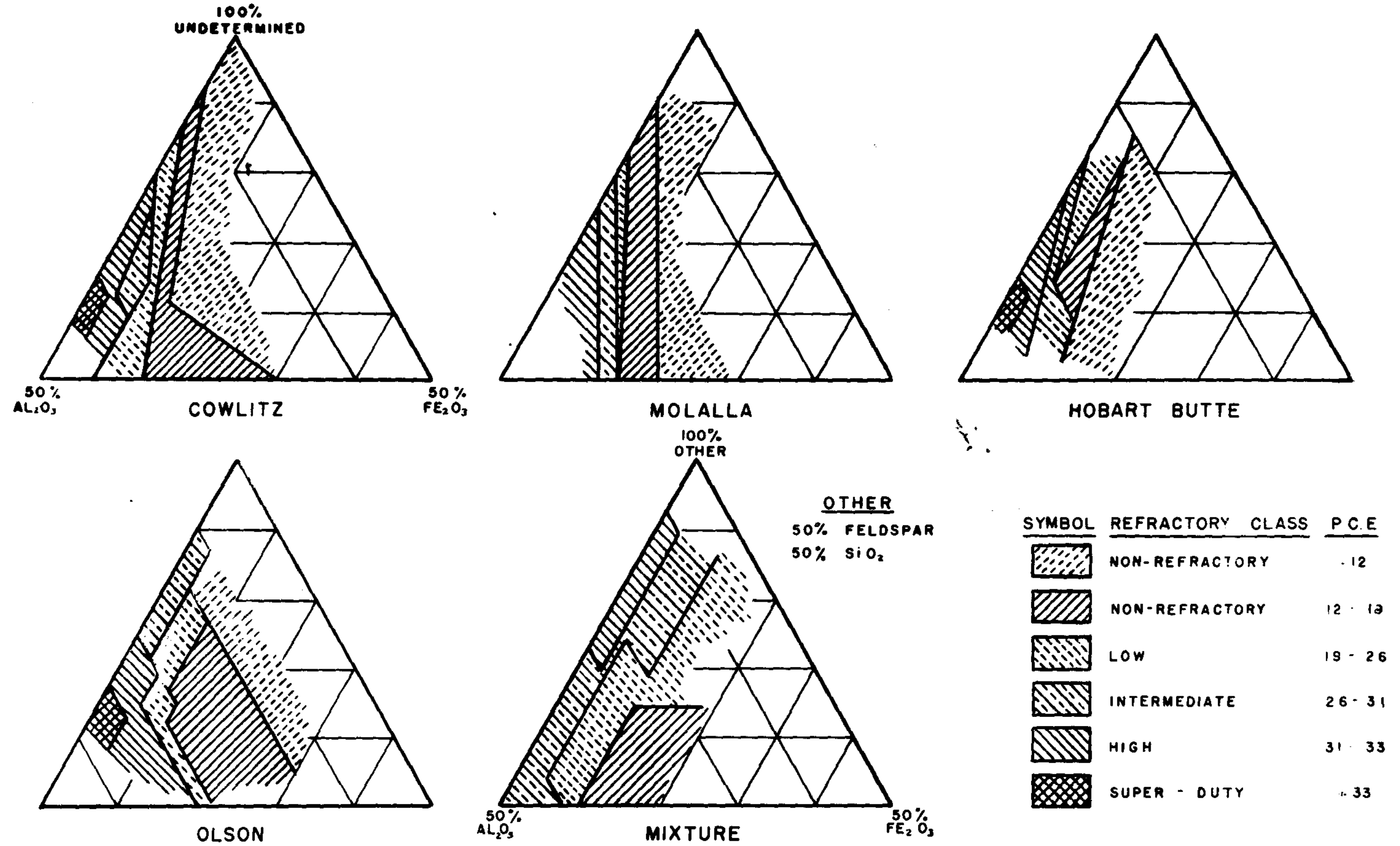

Figure 2. - Tri-axial diagrams showing the effect of available alumina and available ferric oxide on fusion of clays and artificial mixture.

Estimation of the refractory classification of entire blocks of clay found in the Cowlitz, Molalla, Hobart Butte, and Olson deposits were made on this basis. Figure 2 shows the triaxial diagrams of the samples from the above deposits and of the artificial mixtures. Other deposits were not plotted because of insufficient data.

Plasticity

Although a good idea of the plasticity of a clay may be obtained by wetting a small amount with water and working the mass between the fingers, the Atterberg test[9] was used in this investigation. This test not only shows the amount of water required for workability but also indicates the type of clay mineral present. It was found that two experienced operators could obtain fairly close check values for the same sample.

Procedure. - A 100-gram sample of minus 20-mesh material dried at 110° C. is placed in an evaporating dish, small amounts of water are added from a 100-ml. burette, and the mass is worked with a spatula until it is uniformly wet. At a certain water content, the spatula, used knife fashion, will make a clean, sharp cut with no sticking, and the separated portions of the clay will remain as consolidated masses. The number of milliliters of water required represents the lower plasticity range of the sample. Additional water is added in small increments, and the clay is again worked until the water is evenly distributed. Knife cuts are made after each addition of water until the clay tends to stick to the spatula and the separated portions tend to flow together. Another burette reading then gives the upper limit of workability or plasticity range.

Indicated clay mineral. - Table 2, abstracted from Klinefelter,[10] shows the general relationship between plasticity and clay mineral group.

TABLE 2. - General relationship between plasticity range and indicated clay mineral

Plasticity range, percent	Indicated clay mineral
Less than 20...	Clay of little plasticity or a nonclay mineral
20-40..........	Clay of moderate plasticity. Shales, flint clays, and surface clays. Mostly kaolinitic
35-60..........	Plastic clays. Kaolins and ball clays[1]
Above 65.......	Bentonitic clays and bentonites. Swelling type indicated by extreme values and bloating during test

[1] For the present investigation, plasticity ranges of 45 to 60 were considered as indicating kaolin plus bentonite, because thermal analyses showed the presence of bentonite for type samples having this range.

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[9] Kinneson, C. S., A Study of the Atterberg Plasticity Method: Bureau of Standards Tech. Paper 46, 1915, 18 pp.

[10] Klinefelter, Theron A., O'Meara, Robert G., Gottlieb, Sidney, and Truesdell, Glenn C., Syllabus of Clay Testing, Part I: Bureau of Mines Bull. 451, 1943, pp. 6-7.

Preliminary Firing Tests

Preliminary firing tests were made at cones 04 (about 1,055° C.) and 4 (about 1,175° C.) to obtain information, such as fired color, which would be useful for determining possible uses other than for refractories as indicated by pyrometric cone-equivalent tests (described later). Because these firings were made in a rapidly-heated laboratory kiln, the physical effects obtained do not agree with those produced in commercial kilns fired to the same temperatures. Experience has shown that for most clays, using the laboratory procedure followed in this investigation, the fired physical properties are similar to those obtained in commercial kilns fired 2 to 3 cones lower. For example, a cone 04 firing is equivalent to a cone 07-06 (about 995° C.), and a cone 4 firing is equivalent to a cone 1 to 2 (about 1,145° C.). Table 3 gives the average firing temperatures of some ceramic products.

The colors in the laboratory firing may differ from those obtained in commercial firing owing to differences in firing procedure, gas atmosphere, and rate of cooling.

Procedure. - Samples of minus 20-mesh clay were mixed with the proper amount of water and formed into balls about the size of a golf ball. These were air-dried for 48 hours, dried at 130° C. for 48 hours, and then each ball was placed in an individual fire-clay crucible. The crucibles were placed on the floor of a laboratory down-draft, oil-fired kiln, and the kiln was fired to cone 04 in 6 hours. The burners were turned off, and the kiln was cooled by natural draft about 36 hours before being opened. The crucibles were removed and the fired colors, hardness, and other apparent physical properties were noted.

These fired samples were then refired to cone 4 in 7 hours, cooled for 36 hours, and then reexamined.

Hardness definitions. - Hardness was determined by scratching the fired samples with a knife and was reported as softer than, equal to, or harder than steel. In some cases the following modifying or supplementing terms were used:

Sandy. Sand grains visible as bumps on the fired clay sample or noted when the test balls were being formed.

Gritty. The surface felt sandpapery, but no bumps as coarse as the sandy samples.

Powder. The sample pulverized between the fingers. This was usually caused by either high organic or high nonplastic content.

Friable. Slightly cohered but easily broken between the fingers into smaller but stronger fragments.

Punky. Fairly strong but porous and usually containing fine cracks.

Light weight. Usually strong but appeared to be lighter-weight than the average sample. This was caused by the burning-out of combustible material.

TABLE 3. - Average commercial firing temperatures of some ceramic products[11]

Product	Firing temperature, °C.
Heavy clay products:	
Common brick:	
Surface clay	870-985
Shale	985-1,095
Face brick:	
Surface clay	955-1,010
Shale	1,065-1,205
Fire clay	1,150-1,260
Paving brick (vitrified)	1,095-1,230
Structural clay tile:	
Surface clay	870-985
Shale	985-1,095
Fire clay	1,065-1,150
Drain tile	925-1,040
Sewer pipe	1,110-1,270
Roofing tile	1,070-1,170
Terra cotta	1,130-1,270
Pottery:	
Flower pots	860-1,010
Stoneware:	
Chemical	1,455-1,480
Once-fired	1,270-1,350
Earthenware or semivitreous:	
Bisque	1,250-1,290
Glost	1,190-1,250
Artware:	
Bisque	1,110-1,330
Glost	990-1,330
Pottery decalcomanias	760-815
Refractories:	
Fire brick, clay	1,260-1,370
Bauxite brick	1,455-1,540
Whitewares:	
Electrical porcelains	1,310-1,370
Hotel china:	
Bisque	1,310-1,335
Glost	1,210-1,250
Sanitary ware:	
Bisque	1,270-1,330
Glost	1,230-1,270
Floor tile	1,270-1,370
Wall tile:	
Bisque	1,030-1,290
Glost	1,030-1,230

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[11] Industrial Publications, Inc., Chicago, Ill., Ceramic Data Book: 1941-1942 ed., p. 213.

Pyrometric Cone Equivalent Tests

Pyrometric cone equivalent (P.C.E.) tests indicate possible uses for clays; for example, values lower than cone 19 (1,520° C.) indicate that the clays might be used in the manufacture of heavy-clay products. Values of cone 19 and above indicate possible use of the clay as a refractory, the refractory classification being shown by the P.C.E. value. Table 4 shows the American Society for Testing Materials classification for fire-clay refractories and fire-clay mortars. It must be emphasized that this classification is based only upon P.C.E. values, and that other physical and chemical characteristics must also be considered before a clay is chosen to manufacture refractories or other ceramic products.

Colors of the fired test cones are valuable in selection of clays for different uses. Lighter colors are preferable for most products.

TABLE 4. - Refractory classification of clays for manufacturing firebrick and fire-clay mortar[1]

Refractory classification	Minimum P.C.E. value		Temperature, °C.[2]	
	Refractory[3]	Mortar	Refractory	Mortar
Super duty........................	[4]33	31	1,745	1,680
High heat duty....................	[5]31-32	28	1,685	1,615
Intermediate heat duty............	29	26	1,640	1,595
Low heat duty.....................	19	16	1,520	1,465

[1] American Society for Testing Materials, Ground Fire Clay as a Mortar for Laying-Up Fireclay Brick; C 105-41: A.S.T.M. Standards, Pt. II, Nonmetallic Materials, Constructional, 1944, pp. 267-268.
Standard Classification of Fireclay Refractories; C 27-41: pp. 269-270.

[2] Temperature at standard heating rate. For discussion of pyrometric cones and their use, see: The Edward Orton, Jr. Ceramic Foundation, The Properties and Uses of Pyrometric Cones, 44 pp.

[3] Although the A.S.T.M. classification is for burned firebrick, it was the criterion used for this investigation.

[4] For this report this was considered to mean greater than cone 33; that is, 33+ or higher.

[5] Considered as at least cone 31+ for this report.

Procedure. - About 10 grams of minus 65-mesh air-dried sample was mixed with enough 5-percent gum arabic solution to make a workable plastic mass. Small cones similar to standard pyrometric cones in shape were made in a mold approximately the same as the one described by Klinefelter.[12] The cones were air-dried and then dried at 130° C. for 24 hours.

Six cones, in two rows of three each, were mounted in a small plaque (1 x 1-3/8 x 3/8 inches) with standard cones at the corners and test cones of the same sample in the middle of each row. The cones were set so that one face was parallel to the side of the plaque and inclined outward 18°. The plaques were made in a mold of a mixture of 50 percent Al_2O_3 and 50 percent semiflint fire clay with a 5 percent gum arabic solution and were dried before

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[12] Work cited in reference 10, p. 27.

being used to hold the cones. The plaques and cones were dried, and then the P.C.E. values were determined in an oxyacetylene furnace.[13]

The standard cones used were 12, 19, 26, and 31. If the P.C.E. value was about 31, a second test was made with cones 30, 31, 32, and 32-1/2, and if necessary a third test was made with cones 32-1/2, 33, 34, and 35. The P.C.E. values and the colors of the fired test cones were reported.

P.C.E. designations. - The definitions of the P.C.E. designations used in this report are given in table 5.

TABLE 5. - Definitions of P.C.E. designations; also cone temperatures

P.C.E. designations	Definitions
-12	Lower than cone 12
12-19	Between cones 12 and 19
19-26	Between cones 19 and 26
26-31	Between cones 26 and 31
31-	Cone 31 about 3/4 down[1]
31	Cone 31 down
31+	Cone 31 down, cone 32 about 1/4 down
31-1/2	Cone 31 down, cone 32 about 1/2 down

Cone number	Temperature, °C.[2]
12	1,335
19	1,520
26	1,595
29	1,640
31	1,680
32	1,700
32-1/2	1,725
33	1,745
34	1,760
35	1,785

[1] The minus, plus, and 1/2 values apply to all cones for which these fractional notations are used.

[2] Temperature at standard heating rate. Work cited in table 4.

3/ Wilson, Hewitt, An Oxygen-Acetylene High-Temperature Furnace: Jour. Am. Ceram. Soc., vol. 4, 1921, p. 835.

Test Results, by Deposits

Although a large number of clay deposits are known in the Pacific Northwest,[14] only seven were considered of sufficient size and purity to be of interest as possible sources of raw material for an alumina-from-clay industry. These deposits were drilled and sampled, and the physical and chemical data obtained were used to determine grade, tonnages, and minable areas. As a general rule, samples were taken to represent 5 feet of drill core; but if physical changes were noted, samples were taken at shorter intervals.

In some sections of eastern Washington and western Idaho the soil is underlain by kaolinitic materials,[15] but none of these deposits were drilled, because it was thought impracticable to remove the large amount of impurities they contained to produce a product containing high enough alumina and low enough iron for an alumina extraction plant. Much of the mineable material, particularly that in western Idaho, contains about 50 percent quartz and mica.

Presentation of test results. - The large number of data accumulated by the preliminary testing of over 650 individual samples from the 7 Pacific Northwest clay deposits results in voluminous tables, figures, and charts. Lucid presentation of these data necessitates a consistent and orderly arrangement. The following sequence of presentation of tabular and graphic data for each deposit will be adhered to as closely as possible.

1. A general location map of the deposit showing the location of all holes drilled, holes chosen for ceramic testing, and lines along which sections were projected.

2. Drill hole logs showing, by graphic means, the refractory classification and fired colors at cones 04 and 4 of each sample and its relation to other samples in the hole.

3. Idealized sections showing the possible disposition of clay beds between holes sampled for refractory testing.

4. Tables containing all of the data on each sample obtained by test work.

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[14] Glover, Sheldon L., Clays and Shales of Washington: Wash. Dept. Conservation and Develop., Div. of Geol., Bull. 24, 1941, 368 pp.
Wilson, Hewitt, and Treasher, Ray C., Preliminary Report of Some of the Refractory Clays of Western Oregon: Oregon Dept. Geol. and Mineral Industries Bull. 6, 1938, 93 pp.
Hodge, Edwin T., Market for Columbia River Hydroelectric Power Using Northwest Minerals Sec. IV. - Northwest Clays: War Dept. Corps of Eng., U. S. Army, North Pacific Div., Portland, Oreg., vol. 3, pp. 492-804; vol. 4, pp. 805-896, 978-986, 1938.

[15] Wilson, Hewitt, Kaolin and China Clay in the Pacific Northwest: Univ. of Wash. Eng. Exp. Sta. Bull. 76, 1934, 184 pp.

5. The following tables are included in the general summary of each deposit:

    A. Table showing the fired colors of samples in each refractory classification. Results expressed in percent.

    B. Tables giving distribution of fired colors by holes and deposit. Results, in percent of total footage, drilled in holes selected for ceramic testing.

6. The following tables are included in the general summary for deposits of the Pacific Northwest.

    A. Results of firing and cone-fusion tests of samples from Pacific Northwest clay deposits. Results expressed in percent of total samples taken.

    B. Clay types indicated by plasticity tests for deposits of Pacific Northwest.

Cowlitz, Wash., Deposit

The Cowlitz clay deposit is 7 miles northeast of Castle Rock, Cowlitz County, Wash., or about 65 miles north of Portland, Oreg. The central part of the deposit lies in section 18, T. 10 N., R. 1 W., Willamette meridian. The railroad between Portland and Seattle is only 5 miles west of the deposit.

Eight clay areas were explored by the Bureau of Mines. Of these, areas 2, 3, 4, and 7 were proved to constitute economic sources of alumina and are classified as "measured and indicated" clays. In addition to these four areas, there were others that were not explored extensively. Clay is known to occur between areas 1 and 2 and between 2 and 4, and data obtained from limited exploration indicated that the clay is similar to that in area 3 and could be classified as inferred. The "principal" clay bed in areas 2 and 4 is favorably situated for good drainage and overburden disposal. The overburden averages 17.1 feet in depth over clay averaging 42.8 feet in thickness.[16]

As previously stated, representative holes sampled for ceramic tests were chosen primarily on the basis of the available alumina and Fe_2O_3 ratio. Five holes were selected from area 2, 2 from area 3, 5 from area 4, and 7 from area 7.

The location of the deposit, various clay areas, drill holes, and drill holes selected for ceramic tests are shown in figure 3.

P.C.E. values and fired colors. - The largest amount of refractory clay, as indicated by P.C.E. tests, is in area 2. Hole 35 penetrates approximately 70 feet of high-heat duty clay and is overlain with about 8 feet of overburden. A similar bed of clay is found in hole 6, but the bed is less consistent, owing to low-heat duty and nonrefractory beds. A small body of super-duty

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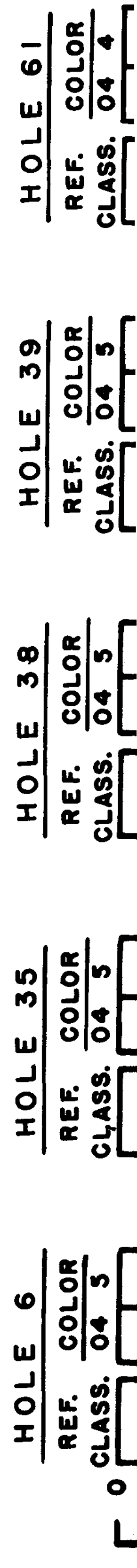
[16] Bureau of Mines, Cowlitz Clay Deposits, Cowlitz County, Wash.: War Minerals Report 242, 1944, pp. 1, 4, and 9.

clay is also found in hole 6. This apparently consistent body of clay overlies a bed of intermediate grade. (See fig. 8.) High-heat duty clays are found in several other holes, but none have the depth or consistency of the bed in area 2. Sixty-six percent of the samples tested from area 2 were of refractory quality, whereas only 43 percent of area 3 clays were so classified. Areas 4 and 7 had 39 and 32 percent, respectively.

Fired colors of clay from area 2 also were consistently light in color. Seventy-nine percent of the clay tested from this area was white, gray, buff, or tan when fired to cone 04; 59 percent remained in the lighter-color group when fired to cone 4.

Figures 4 through 7 are drill logs of the holes tested; the log is based upon refractory classification and fired colors of the samples. The reader is also referred to figures 8 through 12 to idealized sections projected on the basis of refractory classification, and to table 6, which gives the detailed results of test work on individual samples from the Cowlitz deposit.



Molalla, Oreg., Deposit

The Molalla clay deposit is approximately 28 miles south of Portland, Oreg., and only a short distance south of the town of Molalla, Oreg. The area lies on the eastern edge of the Willamette Valley, which is gently irregular and slopes to the northwest. The main portion of the drilling by the Bureau of Mines was done in sections 22 and 27, T. 5 S., R. 2 E.

The drilling program carried out during 1943 outlined 19,589,000 dry tons of clay containing 25 percent of available alumina and 8.05 percent of available Fe_2O_3. This block of clay has an average ratio of waste to clay of 1 to 5.4. Another 12,750,000 tons of inferred clay in a lower bed is reported to contain 27 percent of available alumina and 7 percent of available Fe_2O_3.

Clay occurs in two horizons within the Molalla formation. The upper is overlain with a small amount of overburden and is separated from the lower bed by low-grade material and sandstone. The lower bed is characterized by higher alumina content and better continuity.[17]

Thirteen holes were selected for ceramic tests from this deposit, nine of which were in the main area of drilling, and the others were east of the main clay body in sections 27 and 28.

Location of the deposit, holes drilled, and those selected for ceramic tests are shown in figure 13.

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[17] Bureau of Mines, Molalla Clay, Clackmas County, Oreg.: War Minerals Report 8, 1943, pp. 1, 4, 5, and 7.

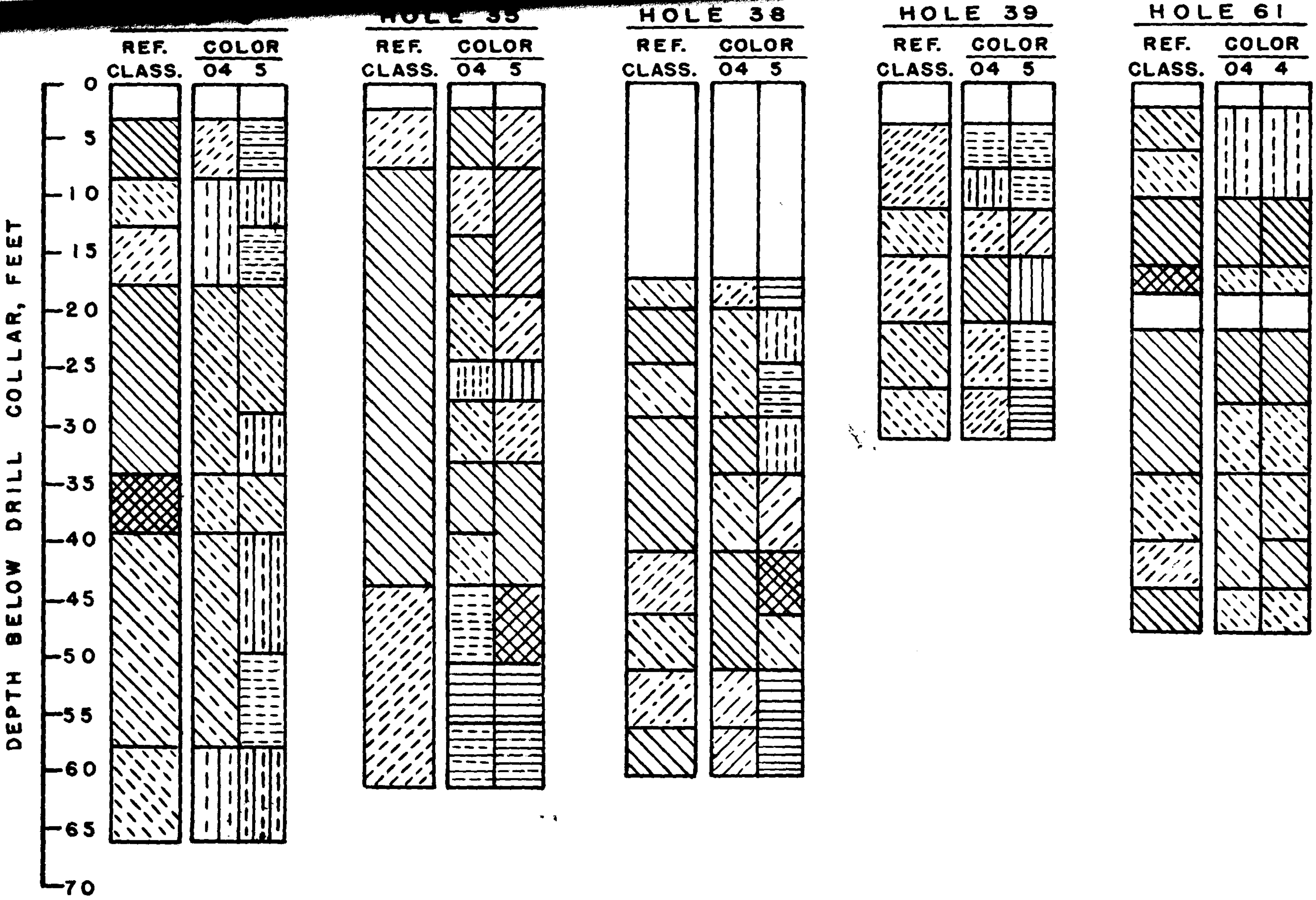

Figure 4. - Refractory classification and fired colors at cones 04 and 5 of clay samples from area 2, Cowlitz deposit, Cowlitz County, Wash. (See fig. 7 for legend for figs. 4-7.)

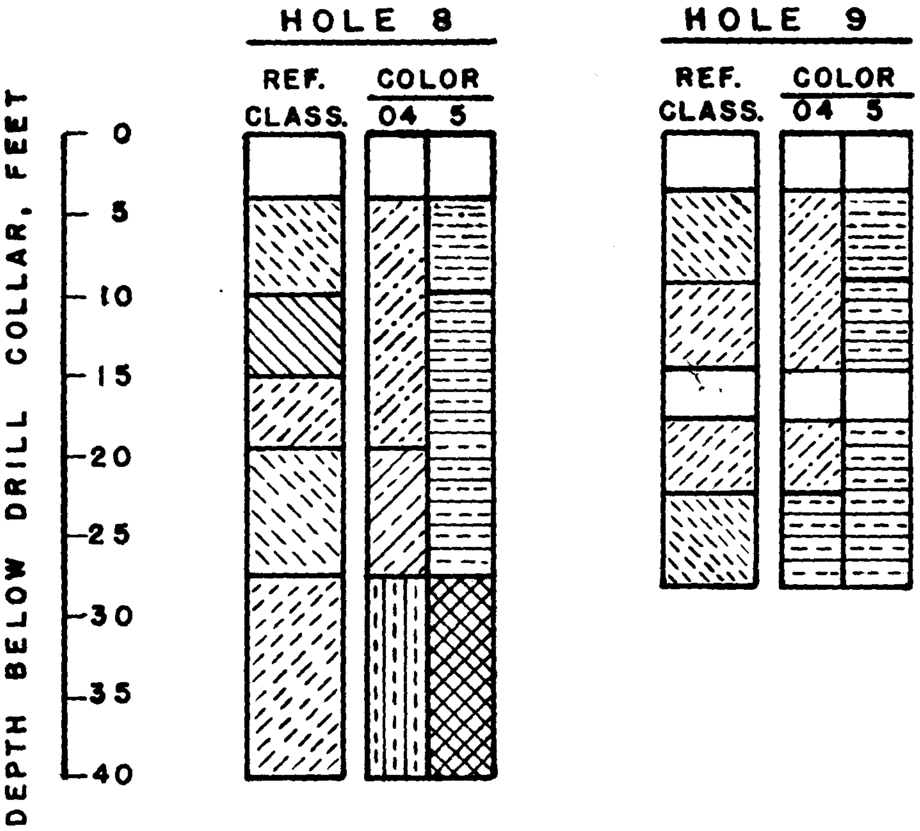

Figure 5. - Refractory classification and fired colors at cones 04 and 5 of clay samples from area 3, Cowlitz deposit, Cowlitz County, Wash.

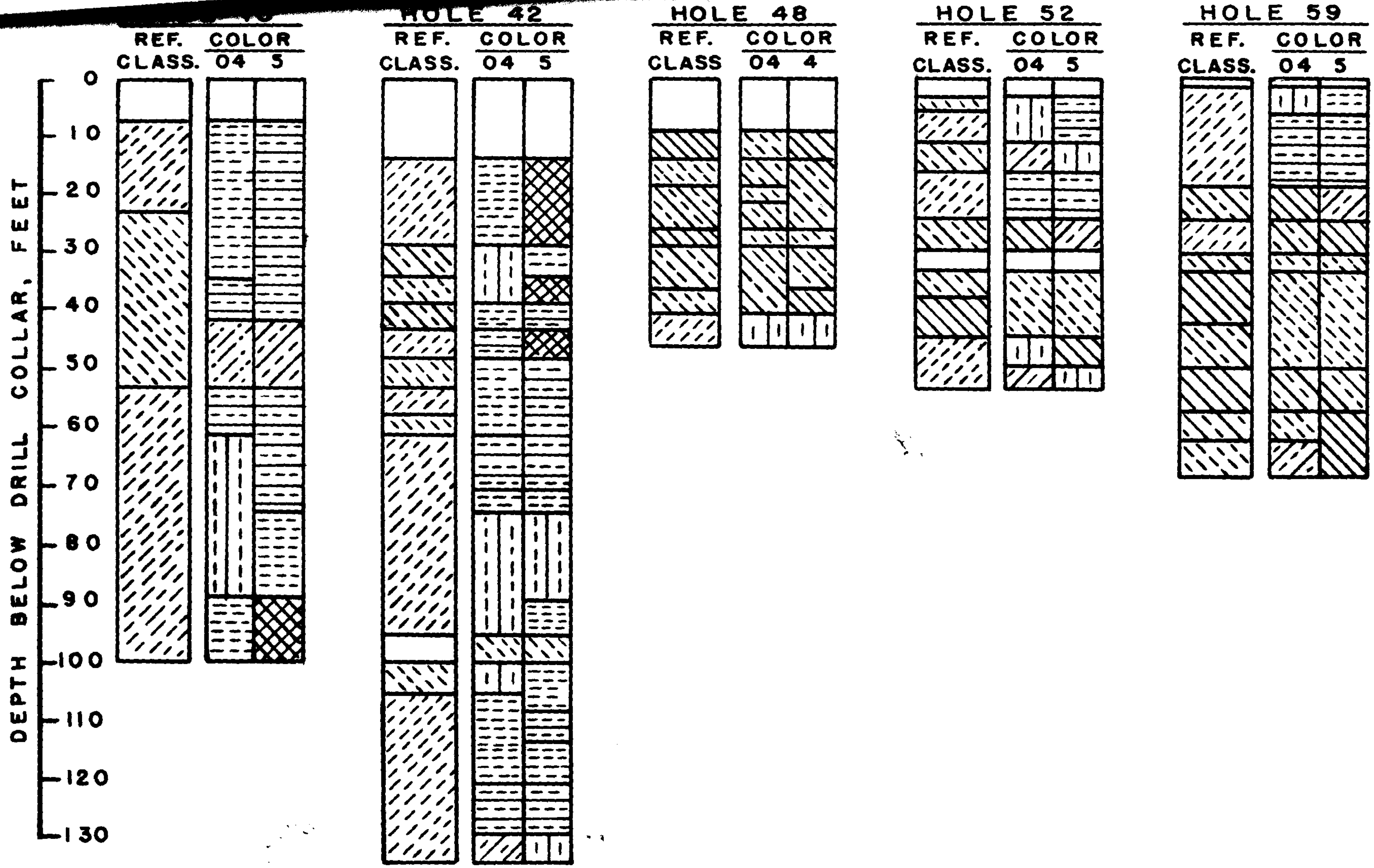

Figure 6. - Refractory classification and fired colors at cones 04 and 5 of clay samples from area 4, Cowlitz deposit, Cowlitz County, Wash.

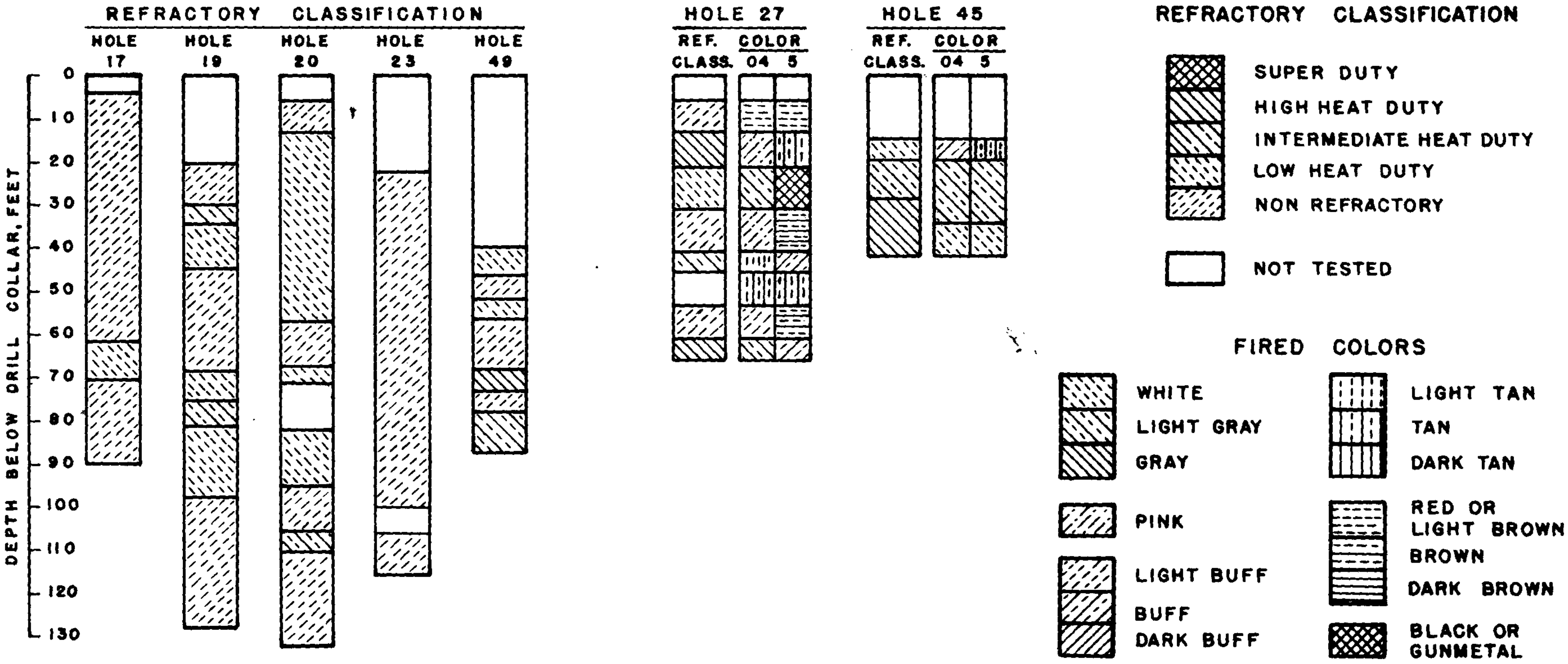

Figure 7. - Refractory classification and fired colors at cones 04 and 5 of clay samples from area 7, Cowlitz deposit, Cowlitz County, Wash.

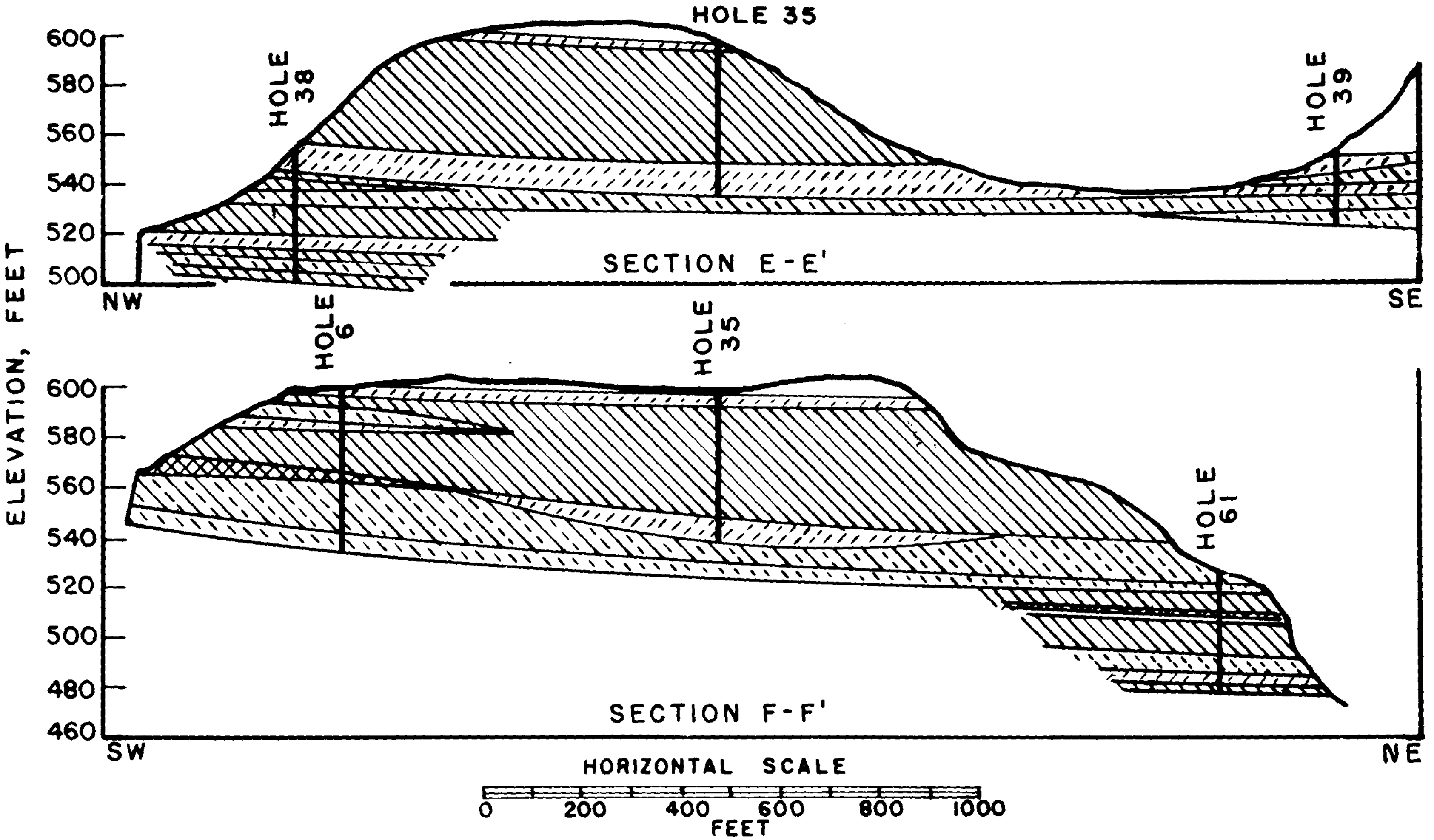

Figure 8. - Idealized sections showing the refractory classification of clay from area 2, Cowlitz deposit, Cowlitz County, Wash. Vertical scale in all sections exaggerated 5 to 1.

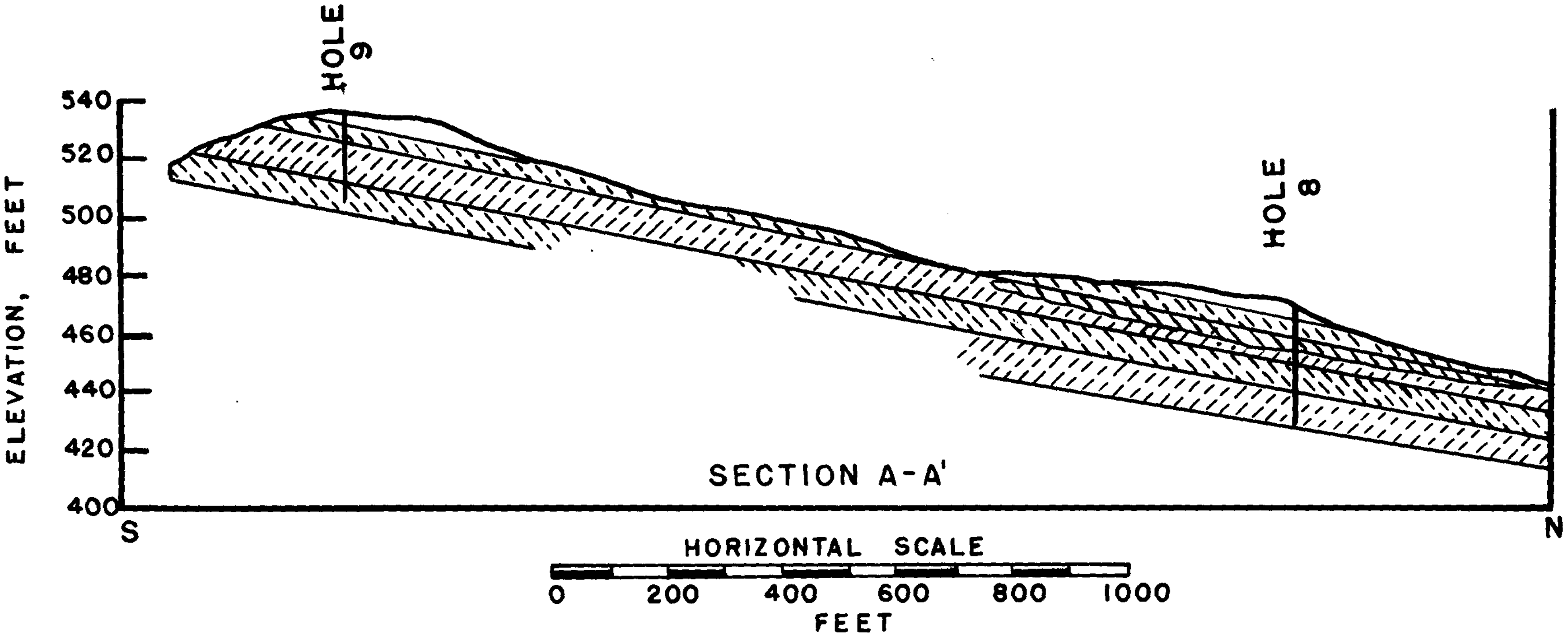

Figure 9. - Idealized sections showing the refractory classification of clay from area 3, Cowlitz deposit, Cowlitz County, Wash.

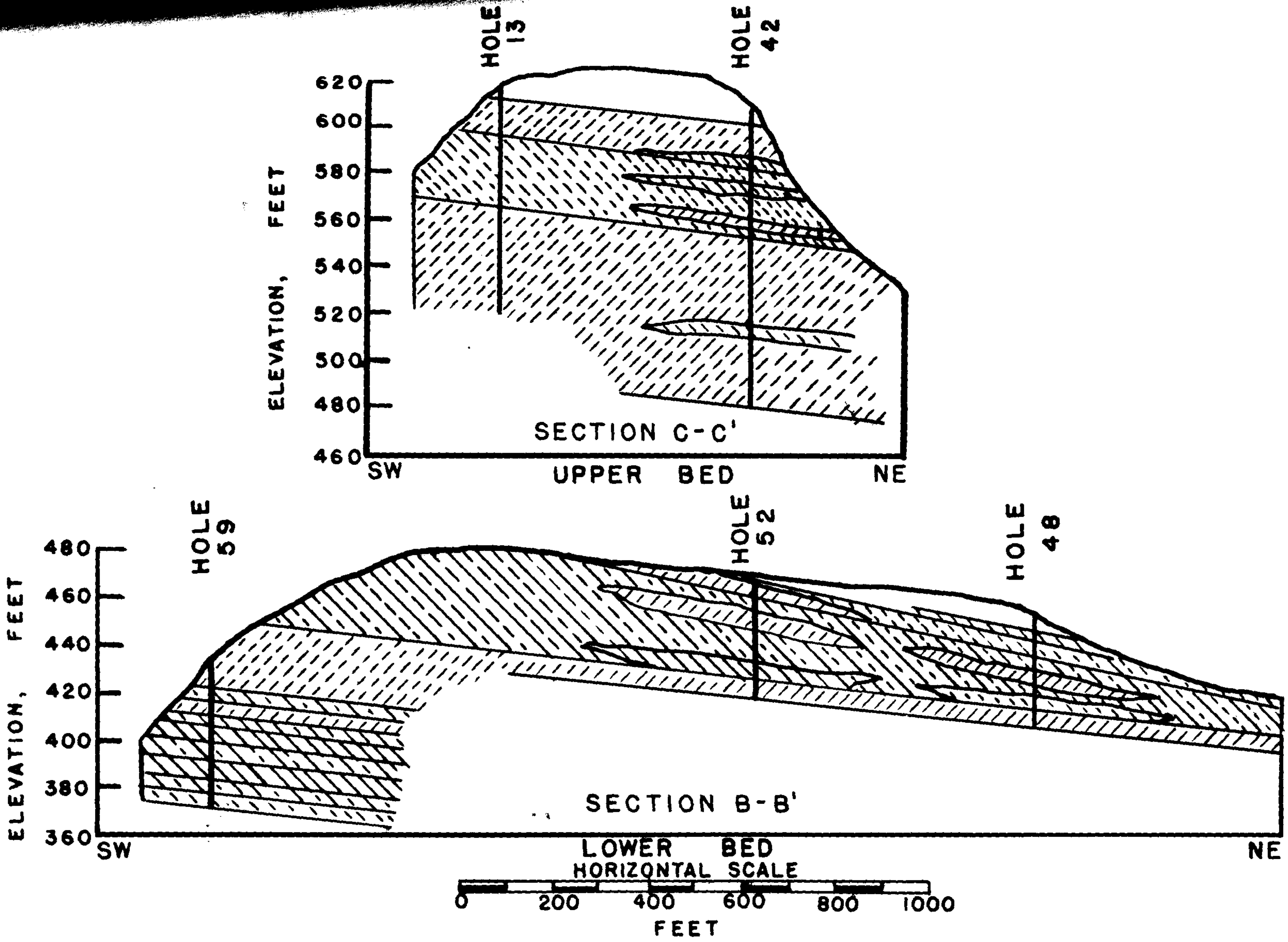

Figure 10. - Idealized sections showing the refractory classification of clay from area 4, Cowlitz deposit, Cowlitz County, Wash.

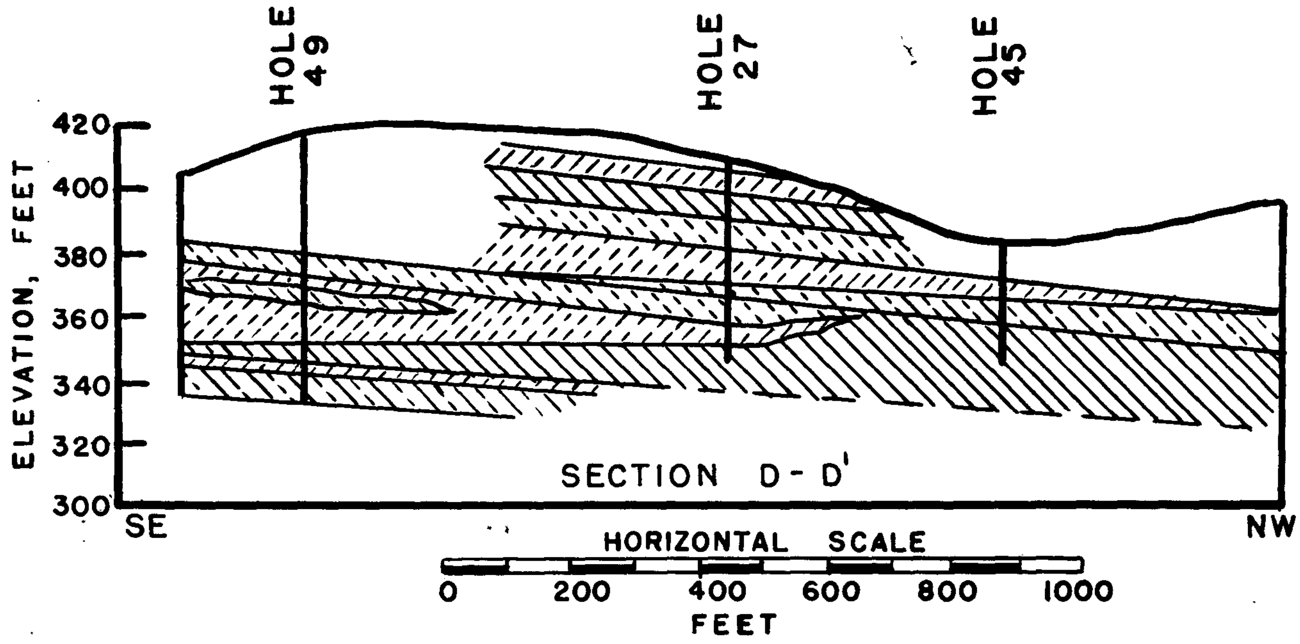

Figure 11. - Idealized sections showing the refractory classification of clay from area 7, Cowlitz deposit, Cowlitz County, Wash.

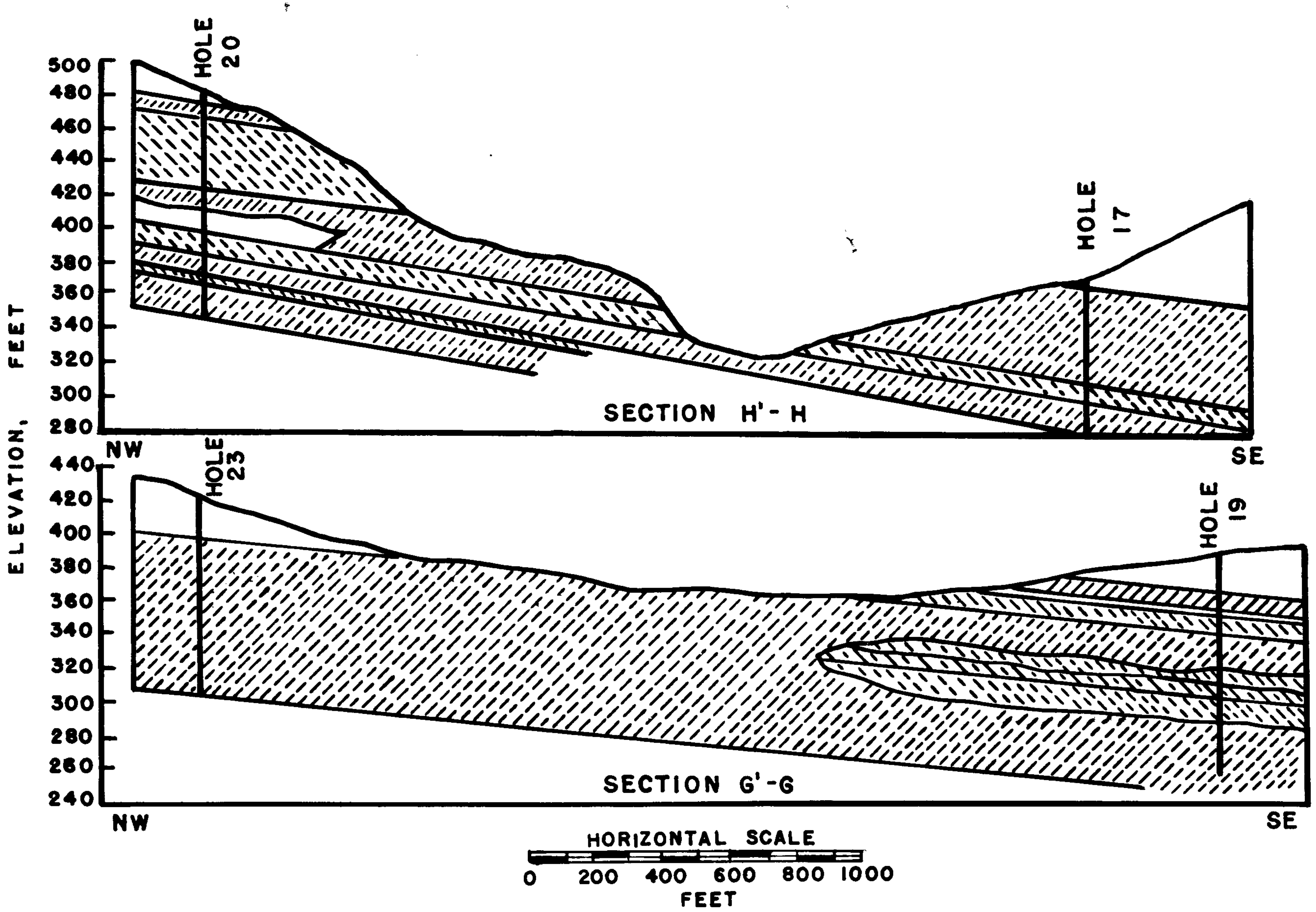

Figure 12. - Idealized sections showing the refractory classification of clay samples from area 7, Cowlitz deposit, Cowlitz County, Wash.

TABLE 6. - Test data for drill-core samples from the Cowlitz area 2 deposit, Cowlitz County, Wash.

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 800° C.	Range	Indicated clay type	Cone 04		Cone 5		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
								HOLE 6					
3.0-8.7	35.8	1.9	14.0	42-71	Kaolin +M[3]	Lt. buff	SS	Lt. brown	HS	-	33	Tan	High heat
8.7-13.0	28.9	4.5	16.6	42-68	do.	Tan	SS	Tan	HS	White specks	19-26	Black, bloated	Low heat
13.0-18.1	15.2	4.8	11.3	36-66	do.	Tan	SS	Lt. brown	S	do.	-12	Brown, bloated	Nonrefractory
18.1-28.8	34.0	5.8	18.8	38-48	Kaolin	Lt. gray	SS	Lt. gray	S-	-	32-	Brown	High heat
28.8-34.3	32.3	4.0	28.4	41-53	do.	Lt. gray	SS	Tan	SS	Very soft at 04	31+	do.	Do.
34.3-39.4	38.3	2.4	20.9	36-53	do.	White	SS	Lt. gray	S	Tan specks at 5	33+	Speckled tan	Super-duty
39.4-49.4	37.0	6.3	19.9	29-44	do.	Lt. gray	SS	Tan	SS	Brown spots at 5	31-	Brown	Intermediate
49.4-57.7	33.7	2.9	13.4	35-44	do.	Lt. gray	HS	Lt. brown	HS	Black specks	31	Speckled tan	Do.
57.7-65.8	22.4	3.4	12.0	43-90	Kaolin +M	Tan	HS	Tan	HS	Green tint at 5	19-26	do.	Low heat
								HOLE 35					
2.5-7.8	23.4	10.3	10.8	38-59	Kaolin	Gray	SS	Buff	SS	Black specks at 5	-12	Brown, bloated	Nonrefractory
7.8-13.7	31.0	1.6	16.9	39-71	Kaolin +M	Lt. buff	SS	Dark buff	S	-	32-	Speckled tan	High heat
13.7-18.7	31.1	2.6	18.9	38-55	Kaolin	Gray	SS	Dark buff	HS	Black specks	31+	do.	Do.
18.7-24.5	34.0	5.0	16.6	35-45	do.	Lt. gray	SS	Buff	HS	do. at 5	31-32	Brown	Do.
24.5-28.1	27.6	4.8	34.3	33-53	do.	Lt. tan	SS	Dark tan	SS	Black specks	32-1/2	do.	Do.
28.1-33.4	37.3	3.8	19.5	36-52	do.	Lt. gray	SS	Lt. buff	HS	do.	31+	do.	Do.
33.4-39.0	35.7	6.4	17.2	34-52	do.	Gray	SS	Gray	HS	do.	32-1/2	Speckled tan	Do.
39.0-44.0	38.2	2.5	15.3	33-50	do.	Lt. gray	SS	Gray	HS	do. at 5	33-	do.	Do.
44 0-50.7	20.6	21.0	19.0	30-56	do.	Lavender	SS	Black	HS	White specks at 5	-12	Brown	Nonrefractory
50.7-55.9	21.9	10.7	33.9	38-68	Kaolin +M	Brown	SS	Brown	HS	Black specks at 5	12-	do.	Do.
55.9-61.3	15.4	8.7	9.2	46-88	do.	Red-brown	SS	Brown	HS	do. at 5	-12	Brown, bloated	Do.
			700° C.					HOLE 38					
17.5-20.0	32.2	5.2	13.2	40-68	Kaolin +M	Pink	SS	Brown	HS	Black specks at 5	31-	Brown	Intermediate
20.0-24.6	36.6	1.1	16.8	40-56	Kaolin	Lt. gray	SS	Lt. tan	HS	-	32+	Buff	High heat
24.6-29.4	38.2	6.7	16.6	34-49	do.	Lt. gray	SS	Lt. brown	HS	Brown specks at 5	31-	Brown	Intermediate
29.4-34.3	35.5	2.2	29.8	41-56	do.	Gray	SS	Lt. tan	SS	Black specks	32-	Brown	High heat
34.3-40.9	37.7	2.4	21.9	38-47	do.	Lt. gray	SS	Buff	SS	Black specks at 5	33	Speckled tan	High heat
40.9-46.5	28.5	20.3	20.6	31-47	do.	Gray	SS	Gunmetal	S	White specks at 5	-12	Brown	Nonrefractory
46.5-51.2	33.8	6.9	15.7	35-42	do.	Gray	SS	Lt. gray	HS	Black specks	31-	Brown	Intermediate
51.2-56.3	31.3	11.4	16.6	32-62	do.	Pink	SS	Brown	HS	Brown specks at 5	-12	Brown	Nonrefractory
56.3-60.5	31.1	3.7	12.4	44-72	Kaolin +M	Buff	HS	Brown	HS	Greenish tint at 5	31+	Brown	High heat
								HOLE 39					
3.6-7.7	19.6	7.4	8.6	35-61	Kaolin	Red-brown	SS	Red-brown	HS	-	12+	Brown, bloated	Nonrefractory
7.7-11.1	25.6	7.9	10.5	38-66	do.	Tan	SS	Lt. brown	SS	Black specks at 5	19-	Brown	Do.
11.1-15.3	36.9	8.1	14.4	39-54	do.	Lt. pink	SS	Buff	SS	Black specks at 5	26-	Brown	Low heat
15.3-21.1	29.2	11.9	17.6	33-50	do.	Gray	SS	Dark tan	HS	Brown specks at 5	19-	Brown	Nonrefractory
21.1-26.7	32.3	7.9	15.0	40-50	do.	Pink	SS	Lt. brown	S	Dark specks at 5	26+	Brown	Intermediate
26.7-31.2	28.0	4.0	11.8	41-90	Kaolin +M	Lt. buff	S	Brown	HS	Greenish tint at 5	19+	Speckled tan	Low heat

See footnotes at end of table.

TABLE 6. - Test data for drill-core samples from the Cowlitz area 2 deposit, Cowlitz County, Wash. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss,			Cone 04		Cone 4					
	Al_2O_3	Fe_2O_3	700° C.	Range	Indicated clay type	Color	Hardness[1]	Color	Hardness[1]	Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
HOLE 61													
2.5-6.2	28.5	5.7	11.7	52-74	Kaolin +M[3]	Tan	SS	Tan	HS	Slightly sandy	26-31	Brown	Intermediate
6.2-10.6	22.0	6.0	10.4	54-86	do.	Tan	SS	Tan	SS	White specks	19+	Brown	Low heat
10.6-16.4	34.0	5.0	14.9	37-46	Kaolin	Gray	SS	Gray	HS	-	32	Dark tan	High heat
16.4-18.7	37.0	1.6	16.0	43-47	do.	White	SS	White	HS	-	34	Tan	Super-duty
18.7-22.0	25.5	1.6	41.2	-	-	Gray	-	Gray	-	Ash (Lignite)	-	-	-
22.0-28.2	35.0	5.0	18.2	38-46	Kaolin	Gray	SS	Gray	SS	Brown specks	32-	Dark brown	High heat
28.2-34.4	37.8	3.3	18.7	38-45	do.	White	SS	White	SS	Brown specks	32-1/2+	Speckled tan	High heat
34.4-40.2	30.8	9.4	17.6	41-50	do.	Lt. gray	SS	Lt. gray	SS	Brown specks	19+	Dark brown	Low heat
40.2-44.2	25.5	12.7	18.6	37-50	do.	Lt. gray	SS	Gray	SS	Brown specks	12	Dark brown	Nonrefractory
44.2-48.1	33.2	1.8	12.5	42-73	Kaolin +M	White	S	Lt. gray	HS	-	32-1/2-	Light tan	High heat
Area 3 - HOLE 8													
			800° C.					Cone 5					
4.0-10.0	32.2	14.6	13.2	41-62	Kaolin	Lt. red	SS	Brick red	HS	Black specks at 5	19+	Brown	Low heat
10.0-15.0	37.0	6.9	14.2	39-61	do.	Pink	SS	Red-brown	HS	Black specks at 5	31+	Brown	High heat
15.0-19.5	34.4	13.7	14.7	40-57	do.	Pink	SS	Brick red	HS	Black specks at 5	12-19	Brown	Nonrefractory
19.5-27.3	33.9	7.2	13.0	43-68	Kaolin +M	Buff	SS	Brown	HS	Black specks at 5	19-26	Brown	Low heat
27.3-40.0	16.3	9.1	12.2	44-71	do.	Tan	SS	Gunmetal	HS	-	-12	Brown	Nonrefractory
HOLE 9													
3.7-9.3	33.3	12.2	15.8	33-54	Kaolin	Lt. red	SS	Red	SS	Black specks at 5	19-26	Brown	Low heat
9.3-14.7	32.2	11.1	17.3	35-48	do.	Lt. red	SS	Brick red	S	Black specks at 5	12-19	Brown	Nonrefractory
17.5-22.4	30.4	11.5	17.0	36-51	do.	Lt. red	SS	Red-brown	HS	Black specks at 5	-12	Brown	Do.
22.4-28.2	29.8	6.9	13.4	39-82	Kaolin +M	Brown	S	Brown	HS	-	19-26	Black	Low heat
Area 4 - HOLE 13													
7.0-23.0	16.4	4.8	7.0	29-58	Kaolin	Lt. brown	SS	Red-brown	SS	Black specks at 5	12-19	Brown	Nonrefractory
23.0-34.5	30.2	11.5	12.0	44-91	Kaolin +M	Lt. red	S	Red	HS	-	19+	do.	Low heat
34.5-42.6	29.6	10.9	11.5	53-90	do.	Red	HS	Red	HS	-	19-26	do.	Do.
42.6-53.0	21.4	1.8	9.5	45-78	do.	Cream	HS	Buff	HS	White specks at 5	19-26	Speckled tan	Do.
53.0-61.0	12.7	2.5	10.0	63-84	M	Brown	S	Brown	HS	White specks	-12	Tan, bloated	Nonrefractory
61.0-74.4	4.5	3.4	6.0	34-51	Kaolin	Tan	SS	do.	SS	-	-12	Tan	Do.
74.4-83.0	19.3	3.7	11.8	53-60	do.	do.	SS	Lt. brown	SS	-	12-19	Tan and brown	Do.
83.0-89.3	16.1	3.3	11.2	-	-	do.	SS	do.	SS	Black specks at 5	-12	Tan, bloated	Do.
89.3-100.0	3.1	2.6	7.3	51-56	Kaolin	Lt. brown	SS	Gunmetal	HS	Bloating at 5	-12	do.	Do.

See footnotes at end of table.

TABLE 6. - Test data for drill-core samples from the Cowlitz area 4 deposit, Cowlitz County, Wash. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.			Cone 04		Cone 5					
	Al_2O_3	Fe_2O_3		Range	Indicated clay type	Color	Hardness[1]	Color	Hardness[1]	Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
								HOLE 42					
14.0-18.9	18.8	10.4	7.6	47-82	Kaolin +M[3]	Red	SS	Gunmetal	HS	Bloating at 5	-12	Brown	Nonrefractory
18.9-22.9	16.5	10.4	7.8	44-77	Kaolin	do.	SS	do.	HS	-	-12	Brown, bloated	Do.
22.9-28.9	18.1	9.8	7.7	50-69	do.	do.	SS	do.	HS	-	12-	Brown	Do.
28.9-34.0	33.0	6.6	15.3	45-69	do.	Tan	SS	Lt. brown	HS	-	26-31	do.	Intermediate
34.0-38.6	29.5	12.6	12.7	58-99	M	do.	S	Gunmetal	HS	-	19-26	Brown, bloated	Low heat
38.6-43.4	31.0	6.6	12.0	43-68	Kaolin +M	Lt. brown	SS	Brown	HS	-	26-31	Brown	Intermediate
43.4-48.5	28.5	13.9	13.1	43-62	Kaolin	Red-brown	SS	Gunmetal	HS	White specks at 5	19-	do.	Nonrefractory
48.5-53.4	30.0	8.4	12.5	40-64	do.	Lt. red	SS	Brown	HS	White specks	19-26	do.	Low heat
53.4-58.0	28.3	11.7	11.0	47-80	Kaolin +M	Red	HS	Dark red	HS	-	19-	do.	Nonrefractory
58.0-61.0	23.5	23.4	10.2	53-58	Kaolin	Brick red	SS	Brick red	SS	-	19+	do.	Low heat
61.0-65.2	26.0	10.8	12.0	51-78	Kaolin +M	Brown	SS	Brown	S	-	12	Brown, bloated	Nonrefractory
65.2-70.9	22.5	3.3	14.4	43-60	Kaolin	Brown	SS	do.	SS	Punky	12-19	do.	Do.
70.9-74.9	18.5	5.8	11.0	51-59	do.	Lt. brown	SS	Lt. brown	SS	Brown specks	-12	do.	Do.
74.9-80.2	21.9	5.5	13.2	51-56	do.	Tan	SS	Tan	SS	White specks at 5	19-	do.	Do.
80.2-89.5	19.2	4.5	10.6	43-49	do.	Tan	SS	do.	SS	do.	12-19	do.	Do.
89.5-94.5	19.6	6.1	22.2	44-54	do.	do.	SS	Lt. brown	SS	Black specks	12-19	do.	Do.
94.5-100.4	15.6	3.3	29.7	40-53	do.	Lt. gray	-	Lt. gray	-	-	-	-	-
100.4-105.3	16.8	2.8	9.9	52-60	do.	Tan	SS	Lt. brown	HS	White specks at 5	19-26	Brown, bloated	Low heat
105.3-110.1	13.6	3.3	20.7	45-55	do.	Lt. brown	SS	do.	SS	do.	19-	do.	Nonrefractory
110.1-115.5	19.1	6.6	9.9	42-51	do.	do.	SS	Brown	SS	Gritty	-12	do.	Do.
115.5-120.7	19.6	7.1	9.4	43-49	do.	Red-brown	SS	Red-brown	SS	-	-12	do.	Do.
120.7-125.5	18.9	8.2	8.7	41-50	do.	do.	SS	do.	SS	-	-12	do.	Do.
125.5-129.6	19.3	6.8	10.3	41-47	do.	Brown	SS	do.	SS	-	-12	do.	Do.
129.6-134.4	18.5	9.5	9.8	33-41	do.	Buff	SS	Tan	SS	White specks at 5	-12	Black	Do.
								HOLE 48					
								Cone 4					
9.7-14.2	29.1	1.9	27.3	42-54	Kaolin	White	SS	Gray	SS	Brown specks	32-1/2-33	Tan	High heat
14.2-19.1	31.4	7.3	17.7	40-48	do.	Lt. gray	SS	Lt. gray	SS	Black specks	26-	Dark brown	Low heat
19.1-21.9	28.1	3.1	29.7	39-54	do.	White	SS	do.	SS	do.	31	Brown	Intermediate
21.9-26.0	31.5	9.2	17.2	36-41	do.	Lt. gray	SS	do.	SS	Brown specks	26+	Dark brown	Do.
26.0-29.0	25.9	1.9	39.7	-	-	White	SS	White	SS	do.	32+	Tan	High heat
29.0-36.4	32.8	6.9	16.5	40-48	Kaolin	Lt. gray	SS	Lt. gray	SS	do.	31	Brown	Intermediate
36.4-40.6	29.2	8.6	15.3	40-60	do.	do.	SS	Gray	SS	do.	19	do.	Low heat
40.6-46.4	20.7	5.5	10.8	47-92	Kaolin +M	Tan	SS	Tan	HS	White specks	12+	Tan, speckled	Nonrefractory
								HOLE 52					
3.5-5.8	22.6	11.4	11.1	50-60	Kaolin	Tan	SS	Brick red	S	-	19+	Brown	Low heat
5.8-11.4	20.3	6.2	10.3	60-75	M	do.	S	Brown	HS	Cracked	12-19	do.	Nonrefractory
11.4-16.7	20.2	2.4	12.1	58-62	do.	Buff	SS	Tan	SS	White specks	26+	Tan, bloated	Intermediate
16.7-24.5	10.9	2.5	9.3	56-84	do.	Brown	SS	Brown	SS	Badly cracked	12-	do.	Nonrefractory
24.5-29.9	29.5	3.0	15.3	56-58	Kaolin	Gray	SS	Buff	S	White specks at 4	26+	Tan and brown	Intermediate
29.9-37.6	21.9	2.4	43.5	-	-	do.	-	Gray	-	Ash (Lignite)	-	-	-
33.5-37.6	31.5	4.1	21.6	41-48	Kaolin	White	SS	White	SS	Dark specks	26-31	Brown	Intermediate
37.6-44.8	35.7	2.3	14.7	40-48	do.	do.	SS	do.	HS	-	32+	Tan	High heat
44.8-49.6	25.6	11.8	18.0	33-54	do.	Tan	SS	Dark gray	SS	Cracked	-12	Brown	Nonrefractory
49.6-53.5	23.3	4.2	11.5	50-82	Kaolin +M	Buff	S	Olive-green	S	White specks at 4	-12	do.	Do.

See footnotes at end of table.

TABLE 6. - Test data for drill-core samples from the Cowlitz area 4 deposit, Cowlitz County, Wash. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
HOLE 59													
1.5-6.3	22.4	6.7	9.4	42-76	Kaolin +M[3]	Tan	S	Lt. brown	HS	-	19-	Brown	Nonrefractory
6.3-11.0	23.2	16.3	10.3	44-71	do.	Red-brown	SS	Red-brown	SS	-	12-	do.	Do.
11.0-19.1	23.9	12.4	10.4	49-69	do.	do.	SS	do.	SS	-	12+	do.	Do.
19.1-24.5	27.0	4.1	19.2	43-48	Kaolin	Gray	SS	Buff	SS	Brown specks	26+	do.	Intermediate
24.5-30.3	29.4	10.1	17.6	38-42	do.	Lt. gray	SS	Gray	SS	do. at 4	12-19	do.	Nonrefractory
30.3-32.8	34.3	4.6	16.6	39-48	do.	White	SS	White	HS	-	31	do.	Intermediate
32.8-41.8	29.6	7.8	22.5	39-44	do.	Gray	SS	Dark gray	S	Brown specks	26+	do.	Do.
36.6-41.8	28.2	2.6	33.1	-	-	White	SS	White	SS	Punky	32	do.	High heat
41.8-50.2	34.2	4.4	18.7	42-49	Kaolin	do.	SS	do.	SS	Brown specks	31	do.	Intermediate
50.2-57.2	34.3	2.8	13.0	42-53	do.	Lt. gray	S	Lt. gray	HS	-	31+	Tan	High heat
57.2-62.7	32.5	5.2	14.4	34-48	do.	White	SS	Gray	HS	Black specks at 4	26+	Brown	Intermediate
62.7-68.7	22.4	5.7	11.7	52-81	Kaolin +M	Buff	HS	Dark gray	HS	White specks at 4	19-26	do.	Low heat
Area 7 - HOLE 17													
								Cone 5					
3.7-11.0	19.3	14.9	9.6	-	-	-	-	-	-	-	12-19	Brown, bloated	Nonrefractory
11.0-16.5	7.2	3.1	7.5	-	-	-	-	-	-	-	12-	Tan, bloated	Do.
16.5-24.3	21.8	4.0	15.1	-	-	-	-	-	-	-	12-19	Brown, bloated	Do.
24.3-31.0	16.8	9.3	12.3	-	-	-	-	-	-	-	12-19	do.	Do.
31.0-38.3	12.0	2.1	14.0	-	-	-	-	-	-	-	12-19	Tan, bloated	Do.
38.3-47.1	2.8	4.5	7.6	-	-	-	-	-	-	-	-12	do.	Do.
47.1-51.3	1.6	1.7	2.4	-	-	-	-	-	-	-	-12	Brown	Do.
51.3-61.5	22.9	4.1	11.9	-	-	-	-	-	-	-	12-19	Speckled brown	Do.
61.5-70.2	23.8	5.2	15.3	-	-	-	-	-	-	-	19-26	Dark brown	Low heat
70.2-80.2	24.7	4.3	12.1	-	-	-	-	-	-	-	19-	do.	Nonrefractory
80.2-89.9	17.6	4.0	11.2	-	-	-	-	-	-	-	12+	Speckled brown	Do.
HOLE 19													
20-25	15.0	8.2	7.1	-	-	-	-	-	-	-	12-	Black	Nonrefractory
25-29.5	5.7	5.9	6.7	-	-	-	-	-	-	-	-12	do.	Do.
29.5-34.3	21.7	2.6	10.4	-	-	-	-	-	-	-	26-31	Tan	Intermediate
34.3-44.8	19.2	5.8	11.0	-	-	-	-	-	-	-	19+	Black	Low heat
44.8-49.0	11.1	1.7	15.5	-	-	-	-	-	-	-	12-19	Tan, bloated	Nonrefractory
49.0-52.5	2.2	1.0	5.3	-	-	-	-	-	-	-	-12	Black	Do.
52.5-62.5	2.3	3.3	5.0	-	-	-	-	-	-	-	-12	do.	Do.
62.5-68.1	18.1	8.6	12.9	-	-	-	-	-	-	-	12+	Brown	Do.
68.1-75.0	24.6	7.6	13.3	-	-	-	-	-	-	-	19-26	Brown, bloated	Low heat
75.0-80.6	26.2	2.6	16.2	-	-	-	-	-	-	-	26-31	Tan, blistered	Intermediate
80.6-90.1	23.0	5.7	11.7	-	-	-	-	-	-	-	19+	Brown, bloated	Low heat
90.1-97.5	21.8	7.6	12.4	-	-	-	-	-	-	-	19-26	Dark brown	Do.
97.5-103.3	14.8	2.2	11.7	-	-	-	-	-	-	-	12-19	Tan, bloated	Nonrefractory
103.3-108.6	4.5	1.7	4.1	-	-	-	-	-	-	-	-12	Tan	Do.
108.6-115.2	6.4	4.5	8.6	-	-	-	-	-	-	-	-12	do.	Do.
115.2-123.4	5.3	2.4	6.3	-	-	-	-	-	-	-	12-	do.	Do.

											-12	do.	Do.
115.2-123.4	5.3	2.4	6.3	-	-	-	-	-	-	-	12-	do.	Do.
123.4-127.8	2.2	1.5	5.1	-	-	-	-	-	-	-	-12	do.	Do.

See footnotes at end of table.

TABLE 6. - Test data for drill-core samples from the Cowlitz area 7 deposit, Cowlitz County, Wash. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.			Cone 04		Cone 5					
	Al_2O_3	Fe_2O_3		Range	Indicated clay type	Color	Hardness[1]	Color	Hardness[1]	Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
								HOLE 20					
5.7-13.1	20.1	9.5	10.6	-	-	-	-	-	-	-	19-	Black	Nonrefractory
13.1-21.8	26.5	6.5	10.7	-	-	-	-	-	-	-	19-26	do.	Low heat
21.8-25.2	20.7	2.4	9.6	-	-	-	-	-	-	-	19-26	Dark brown	Do.
25.2-30.7	19.1	2.4	11.0	-	-	-	-	-	-	-	19+	Brown, bloated	Do.
30.7-40.7	22.3	5.4	9.6	-	-	-	-	-	-	-	19-26	Brown	Do.
40.7-49.0	22.3	4.9	9.5	-	-	-	-	-	-	-	26-	Dark brown	Do.
49.0-57.0	20.9	5.8	8.8	-	-	-	-	-	-	-	19-26	Black	Do.
57.0-67.3	19.2	4.2	8.8	-	-	-	-	-	-	-	19-	do.	Nonrefractory
67.3-72.1	20.6	4.6	8.7	-	-	-	-	-	-	-	19+	do.	Low heat
82.1-90.4	23.3	11.7	15.2	-	-	-	-	-	-	-	19-26	Black	Do.
90.4-95.1	23.3	4.4	11.2	-	-	-	-	-	-	-	26-	Speckled brown	Do.
95.1-105.4	11.3	6.1	9.9	-	-	-	-	-	-	-	-12	Black	Nonrefractory
105.4-110.4	17.6	1.2	47.9	-	-	-	-	-	-	-	31	Lt. tan	Intermediate
110.4-118.5	27.1	12.6	19.4	-	-	-	-	-	-	-	12-19	Dark brown	Nonrefractory
118.5-128.0	24.9	14.6	17.6	-	-	-	-	-	-	-	19-	Black	Do.
128.0-131.9	26.2	9.5	13.7	-	-	-	-	-	-	-	12-19	Dark brown	Do.
								HOLE 23					
21.8-31.4	13.4	4.9	7.5	-	-	-	-	-	-	-	12-19	Black	Nonrefractory
31.4-35.0	13.7	3.5	7.7	-	-	-	-	-	-	-	12-19	do.	Do.
35.0-45.0	7.8	5.4	4.7	-	-	-	-	-	-	-	-12	do.	Do.
45.0-55.0	6.4	4.1	4.1	-	-	-	-	-	-	-	-12	do.	Do.
55.0-63.0	9.2	5.6	6.9	-	-	-	-	-	-	-	-12	do.	Do.
63.0-68.0	11.6	6.5	7.8	-	-	-	-	-	-	-	-12	do.	Do.
68.0-78.6	15.4	6.6	8.8	-	-	-	-	-	-	-	-12	Brown, bloated	Do.
78.6-86.8	19.8	7.6	10.8	-	-	-	-	-	-	-	12-19	do.	Do.
86.8-100.1	18.3	5.8	10.4	-	-	-	-	-	-	-	12-19	do.	Do.
100.1-107.3	21.0	2.5	29.0	-	-	-	-	-	-	-	19-26	Tan	Low heat
107.3-115.5	23.8	2.8	15.0	-	-	-	-	-	-	-	19-	Tan, bloated	Nonrefractory
								HOLE 27					
			800° C.										
3.2-12.9	20.7	8.6	9.1	38-64	Kaolin	Red-brown	SS	Red-brown	SS	-	12-	Brown	Nonrefractory
12.9-21.0	34.0	2.2	14.9	40-64	do.	Pink	S	Tan	HS	-	33	Speckled brown	High heat
21.0-31.0	32.3	7.2	13.9	45-65	Kaolin +M[3]	Lt. gray	HS	Gunmetal	HS	Black specks	19-26	Brown	Low heat
31.0-40.6	27.9	11.7	13.7	41-73	do.	Lt. red	HS	Brick red	HS	Black specks at 5	19-	do.	Nonrefractory
40.6-45.3	29.3	2.7	11.4	55-100	M	Lt. tan	SS	Buff	S	White specks at 5	31-	Tan, speckled	Intermediate
45.3-53.5	21.3	1.9	29.3	-	-	Tan	-	Tan	-	Ash (lignite)	-	-	-
53.5-61.0	15.9	7.2	11.5	60-102	M	Lt. brown	SS	Brown	SS	Black specks at 5	-12	Brown, bloated	Nonrefractory
61.0-66.0	33.2	5.3	14.6	40-46	Kaolin	Lt. gray	SS	Buff	SS	Black specks at 5	31+	Brown	High heat

See footnotes at end of table.

TABLE 6. - Test data for drill-core samples from the Cowlitz area 7 deposit, Cowlitz County, Wash. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.			Cone 04		Cone 4					
	Al_2O_3	Fe_2O_3		Range	Indicated clay type	Color	Hardness[1]	Color	Hardness[1]	Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
HOLE 45													
14.2-19.3	23.8	3.5	10.3	46-77	Kaolin +M[3]	Buff	HS	Tan	HS	White specks	19+	Brown	Low heat
19.3-27.7	28.4	4.8	19.2	37-50	Kaolin	Lt. gray	SS	Lt. gray	S	Black specks	31-	Dark brown	Intermediate
27.7-34.1	33.1	6.4	14.4	46-80	Kaolin +M	do.	SS	do.	HS	-	31+	do.	High heat
34.1-41.5	31.0	3.0	12.8	53-76	do.	White	SS	White	HS	White	31-32	Tan	Do.
HOLE 49													
39.7-46.3	22.3	3.2	16.7	-	-	-	-	-	-	-	19-26	Speckled brown	Low heat
46.3-51.2	22.7	9.6	15.9	-	-	-	-	-	-	-	12-	Black	Nonrefractory
51.2-56.3	28.5	8.0	14.1	-	-	-	-	-	-	-	19-26	do.	Low heat
56.3-62.2	29.0	8.1	15.1	-	-	-	-	-	-	-	12-19	do.	Nonrefractory
62.2-67.8	27.5	9.3	15.6	-	-	-	-	-	-	-	12-19	do.	Do.
67.8-73.0	30.0	2.9	14.5	-	-	-	-	-	-	-	31+	Speckled tan	High heat
73.0-77.9	23.5	6.3	21.9	-	-	-	-	-	-	-	19-	Dark brown	Nonrefractory
77.9-87.7	15.1	1.5	51.0	-	-	-	-	-	-	-	26-31	Tan	Intermediate

[1] SS = Softer than steel.
S = Equal to steel.
HS = Harder than steel.

[2] A.S.T.M. designation by P.C.E. only.

[3] Montmorillonite.

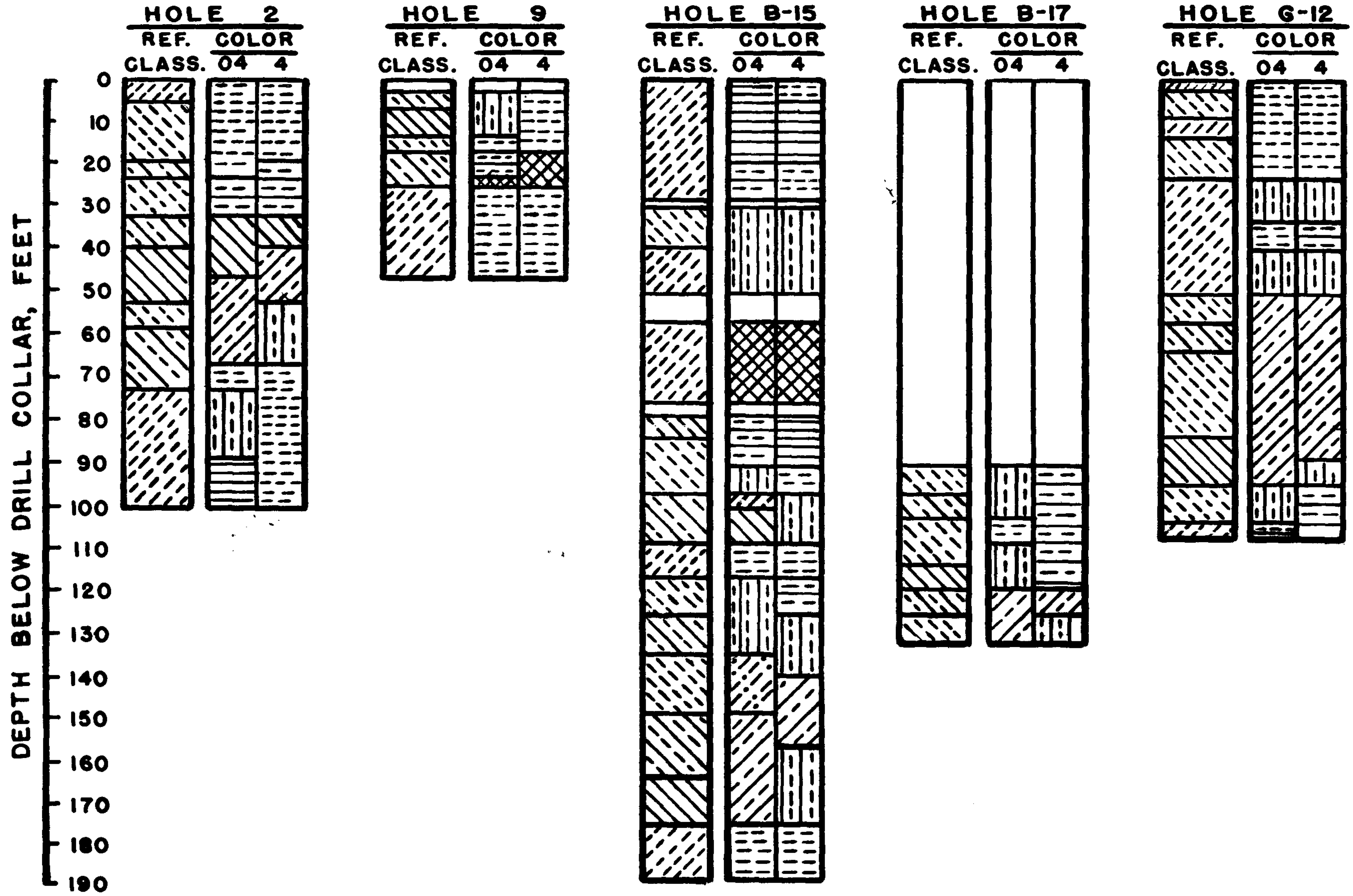

Figure 14. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Molalla deposit, Clackamas County, Oreg. (See fig. 16 for legend for figs. 14-16.)

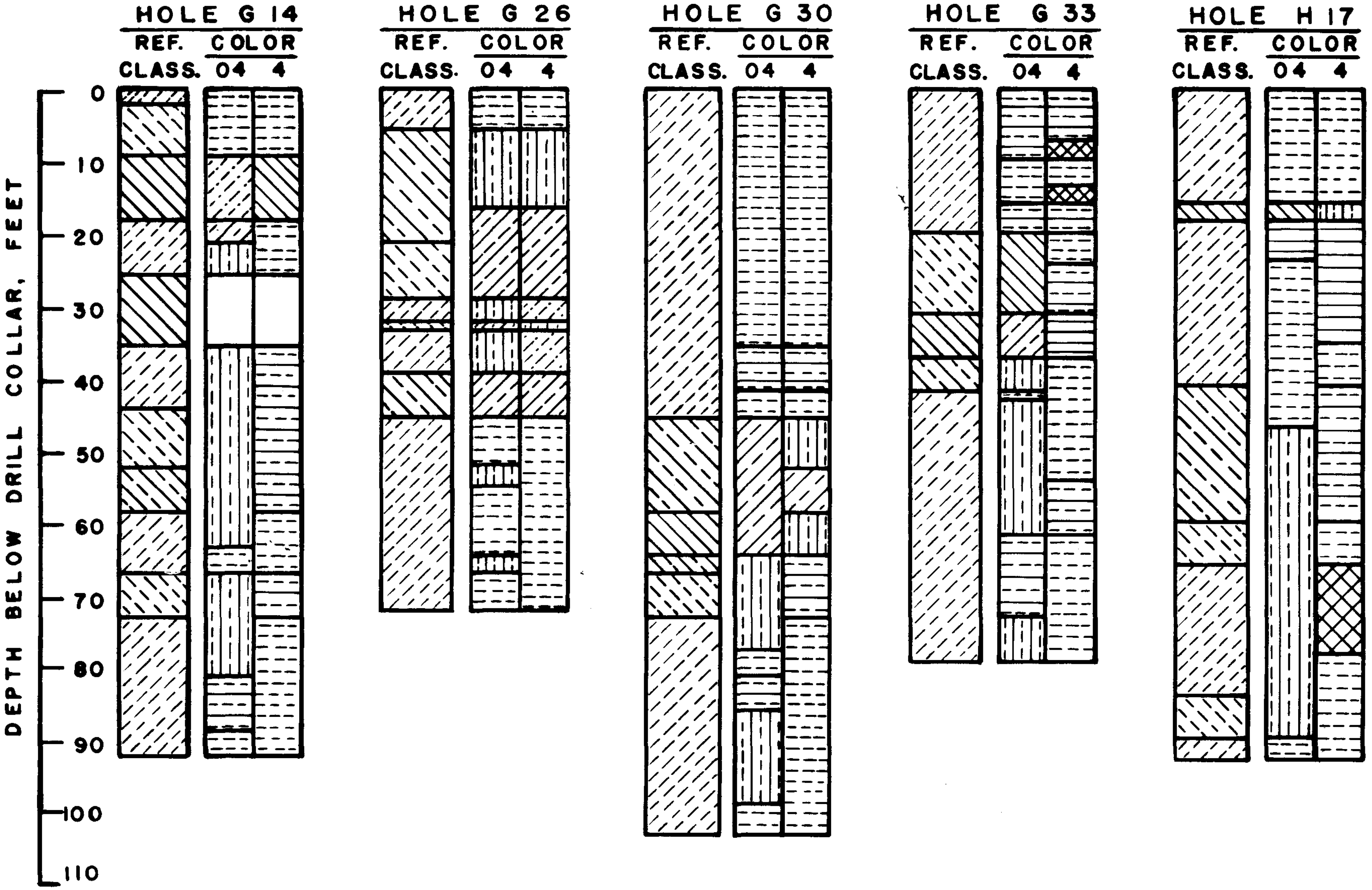

Figure 15. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Molalla deposit, Clackamas County, Oreg.

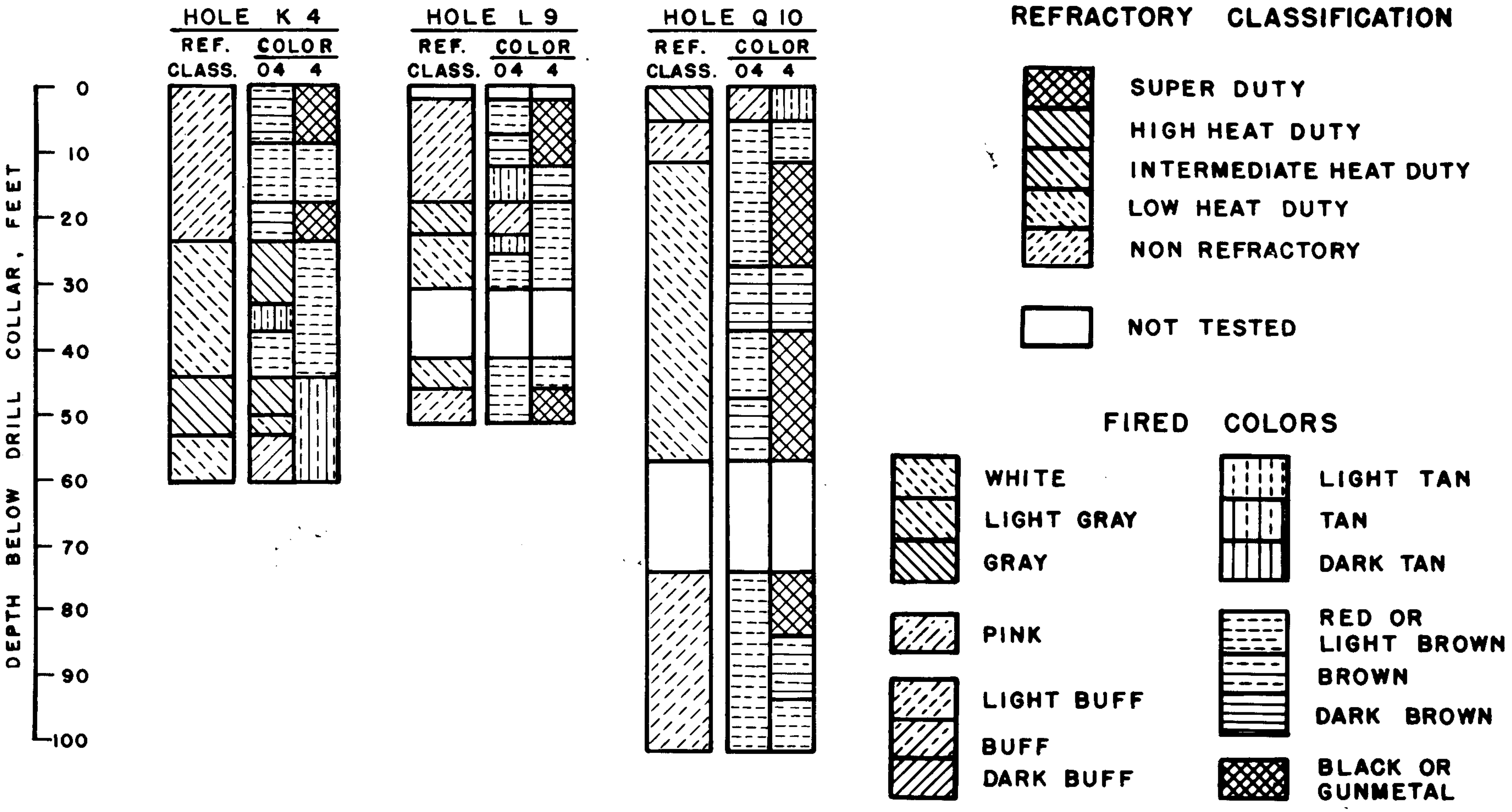

Figure 16. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Molalla deposit, Clackamas County, Oreg.

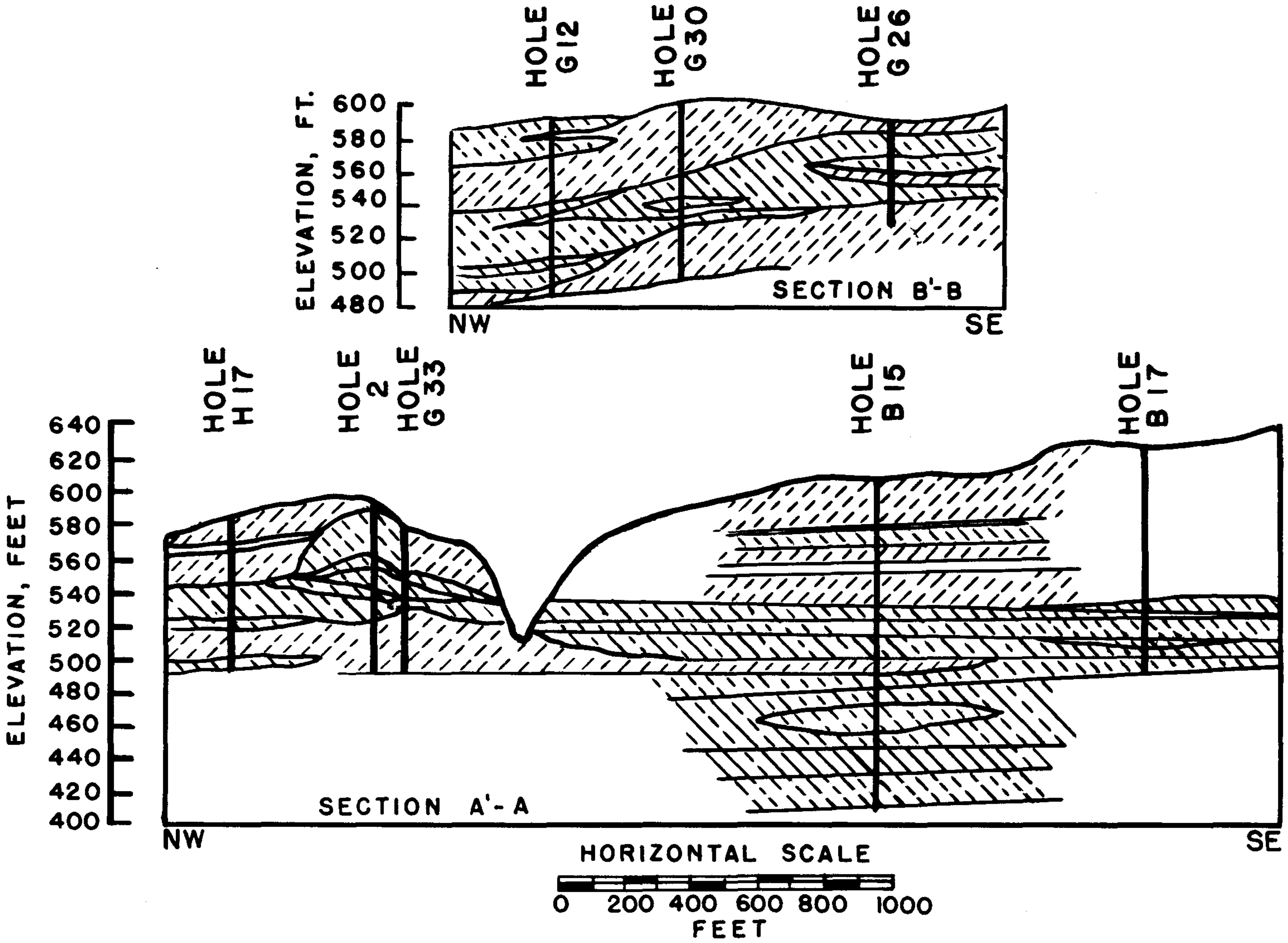

Figure 17. - Idealized sections showing the refractory classification of clay from Molalla deposit, Clackamas County, Oreg.

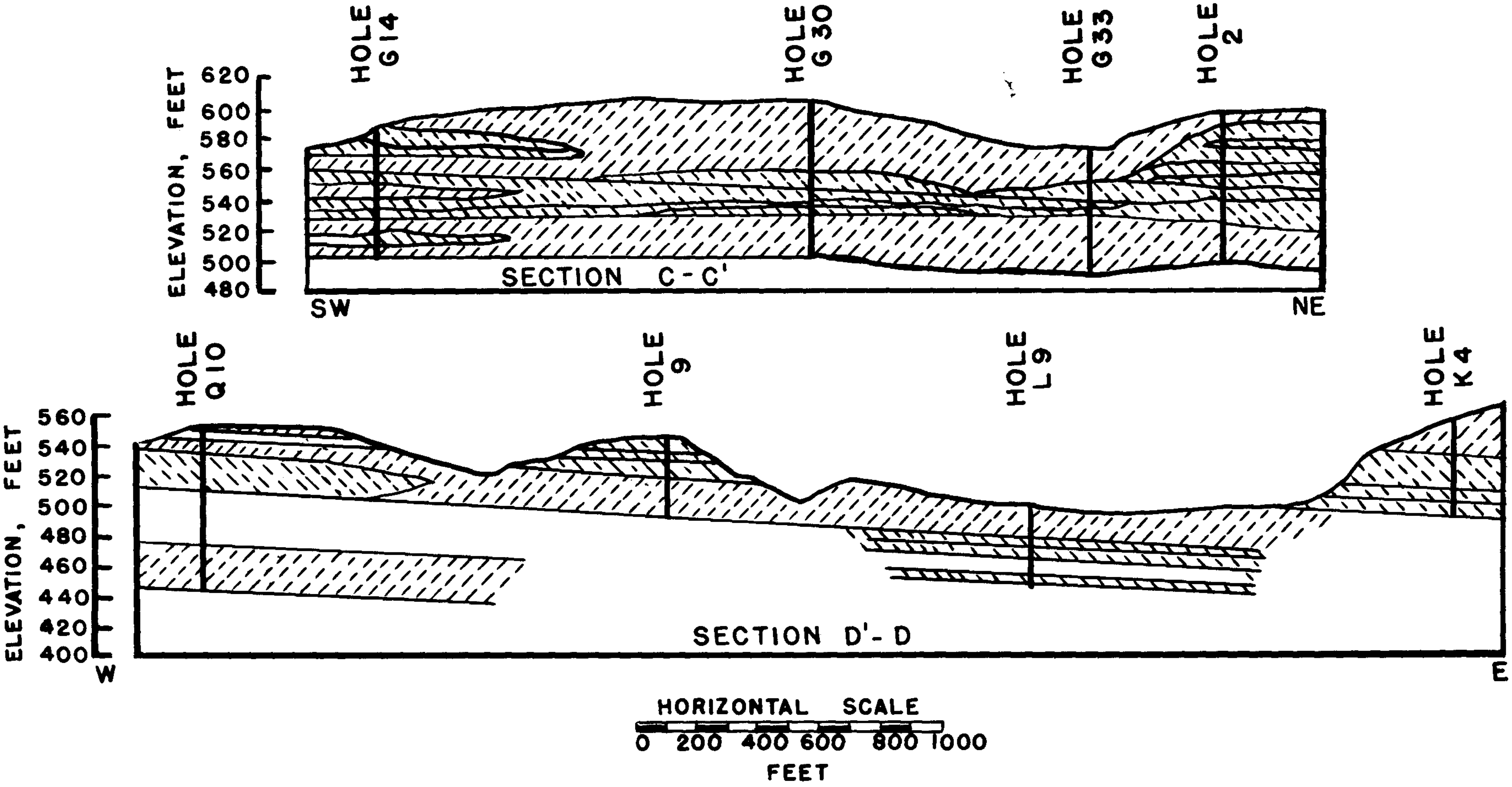

Figure 18. - Idealized sections showing the refractory classification of clay from Molalla deposit, Clackamas County, Oreg.

P.C.E. values and fired colors. - One hundred and eighty samples from the Molalla clay deposit were tested and only 25 percent were classified as high- or intermediate-heat duty. None were in the super-duty group. Intermediate and some high heat-duty clay overlain with little overburden is exposed in hole 9. The total depth of this clay is approximately 25 feet, and it is interbedded with a stratum of low-heat clay. Two beds of high heat-duty clay are found in hole G-14, the upper one being about 9 feet deep and the lower 10 feet. These beds are separated by 7.5 feet of low and nonrefractory clays. The upper bed is overlain with about 8 feet of low heat-duty clay and 2 feet of nonrefractory material. Twelve feet of intermediate clay is shown in hole H-17, but it is overlain with 41 feet of nonrefractory material. This disposition of relatively thin beds of refractory clays interbedded with nonrefractory strata is characteristic of the Molalla deposit. (See figs. 14 through 18 and table 7.)

Reds and browns are the predominate fired colors of the clays from this deposit. Sixty-two percent of the total footage tested had fired colors of red, brown, gunmetal, or black when burned to cone 4.

Hobart Butte, Oreg., Deposit

Located in Lane and Douglas Counties, Oreg., the Hobart Butte clay deposit is about 15 miles south of Cottage Grove and about 37 miles south of Eugene, Oreg. The nearest railroad is at Cottage Grove. The principal clay deposit located on the top and flanks of Hobart Butte is easily accessible to trucks. The butte rises about 1,600 feet above the valley floor to an altitude of about 2,530 feet. The deposit is in sections 1, 6, 31, and 36, T. 22 S., R. 3 and 4 W., Willamette meridian. The most extensive drilling was done in S. W. 1/4 of section 31, in which area the crest of the butte is located.

Total clay reserves in the Hobart Butte deposit exceed 28,898,000 tons, which contain an average of 26.9 percent of available alumina and 4.5 percent of available Fe_2O_3. This tonnage estimate was based upon the first 30 holes drilled by the Bureau of Mines. Since that time, 10 additional holes have been drilled. Of the total tonnage, over 14,000,000 was classified as measured high-grade ore that contained 29.3 percent available alumina and only 3.2 percent of available Fe_2O_3.[18]

The clay mineral, largely a product of the decomposition of volcanics, is classified as a flint-type kaolin. Fine grinding develops but weak plasticity, although stiff mud brick have been made from the clay. Characteristic colors are white, gray, buff, and tan.

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[18] Work cited in footnote 4.

TABLE 7. - Test data for drill-core samples from the Molalla deposit, Clackamas County, Oreg.

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 800° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
HOLE 2													
0-5	24.3	10.5	12.9	39-52	Kaolin	Brick red	SS	Dark red	SS	-	-12	Dk. brown, bloated	Nonrefractory
5-9	24.0	9.8	10.8	45-59	do.	Brown	SS	Brick red	HS	-	19	Dark brown	Low heat
9-19	27.3	7.9	11.7	53-71	Kaolin +M[3]	Lt. brown	SS	do.	SS	-	19-26	do.	Do.
19-23	29.0	3.3	12.4	58-66	do.	do.	SS	Brown	P	White specks, sandy	30	do.	Intermediate
23-32	25.2	7.7	13.7	50-58	Kaolin	Brown	Fr	do.	Fr	do.	19+	do.	Low heat
32-39	30.0	6.2	14.8	50-57	do.	Gray	SS	Dk. gray	SS	Sandy	26+	do.	Intermediate
39-46	31.0	4.6	13.4	62-65	Kaolin +M	do.	SS	Buff	HS	-	31+	Brown	High heat
46-52	31.9	4.5	13.0	60-69	do.	Buff	SS	do.	S	-	31+	do.	Do.
52-58	29.6	6.7	13.6	51-58	Kaolin	do.	SS	Tan	SS	-	26	Black	Low heat
58-66	27.3	6.7	12.6	60-62	Sandy M	do.	SS	do.	SS	Sandy	26+	do.	Intermediate
66-72	24.3	4.2	10.1	57-67	Kaolin +M	Red	Fr	Red	Fr	do.	26	Brown, bloated	Do.
72-80	19.0	3.8	7.9	48-60	Kaolin	Tan	Powd	do.	Powd	-	12-19	do.	Nonrefractory
80-89	21.3	7.0	10.2	49-73	Kaolin +M	do.	Fr	do.	Fr	-	19-	do.	Do.
89-95	19.0	6.2	9.9	41-65	Kaolin	Brown	Fr	do.	SS	-	12	do.	Do.
95-100	18.0	5.8	10.3	50-66	Kaolin +M	do.	SS	do.	S	-	12-19	Brown	Do.
HOLE 9													
2-7	33.1	9.7	13.6	42-58	Kaolin	Tan	SS	Lt. red	HS	-	31	Brown	Intermediate
7-13	33.3	8.0	13.6	46-57	do.	do.	SS	do.	HS	-	31+	do.	High heat
13-17	31.3	13.1	13.1	56-67	Kaolin +M	Lt. brown	SS	Red	HS	-	19-26	do.	Low heat
17-22	35.0	6.1	13.4	51-60	Kaolin	Brown	S	Gunmetal	HS	-	31	do.	Intermediate
22-25	32.7	9.8	13.0	44-65	Kaolin +M	Gunmetal	HS	do.	HS	Bloating	26-31	do.	Do.
25-30	27.6	16.2	14.6	40-48	Kaolin	Brick red	SS	Brick red	SS	Black specks at 4	12+	do.	Nonrefractory
30-37	26.4	16.5	12.7	43-48	do.	Red-brown	SS	Red brown	SS	-	12-	do.	Do.
37-46	21.6	17.7	10.6	50-54	do.	Brick red	SS	Brick red	SS	-	12-19	do.	Do.
HOLE B-15													
0-4.75	14.6	6.4	8.4	47-62	Kaolin	Dk. brown	HS	Dk. red	HS	-	12+	Brown, bloated	Nonrefractory
4.75-20	5.4	3.6	2.5	45-54	do.	do.	SS	Dk. brown	SS	Sandy	-12	do.	Do.
20-28	17.0	5.1	6.9	46-50	do.	Brown	SS	Red brown	SS	do.	12-	Brown	Do.
30-40	20.6	6.0	11.2	55-64	Kaolin +M	Tan	SS	Tan	SS	Gritty	19-26	do.	Low heat
40-51	17.3	5.8	10.6	58-60	Kaolin	do.	SS	Tan	SS	Sandy	12-19	do.	Nonrefractory
51-56	6.9	7.4	6.2	-	-	-	-	-	-	-	-	-	-
56-76	8.5	7.2	4.2	62-84	Kaolin +M	Black	Crumbly	Black	Fr	Sandy	-12	Powdered below 12	Nonrefractory
78-84	28.1	7.6	12.2	48-62	do.	Brown	SS	Brown	Fr	do.	26+	Brown	Intermediate
84-91	26.4	10.4	12.9	56-70	do.	do.	P	Dk. brown	Fr	-	19-26	do.	Low heat
91-97	28.4	9.5	11.9	56-66	do.	Tan	SS	Red	SS	-	19-26	do.	Do.
97-101	30.4	6.8	13.1	27-61	Kaolin	Buff	SS	Tan	SS	White specks at 4	26+	do.	Intermediate
101-109.5	29.7	6.1	12.2	53-62	do.	Gray	SS	do.	SS	-	26+	do.	Do.
109.5-117.0	20.1	10.0	8.8	58-71	Kaolin +M	Red	Powd	Red	Fr	-	12+	Dark brown	Nonrefractory

109.5-117.0	20.1	10.0	8.8	58-71	Kaolin +M	Red	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
117-126	25.5	5.6	11.7	56-70	do.	Tan	Fr	Brown	Fr	-	26-	do.	Low heat
126-130	29.9	7.8	15.4	62-73	do.	do.	Powd	Tan	Powd	-	31-	do.	Intermediate
130-135	30.5	6.8	16.4	56-70	do.	do.	Powd	do.	Powd	-	26-31	do.	Do.
135-141	29.6	7.8	14.9	53-59	Kaolin	Pink	Fr	do.	SS	-	19	do.	Low heat

See footnotes at end of table.

TABLE 7.- Test data for drill-core samples from the Molalla deposit, Clackamas County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 800° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
HOLE B-15 (Cont'd)													
141-148.5	28.7	7.8	14.9	50-63	Kaolin +M[3]	Pink	SS	Buff	S	-	19-26	Dark brown	Low heat
148.5-156.5	27.8	5.9	11.5	60-68	do.	Buff	SS	do.	SS	-	26+	do.	Intermediate
156.5-164.0	28.4	4.2	10.9	66-80	do.	do.	SS	Tan	SS	-	26-31	do.	Do.
164-174	28.4	3.1	10.1	61-74	do.	do.	SS	do.	S	-	31+	Brown	High heat
174-188	13.2	7.6	5.3	55-72	do.	Red	Powd	Brick red	Powd	-	-12	Dark brown	Nonrefractory
HOLE B-17													
			700° C.										
91-96.5	27.6	8.8	12.7	58-66	Kaolin +M	Tan	SS	Brown	SS	-	19+	Dark brown	Low heat
96.5-102.5	28.8	8.2	12.8	49-62	Kaolin	do.	SS	do.	S	-	26-31	do.	Intermediate
102.5-108.0	29.6	8.2	12.4	60-74	Kaolin +M	Lt. brown	SS	do.	SS	-	26-	do.	Low heat
108-114.33	28.7	8.2	12.0	52-65	Kaolin	Tan	SS	do.	S	-	19-26	do.	Do.
114.33-119.0	28.0	6.2	11.7	52-58	do.	do.	SS	do.	S	Speckled at 4	31+	do.	High heat
119-125	28.1	5.6	11.5	56-61	do.	Buff	SS	Buff	SS	-	26-31	do.	Intermediate
125-132	26.5	5.8	11.5	55-62	do.	do.	SS	Tan	S	-	19-26	do.	Low heat
HOLE G-12													
			800° C.										
0-1.5	18.3	11.0	10.2	32-38	Kaolin	Red	SS	Dark red	SS	-	-12	Dk. brown, bloated	Nonrefractory
1.5-8.0	28.2	12.2	11.3	52-60	do.	do.	SS	do.	SS	Light specks at 4	19-26	Dark brown	Low heat
8.0-13	26.3	10.5	11.0	56-65	Kaolin +M	do.	SS	do.	Powd	Light weight at 04	12-19	do.	Nonrefractory
13-23	23.3	5.3	10.1	50-64	Kaolin	Lt. brown	SS	Red	Powd	Light weight	19-26	do.	Low heat
23-27	18.4	6.9	11.2	55-63	do.	Tan	SS	Tan	Fr	do.	12-19	do.	Nonrefractory
27-33	23.0	6.7	10.7	54-66	do.	do.	SS	do.	Powd	do.	12-19	do., bloated	Do.
33-40	25.3	7.4	13.3	55-64	do.	Red	SS	Brown	Fr	do.	19-	Dark brown	Do.
40-50	25.5	5.5	18.5	52-65	Kaolin +M	Tan	SS	Tan	Fr	-	12-19	do., bloated	Do.
50-56	28.0	7.4	15.0	46-57	Kaolin	Buff	SS	Buff	SS	-	19+	Dark brown	Low heat
56-64	27.4	4.8	12.0	52-58	do.	do.	SS	do.	SS	-	26+	do.	Intermediate
64-73	27.8	5.2	12.0	50-58	do.	do.	SS	do.	SS	White specks at 4	19-26	do.	Low heat
73-83	26.7	6.5	12.4	45-58	do.	do.	SS	do.	SS	-	19-26	do.	Do.
83-89	29.1	4.3	12.9	49-65	Kaolin +M	do.	SS	do.	SS	White specks	31+	Brown	High heat
89-95	30.2	3.3	12.3	52-62	Kaolin	do.	SS	Tan	S	-	31+	do.	Do.
95-103	16.8	4.5	10.8	54-68	Kaolin +M	Tan	SS	Brown	SS	-	19+	Dark brown	Low heat
103-107	11.8	7.2	7.9	60-86	Kaolin	Brown	SS	Dark red	SS	-	-12	Jet black	Nonrefractory
HOLE G-14													
0-2	23.0	11.5	10.8	28-52	Kaolin	Red	SS	Dark red	SS	-	12-19	Dk. brown, bloated	Nonrefractory
2-9	30.7	10.3	12.3	50-80	Kaolin +M	do.	S	do.	HS	-	19-26	Dark brown	Low heat
9-18	32.4	4.8	12.7	48-63	Kaolin	Pink	S	Dark gray	HS	-	31-1/2	do.	High heat
18-21	27.6	8.9	13.2	52-58	do.	Buff	SS	Lt. brown	Fr	Light weight	19	do.	Low heat
21-25.5	20.4	4.6	8.2	60-63	Sandy M	Tan	SS	Lt. red	Fr	Light weight	19-	do.	Nonrefractory
25.5-35.5	28.9	2.3	12.0	-	-	-	-	-	-	-	32+	Gray	High heat
35.5-44.0	12.3	2.3	4.3	32-40	Kaolin	Tan	SS	Brown	Powd	-	-12	Jet black	Nonrefractory
44-52	27.8	8.2	12.6	56-60	do.	do.	SS	do.	S	-	19-26	Dark brown	Low heat
52-58	29.4	7.9	12.3	54-64	do.	do.	SS	do.	HS	-	26+	do.	Intermediate

See footnotes at end of table.

TABLE 7. - Test data for drill-core samples from the Molalla deposit, Clackamas County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 800° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
						HOLE G-14 (Cont'd)							
58-63	22.3	9.1	11.2	62-72	Kaolin +M[3]	Tan	SS	Red	HS	-	19-	Dark brown	Nonrefractory
63-67	20.9	15.1	11.3	69-76	M	Red	SS	do.	Fr	-	-12	do.	Do.
67-73	26.3	5.2	11.4	58-67	Kaolin +M	Tan	SS	Brown	HS	-	26	do.	Low heat
73-81	16.6	7.6	11.2	56-64	Kaolin	do.	SS	Red	SS	-	-12	Black	Nonrefractory
81-88.5	10.4	8.6	6.6	90-97	M	Brown	SS	Dark red	Fr	-	-12	do.	Do.
88.5-92.0	6.7	7.9	4.7	80-88	do.	Red	Powd	do.	Powd	-	-12	do.	Do.
						HOLE G-26							
			700° C.										
0-5.33	21.3	12.8	9.5	42-60	Kaolin	Brick red	SS	Brick red	S	-	12+	Dark brown	Nonrefractory
5.33-16.5	30.4	7.2	11.8	44-51	do.	Tan	SS	Tan	S	-	31	do.	Intermediate
16.5-20.5	28.8	5.3	11.9	47-58	do.	Buff	SS	Buff	SS	-	31-	do.	Do.
20.5-28.5	24.7	7.4	11.1	44-59	do.	do.	SS	do.	SS	-	19	do.	Low heat
28.5-32.0	22.0	9.1	11.1	41-54	do.	Tan	SS	Pink	SS	-	12-19	do.	Nonrefractory
32-33	25.3	7.4	11.2	50-58	do.	Buff	SS	Tan	SS	-	19-26	do.	Low heat
33-39	22.3	8.1	11.8	45-59	do.	Tan	SS	Pink	Fr	Light weight at 04	12-19	do.	Nonrefractory
39-45.5	25.6	4.1	9.6	47-57	do.	Buff	SS	Buff	Fr	do.	26+	Speckled brown	Intermediate
45.5-51.5	21.4	7.0	9.6	49-68	Kaolin +M	Lt. brown	SS	Red	SS	-	19-	Dark brown	Nonrefractory
51.5-54.5	17.8	7.7	9.1	68-81	M	Tan	SS	do.	SS	-	12-19	Black	Do.
54.5-57.5	18.1	8.5	8.8	68-75	do.	Lt. brown	SS	do.	SS	-	12	Dark brown	Do.
57.5-64.0	17.1	6.9	8.3	67-74	do.	do.	SS	do.	Fr	-	12	do.	Do.
64-67	20.7	6.3	8.8	68-72	do.	Tan	SS	do.	Fr	-	19-	do.	Do.
67-72	14.0	8.1	6.4	74-85	do.	Red	Fr	do.	P	-	-12	do.	Do.
						HOLE G-30							
0-4	19.7	10.1	9.3	31-40	Kaolin	Brick red	SS	Brick red	SS	-	-12	Brown, bloated	Nonrefractory
4-8	28.8	10.4	11.1	42-62	do.	Red	SS	do.	SS	-	12-19	do.	Do.
8-15	28.0	11.8	10.7	38-60	do.	do.	SS	Red	Fr	White specks at 4	12-19	do.	Do.
15-20	24.8	8.5	11.2	42-63	do.	Dark red	SS	Dark red	Fr	-	12-19	Brown	Do.
20-26	22.4	9.0	11.6	45-67	Kaolin +M	Red	Powd	Red	Powd	-	-12	Brown, bloated	Do.
26-30	22.4	8.8	10.7	42-54	Kaolin	do.	SS	do.	Fr	Light weight	12+	Brown	Do.
30-32.3	24.1	8.6	9.0	44-62	do.	do.	Powd	Dark red	Powd	-	-12	Brown, bloated	Do.
32.3-33	25.2	9.4	10.3	49-65	Kaolin +M	do.	Powd	do.	Powd	-	12-19	do.	Do.
33-35	22.9	9.3	10.0	46-61	Kaolin	do.	Powd	do.	Powd	-	12	do.	Do.
35-41.25	28.6	9.7	13.0	48-62	do.	Brown	SS	Brown	Fr	-	-12	Brown	Do.
41.25-45.0	25.7	10.4	11.0	52-72	Kaolin +M	Red	Fr	Dark red	Powd	-	12-19	Brown, bloated	Do.
45-52	29.2	5.8	11.9	51-64	Kaolin	Buff	SS	Tan	SS	-	31-	Brown	Intermediate
52-58	28.3	6.2	11.8	60-73	M + Kaolin	do.	SS	Buff	SS	-	26	do.	Do.
58-64	30.7	4.3	12.3	41-59	Kaolin	do.	S	Tan	S	-	31-32	do.	High heat
64-67	28.7	5.8	12.0	44-60	do.	Tan	SS	Brown	S	-	31	do.	Intermediate
67-73	27.9	8.5	12.2	48-63	do.	do.	SS	do.	SS	-	26-	do.	Low heat
73-77	22.8	16.0	12.7	52-65	Kaolin +M	do.	SS	Red	Fr	-	-12	do.	Nonrefractory
77-80	23.7	17.5	12.0	52-70	do.	Red	SS	Brick red	Fr	-	-12	Brown, bloated	Do.
80-85	26.4	7.0	11.0	46-57	Kaolin	Lt. brown	SS	Red	SS	-	12-19	Brown, glassy	Do.
85-90	26.7	6.7	11.2	45-58	do.	Tan	SS	Lt. brown	S	-	26	Brown	Intermediate
90-99	22.3	7.1	9.9	52-66	Kaolin +M	do.	SS	Red	SS	-	-12	Brown, bloated	Nonrefractory
99-103	12.9	9.8	7.1	71-89	M	Red	Fr	Dark red	Fr	-	-12	do.	Do.

See footnotes at end of table.

TABLE 7. - Test data for drill-core samples from the Molalla deposit, Clackamas County, Oreg. (Cont'd)

85-90	26.7	6.7	11.2	45-58	do.	Tan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
90-99	22.3	7.1	9.9	52-66	Kaolin +M	do.	SS	Red	SS	-	-12	Brown, bloated	Nonrefractory
99-103	12.9	9.8	7.1	71-89	M	Red	Fr	Dark red	Fr	-	-12	do.	Do.

See footnotes at end of table.

TABLE 7. - Test data for drill-core samples from the Molalla deposit, Clackamas County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.			Cone 04		Cone 4					
	Al_2O_3	Fe_2O_3		Range	Indicated clay type	Color	Hardness[1]	Color	Hardness[1]	Remarks	P.C.E. cone	Fired cone color	Refractory classification[2]
						HOLE G-33							
0-3.5	22.6	9.4	10.1	34-60	Kaolin +M[3]	Brown	S	Red brown	HS	-	-12	Brown, bloated	Nonrefractory
3.5-7	22.1	7.8	9.2	38-65	do.	do.	S	do.	HS	-	-12	Tan, bloated	Do.
7-9	25.4	9.7	10.2	40-68	do.	do.	S	Gunmetal	HS	-	-12	Brown, ruptured	Do.
9-13	23.3	17.3	10.0	41-58	Kaolin	Brick red	SS	Brick red	S	Black specks at 4	-12	Brown, bloated	Do.
13-15	18.6	7.8	7.7	34-43	do.	Red	Powd	Red & black	Fr	Started to clinker	-12	Brown	Do.
15-19	30.9	2.8	12.0	40-55	do.	Brown	Fr	Brown	Fr	White specks at 04	12-19	do.	Do.
19-24	27.1	11.4	14.7	38-62	do.	Dk. gray	S	Lt. brown	HS	-	19	do.	Low heat
24-31	28.2	9.9	14.5	44-71	Kaolin +M	do.	S	Red brown	HS	-	19-26	Dark brown	Do.
31-37	32.4-	4.3	12.5	46-70	do.	Buff	HS	Dk. brown	HS	-	31+	Dark tan	High heat
37-41.5	30.6	7.1	12.2	43-65	Kaolin	Tan	S	Red	HS	Black specks at 4	26	Dark brown	Intermediate
41.5-42.5	24.8	15.8	9.2	45-75	Kaolin +M	Red brown	P	Dk. red	Powd	-	12-	Gunmetal	Nonrefractory
42.5-48.0	24.6	10.7	13.2	50-64	Kaolin	Tan	SS	Red	Fr	Black specks at 4	19-	Brown	Do.
48-54	23.5	11.7	14.8	56-64	do.	do.	SS	do.	Fr	do.	12-19	Brown, melted	Do.
54-61.5	25.4	9.1	11.6	60-70	Kaolin +M	do.	SS	Red brown	S	do.	12-19	do.	Do.
61.5-67	20.7	12.2	9.6	62-74	M	Brown	SS	Red	SS	do.	12-19	Gunmetal	Do.
67-73	26.6	5.9	11.1	48-63	Kaolin	Brown	Fr	Brick red	Fr	-	12-19	Brown, bloated	Do.
73-79	23.1	7.9	10.1	52-62	do.	Tan	SS	Lt. brown	S	-	12+	do.	Do.
						HOLE H-17							
0-6.5	22.3	10.4	10.4	35-47	Kaolin	Red	SS	Dark red	S	-	-12	Gunmetal	Nonrefractory
6.5-11.5	25.4	11.2	9.8	43-54	do.	do.	SS	Red	SS	-	19-	do.	Do.
11.5-15.5	23.3	9.7	9.4	40-61	do.	Brick red	Fr	Dark red	Fr	Black specks at 4	12	Black	Do.
15.5-18.0	31.5	4.3	11.9	52-63	do.	Dark gray	SS	Tan	HS	-	31+	Brown	High heat
18-23.5	25.8	8.6	12.6	53-67	Kaolin +M	Dk. brown	Fr	Dk. brown	Fr	-	12-19	Gunmetal	Nonrefractory
23.5-28.16	25.3	8.2	11.7	52-63	Kaolin	Lt. red	P	do.	Fr	-	12-19	do.	Do.
28.16-35.0	24.9	9.1	13.2	48-64	do.	Lt. brown	Fr	Dk. brown	Fr	-	19-	do.	Do.
35-41	25.7	8.7	11.7	54-64	do.	do.	P	Dk. red	Powd	-	-12	Brown, bloated	Do.
41-46.5	28.7	7.9	14.0	52-61	do.	do.	SS	Brown	HS	Black specks at 4	26+	Dark brown	Intermediate
46.5-53.0	30.2	8.2	12.6	60-74	Kaolin +M	Tan	SS	do.	S	-	26+	do.	Do.
53-59.5	31.1	6.3	12.8	58-74	do.	do.	SS	do.	S	-	31-	do.	Do.
59.5-65.5	30.6	7.7	12.9	61-72	do.	do.	SS	Red	HS	Black specks at 4	26-	do.	Low heat
65.5-71.5	29.3	11.5	12.9	61-74	do.	do.	SS	Gunmetal	HS	-	19-	Gunmetal	Nonrefractory
71.5-77.5	27.1	14.4	12.9	55-65	Kaolin	do.	SS	do.	S	-	-12	Red brown	Do.
77.5-83.0	27.5	8.9	11.8	61-68	Kaolin +M	do.	SS	Lt. brown	S	-	12-19	Brown	Do.
83-89	26.4	11.8	12.7	55-63	Kaolin	do.	S	do.	S	-	19-26	Brown, bloated	Low heat
89-92	24.0	17.6	12.0	56-72	Kaolin +M	Red	Fr	Dk. red	Fr	Black specks at 4	-12	Red brown	Nonrefractory

See footnotes at end of table.

TABLE 7. - Test data for drill-core samples from the Molalla deposit, Clackamas County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 800° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
HOLE K-4													
0-3	15.3	8.2	9.4	35-42	Kaolin	Red brown	SS	Gunmetal	HS	-	-12	Brown, bloated	Nonrefractory
3-8.5	17.3	10.1	7.8	38-58	do.	do.	SS	do.	HS	-	-12	do.	Do.
8.5-17.5	28.0	9.6	11.5	46-54	do.	do.	SS	Lt. brown	SS	-	19-	Brown	Do.
17.5-23.0	31.9	9.8	12.3	51-66	Kaolin +M[3]	do.	S	Gunmetal	HS	-	12-19	do.	Do.
23-33	32.9	8.4	15.2	60-71	do.	Gray	SS	Red	HS	Black specks at 4	19+	do.	Low heat
33-37	36.0	9.3	15.2	50-59	Kaolin	Tan	SS	Dk. red	HS	-	19+	do.	Do.
37-44	32.3	9.1	16.2	54-61	do.	Lt. brown	SS	Lt. brown	S	Black specks at 4	19+	do.	Do.
44-50	32.8	5.7	13.2	57-70	Kaolin +M	Gray	SS	Tan	S	-	31+	do.	High heat
50-53	32.9	5.5	13.3	60-71	do.	Lt. gray	SS	do.	HS	-	32-	do.	Do.
53-60	26.5	5.8	11.3	45-59	Kaolin	Buff	Fr	do.	Fr	-	19-26	Brown, bloated	Low heat
HOLE L-9			700° C.										
1.5-7.5	30.1	11.5	12.1	44-68	Kaolin +M	Lt. red	S	Gunmetal	HS	-	12-19	Brown, bloated	Nonrefractory
7.5-12.0	31.9	11.9	13.0	50-69	do.	Lt. brown	S	do.	HS	-	12-19	do.	Do.
12.0-17.5	30.6	11.2	14.0	58-73	do.	Tan	SS	Red brown	HS	Badly cracked at 4	12-19	do.	Do.
17.5-22.5	29.6	9.8	13.9	45-68	do.	Buff	SS	Lt. brown	HS	-	26+	do.	Intermediate
22.5-25.5	28.8	12.2	14.8	44-56	Kaolin	Tan	SS	do.	HS	-	19+	Brown	Low heat
25.5-31.0	30.0	10.2	12.6	46-62	do.	Red	Fr	Dk. red	Fr	-	19-26	do.	Do.
31.0-36.5	28.7	10.9	13.0	-	-	-	-	-	-	-	-	-	-
36.5-41.0	30.2	7.6	12.0	-	-	-	-	-	-	-	-	-	-
41-46	33.0	7.0	12.9	42-62	Kaolin	Red	S	Dk. red	HS	-	31-	Brown	Intermediate
46-51	31.6	9.6	14.4	42-59	do.	do.	SS	Gunmetal	HS	-	19	do.	Nonrefractory
HOLE Q-10													
0-5	32.0	2.3	11.9	41-62	Kaolin	Buff	SS	Tan	HS	-	32	Speckled tan	High heat
5-11.5	16.8	10.3	7.7	26-39	do.	Red	Fr	Dk. red	Fr	Black specks at 4	-12	Black, glassy	Nonrefractory
11.5-17.0	30.4	12.0	12.1	39-68	Kaolin +M	do.	S	Gunmetal	HS	-	26-	Brown	Low heat
17-27	29.9	9.8	12.1	40-76	do.	do.	S	do.	HS	-	19+	do.	Do.
27-37	26.9	7.3	10.4	40-72	do.	Red brown	S	Brown	HS	-	19-26	do.	Do.
37-47	30.1	8.9	11.7	42-74	do.	Red	SS	Gunmetal	HS	-	26-	do.	Do.
47-57	32.8	10.9	12.9	44-68	do.	Red brown	SS	do.	HS	-	26-	do.	Do.
57-67	31.5	11.9	13.6	-	-	-	-	-	-	-	-	-	-
67-73	32.6	9.4	14.0	-	-	-	-	-	-	-	-	-	-
73-83	30.4	12.8	13.5	44-63	Kaolin	Brick red	SS	Gunmetal	HS	-	19-	Brown	Nonrefractory
83.0-92.5	26.5	17.7	11.6	39-74	Kaolin +M	Lt. brown	SS	Red brown	SS	-	-12	Gunmetal	Do.
92.5-100.0	24.1	22.4	11.1	41-54	Kaolin	Red	Fr	Dark red	SS	Black specks at 4	-12	do.	Do.

[1] SS = Softer than steel; S = Equal to steel; HS = Harder than steel; Fr = Friable; P = Punky; Powd = Powder.
[2] A.S.T.M. designation by P.C.E. only.
[3] Montmorillonite.

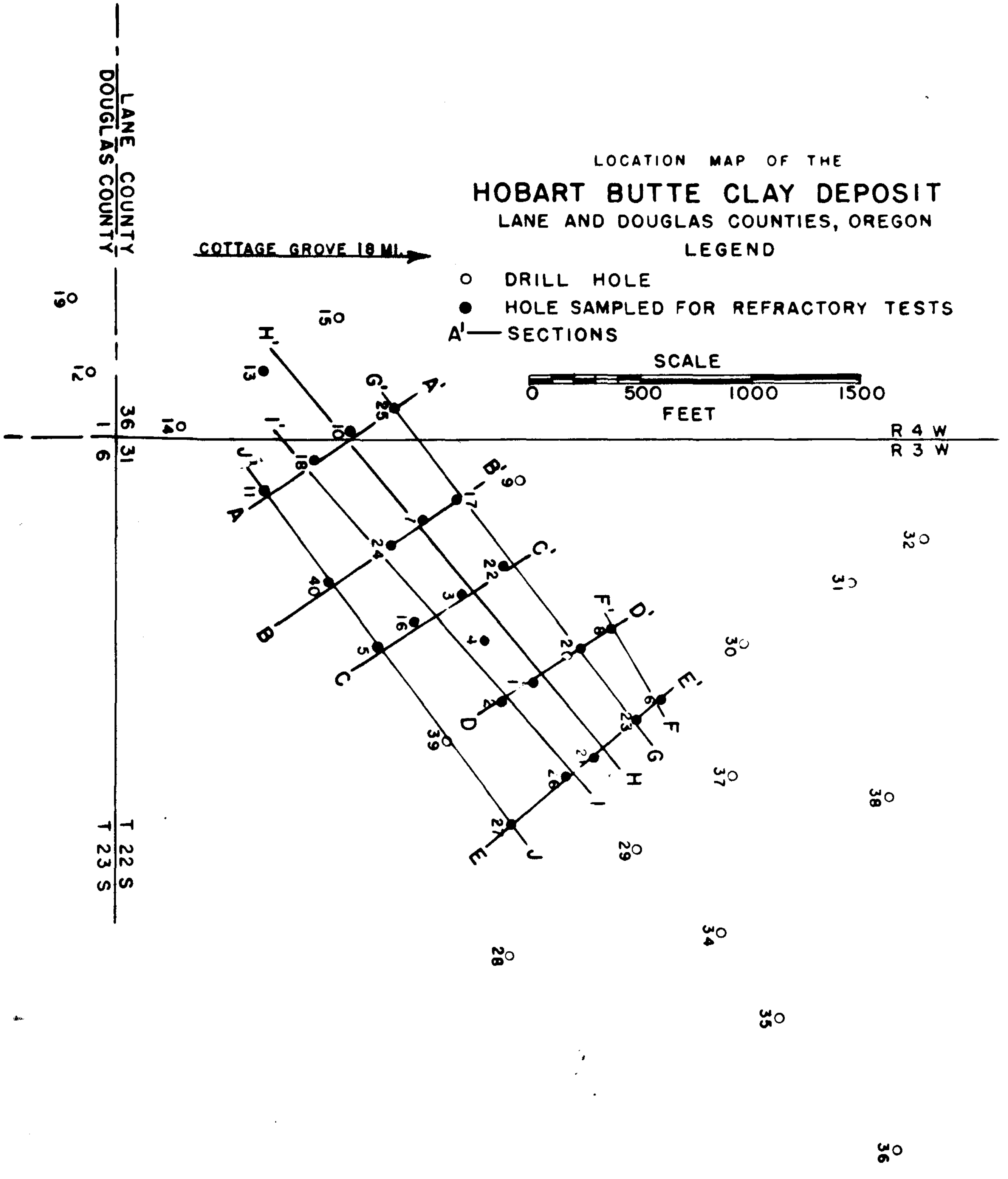

Figure 19. - Map showing the location of drill holes for the Hobart Butte clay deposit, Lane and Douglas Counties, Oreg.

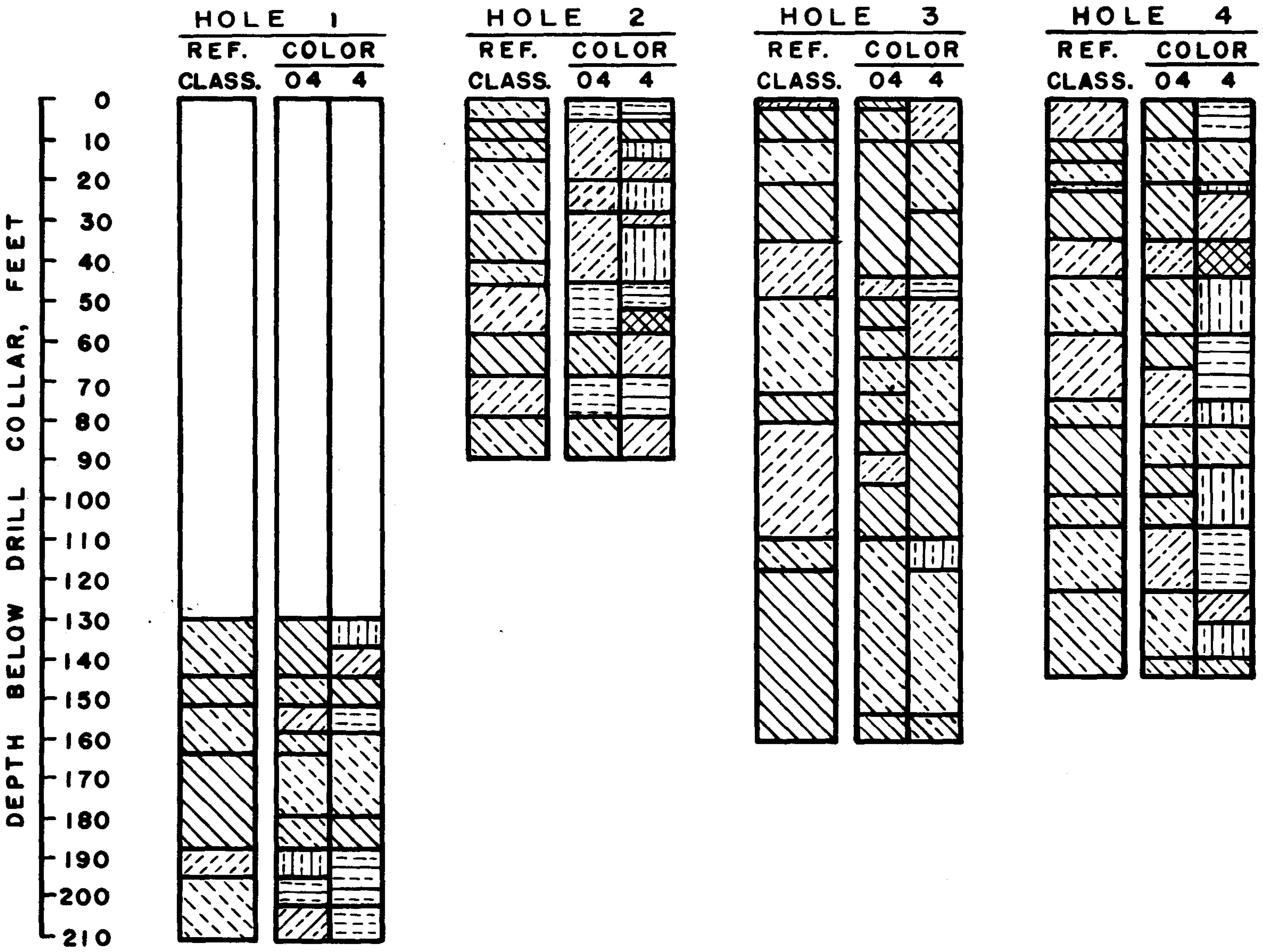

Figure 20. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Hobart Butte deposit, Lane and Douglas Counties, Oreg. (See fig. 24 for legend for figs. 20-24.)

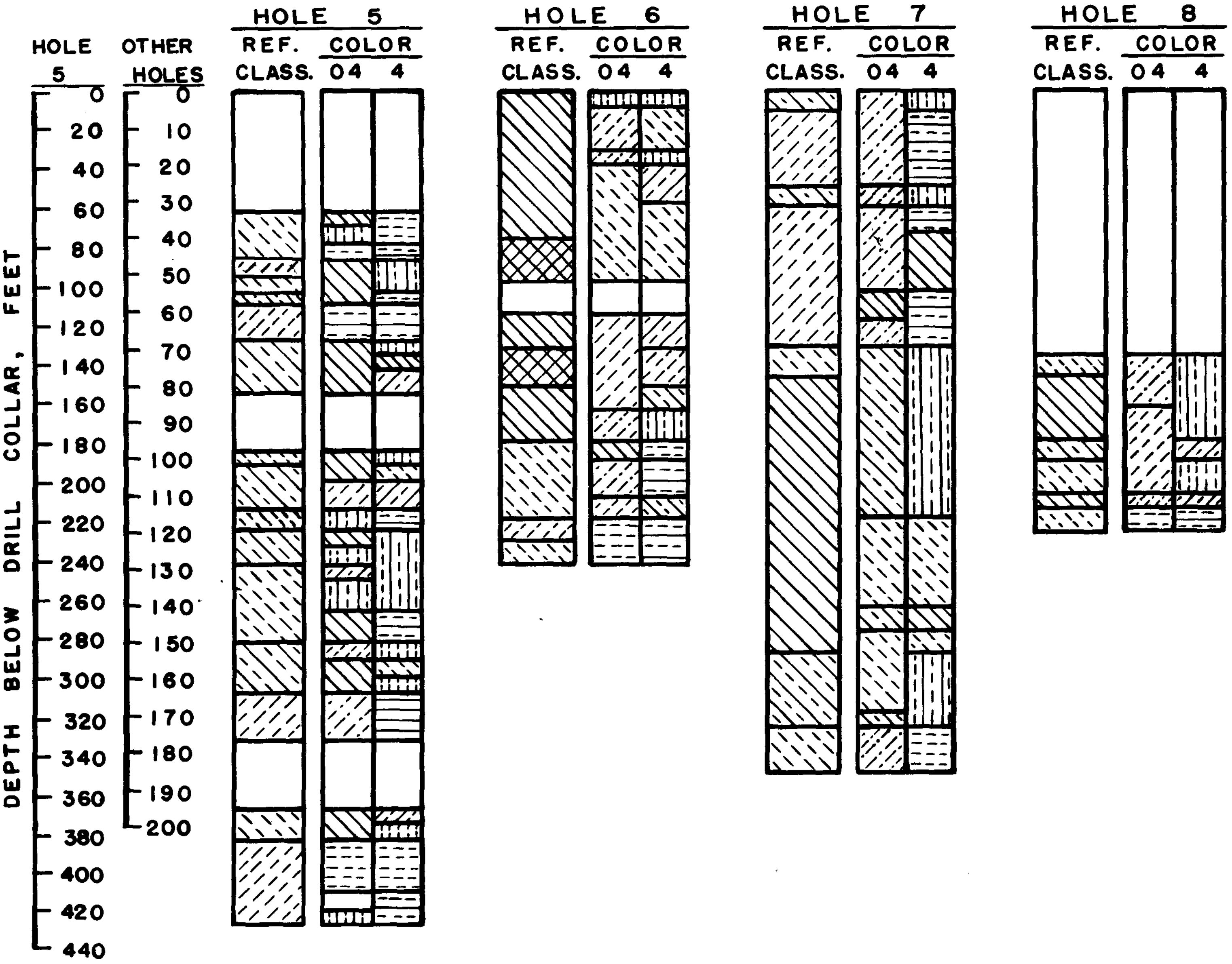

Figure 21. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

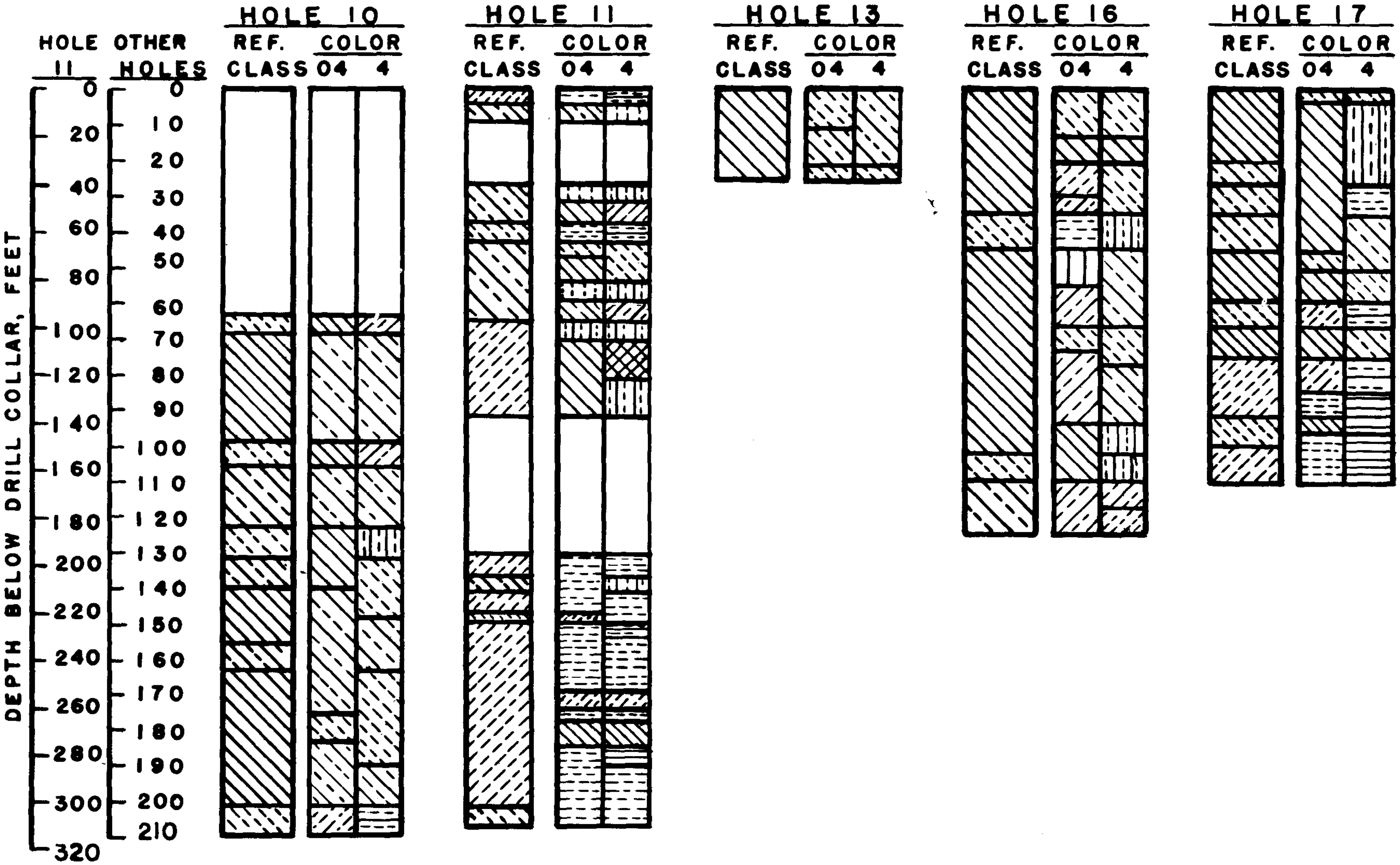

Figure 22. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

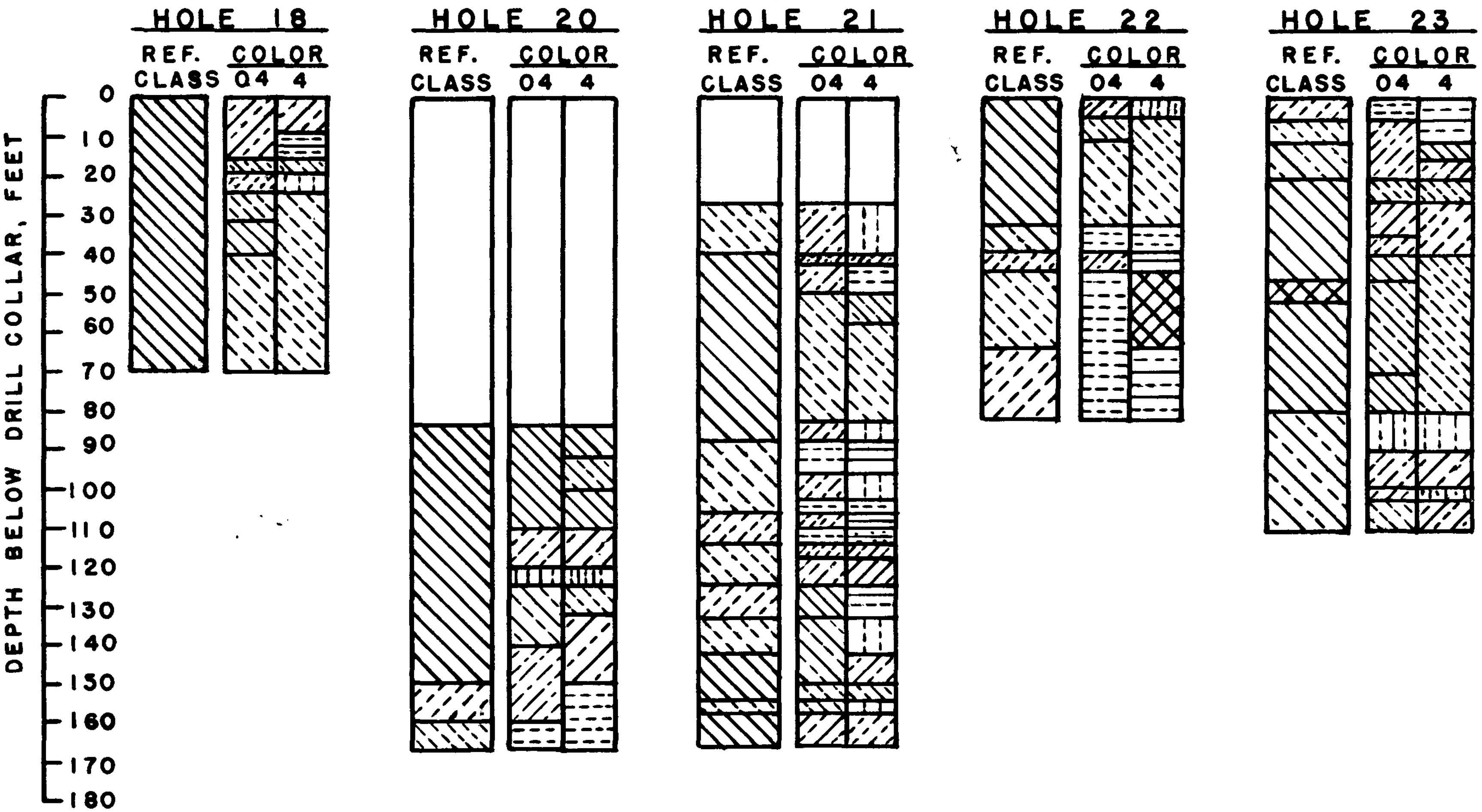

Figure 23. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

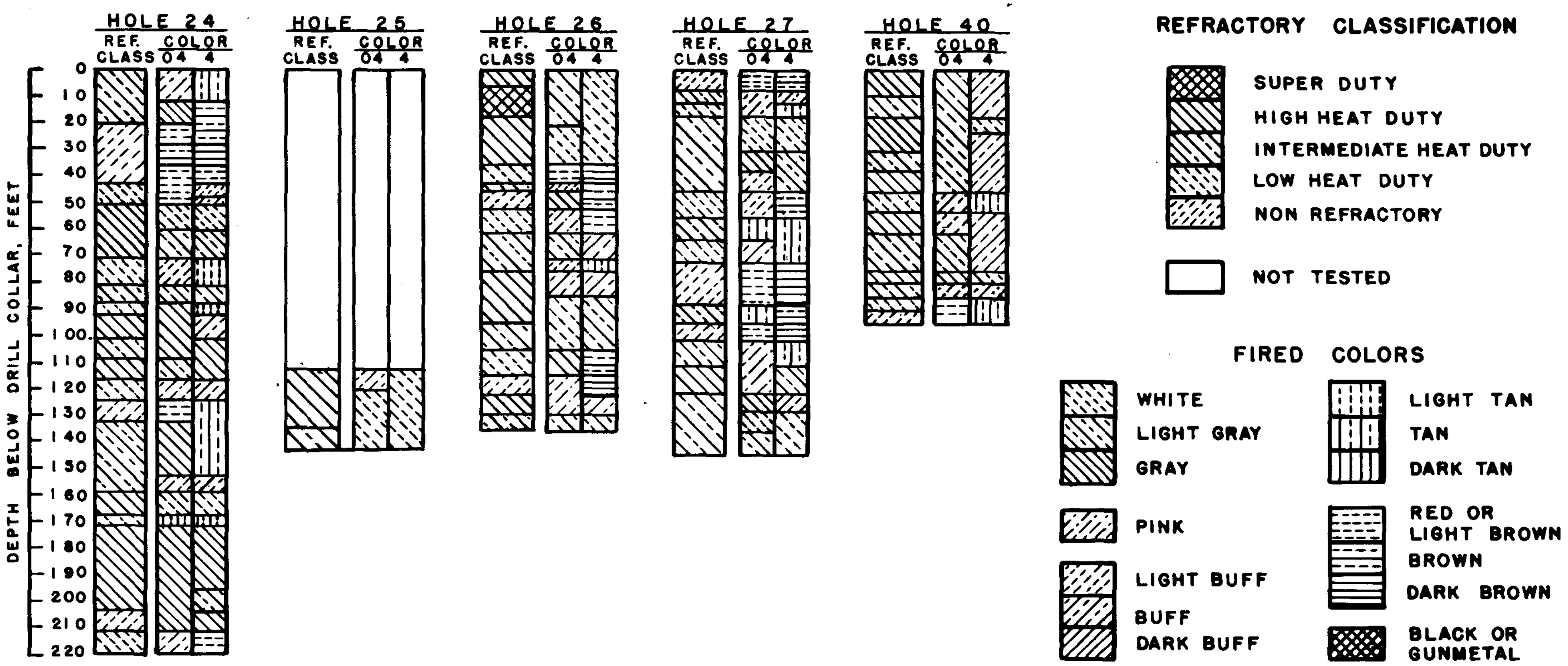

Figure 24. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

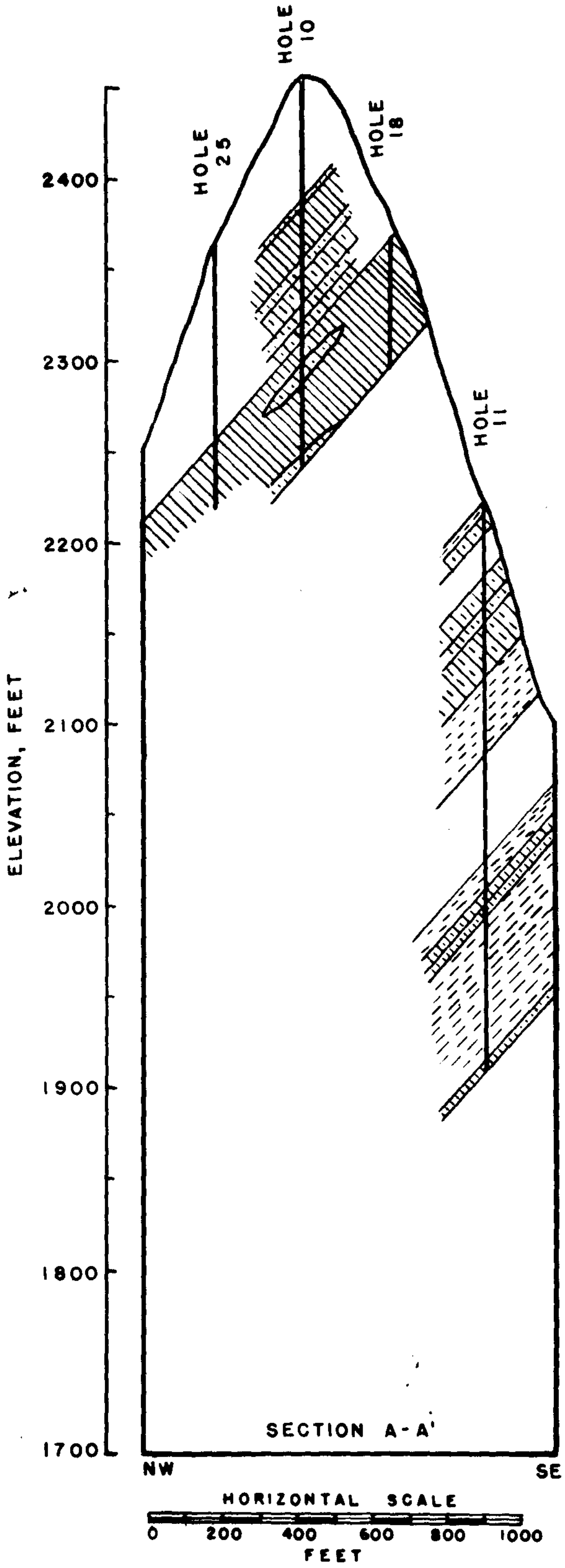

Figure 25. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

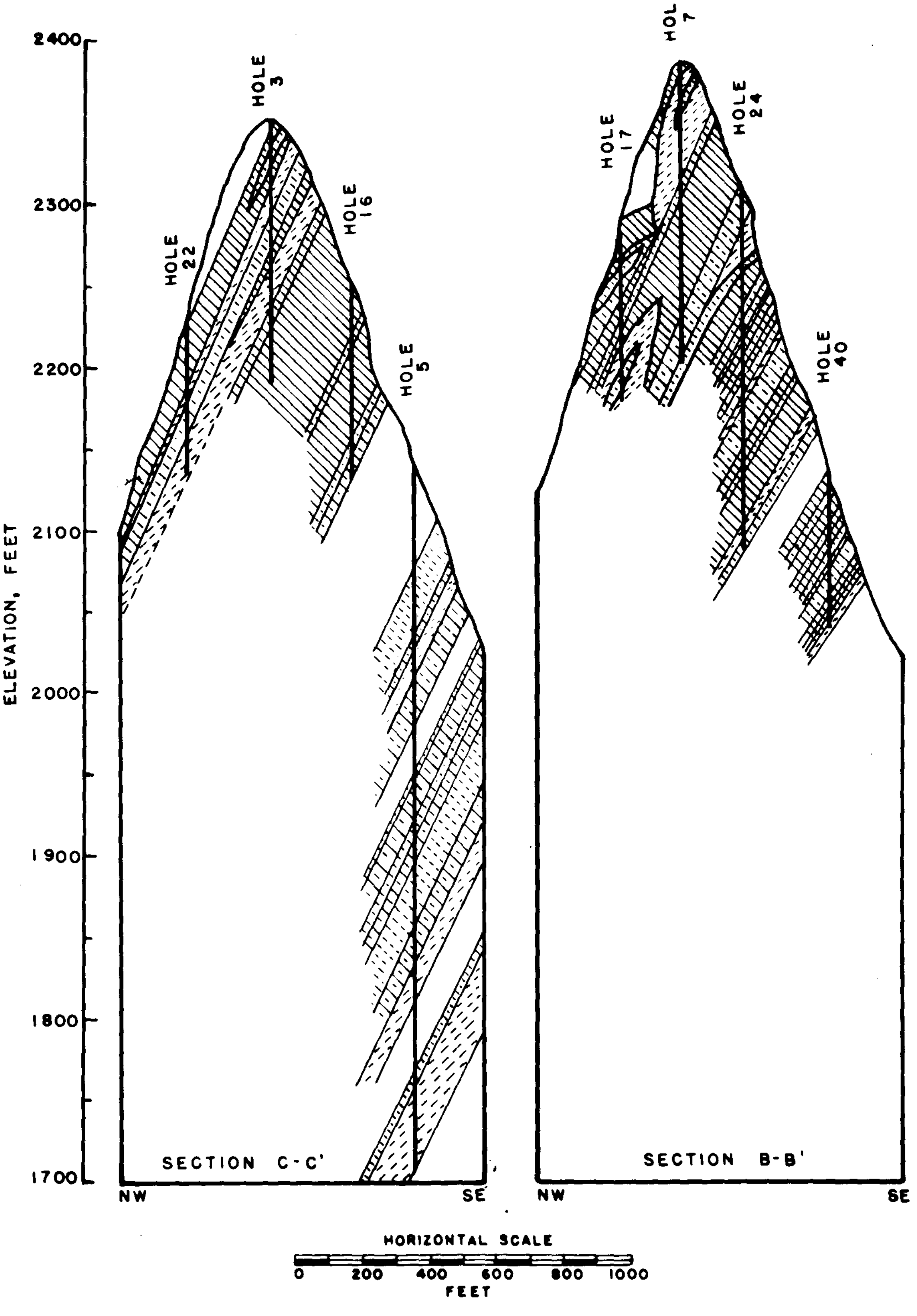

Figure 26. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

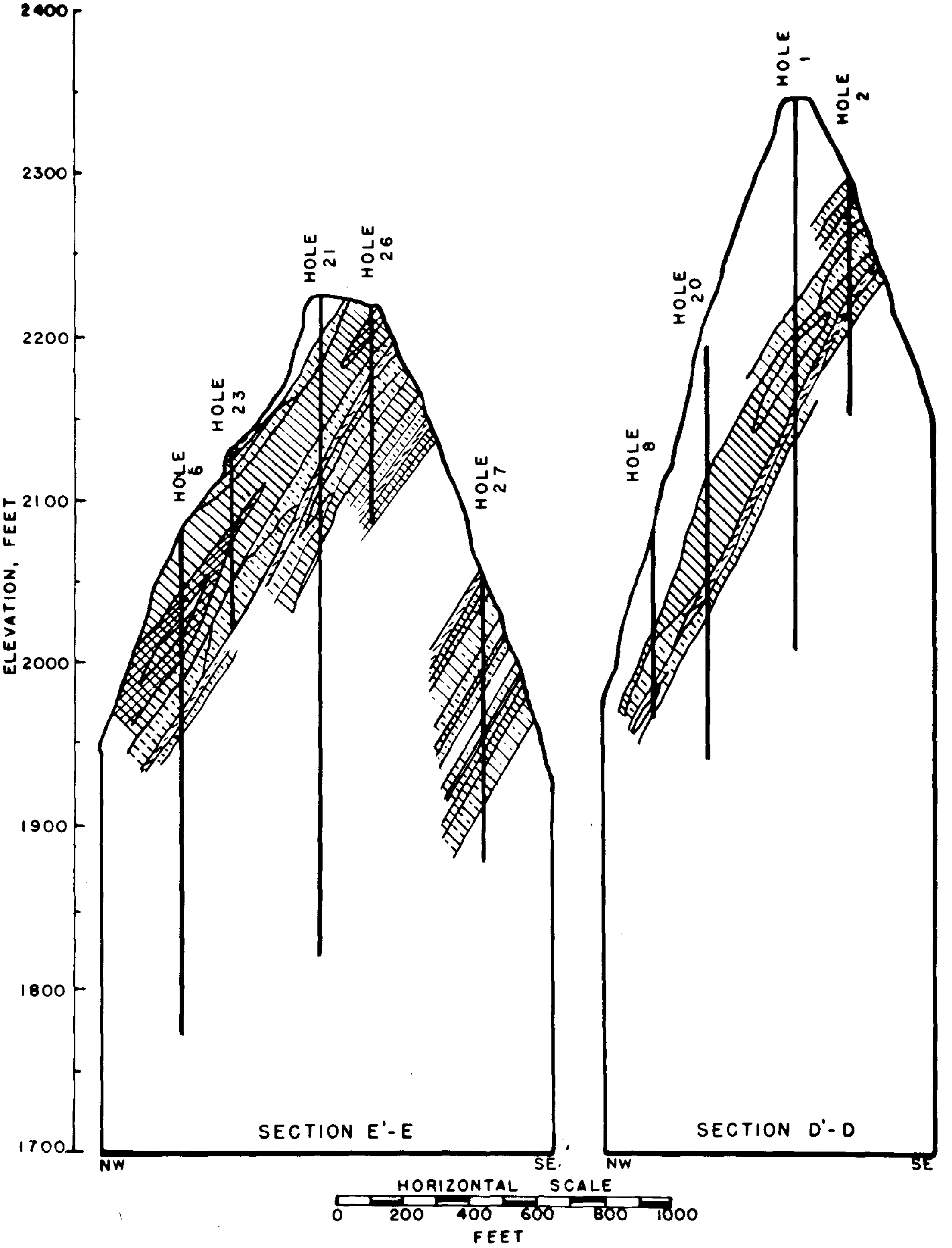

Figure 27. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

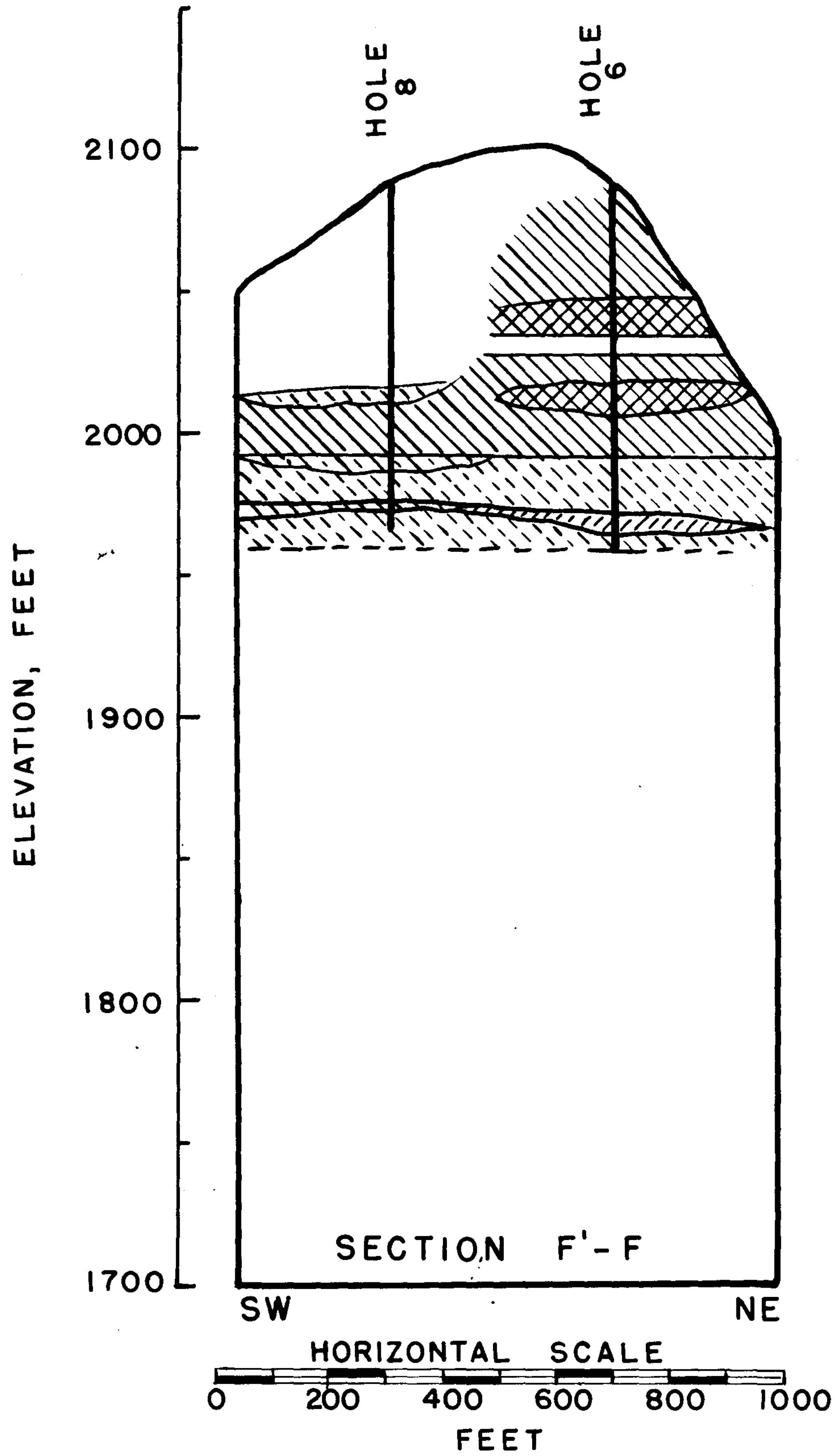

Figure 28. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

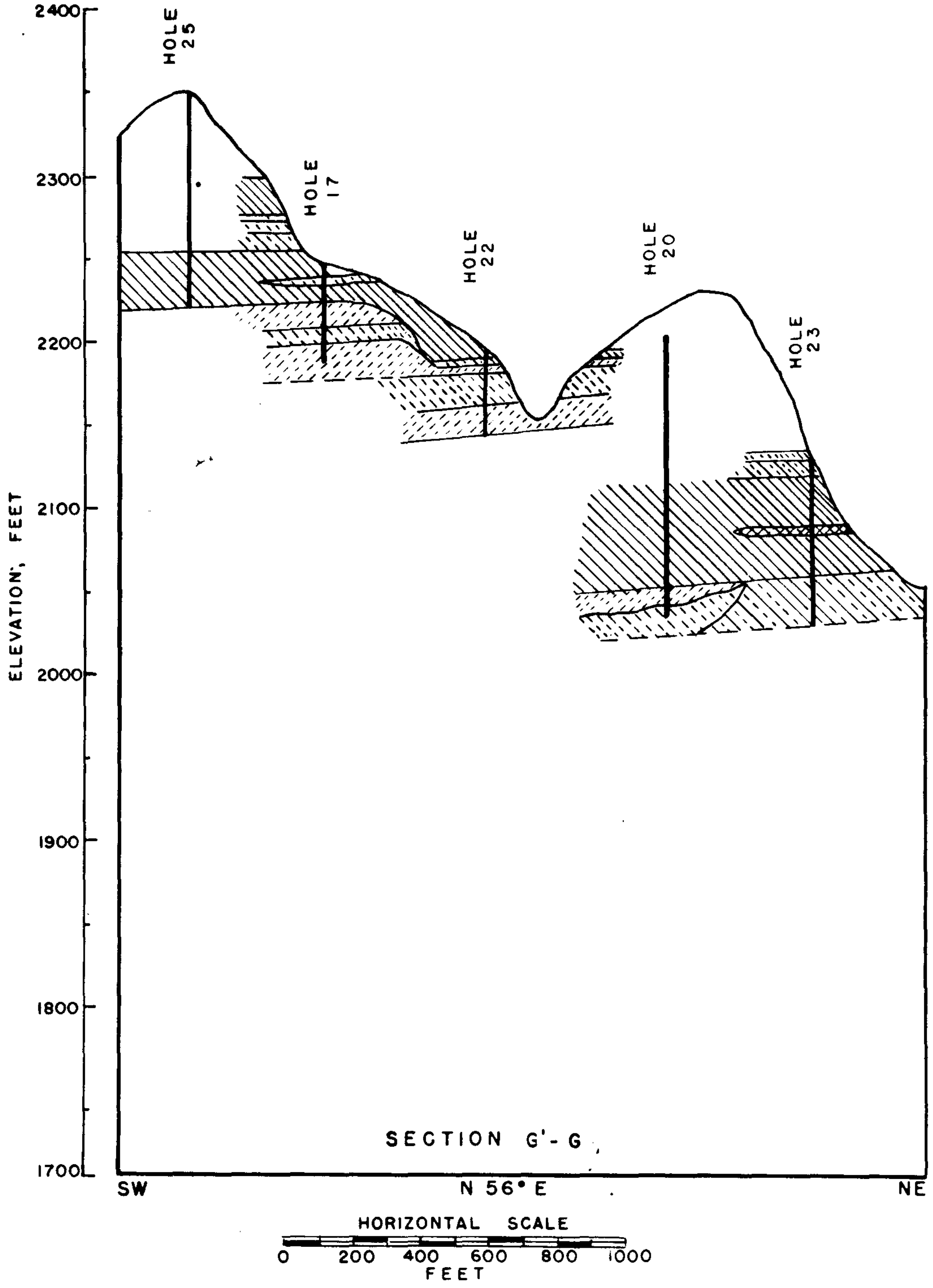

Figure 29. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

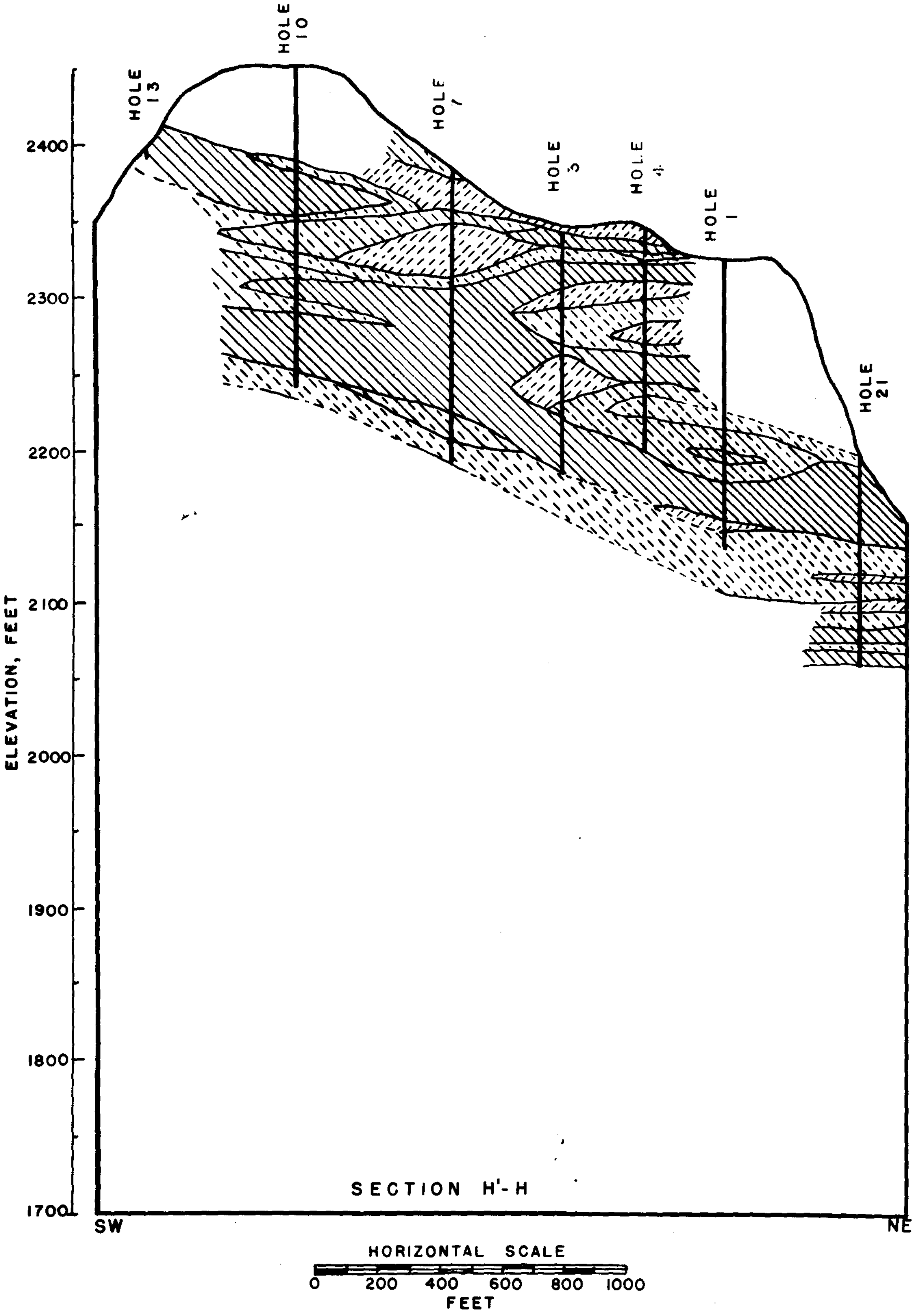

Figure 30. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

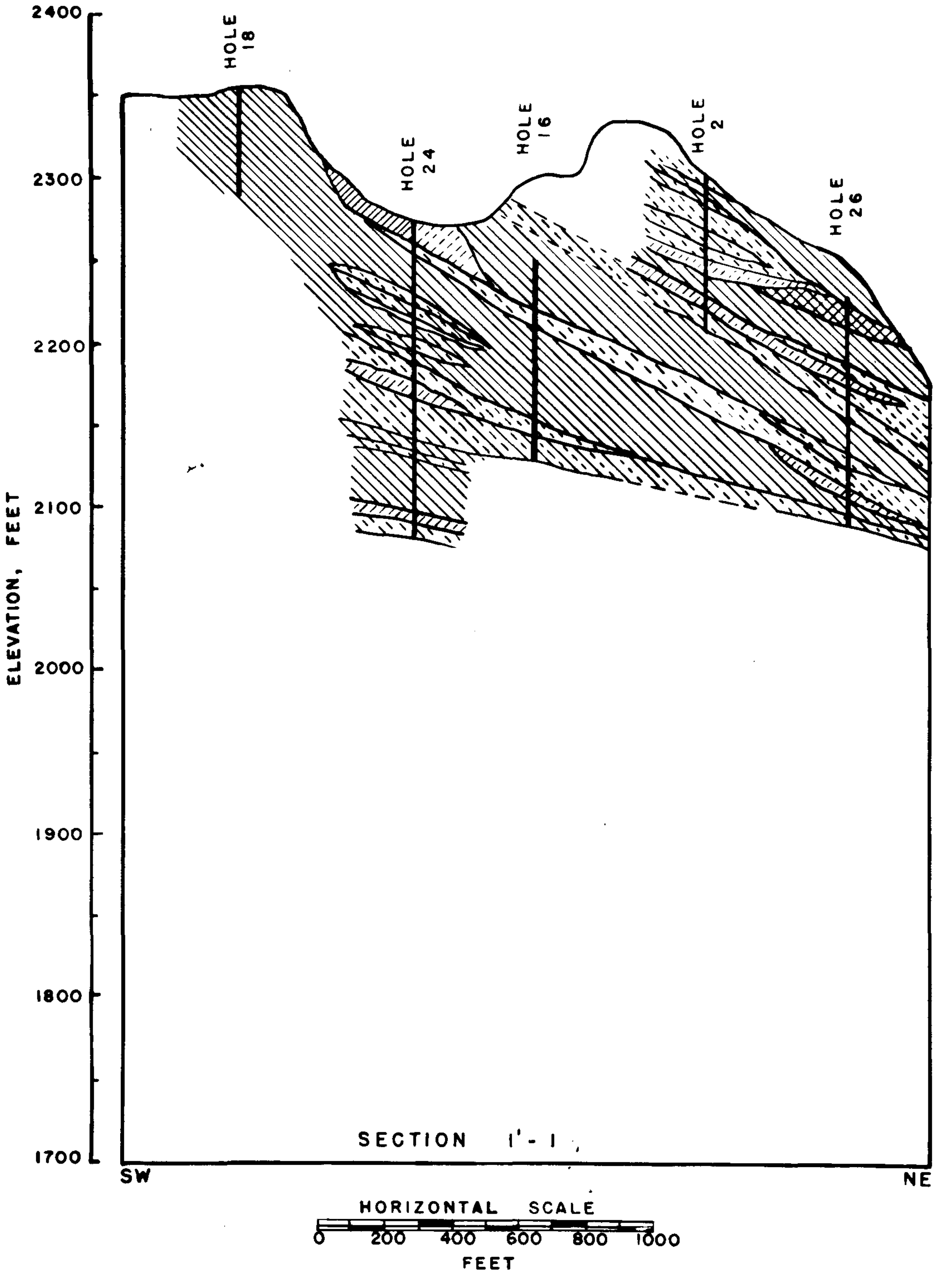

Figure 31. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

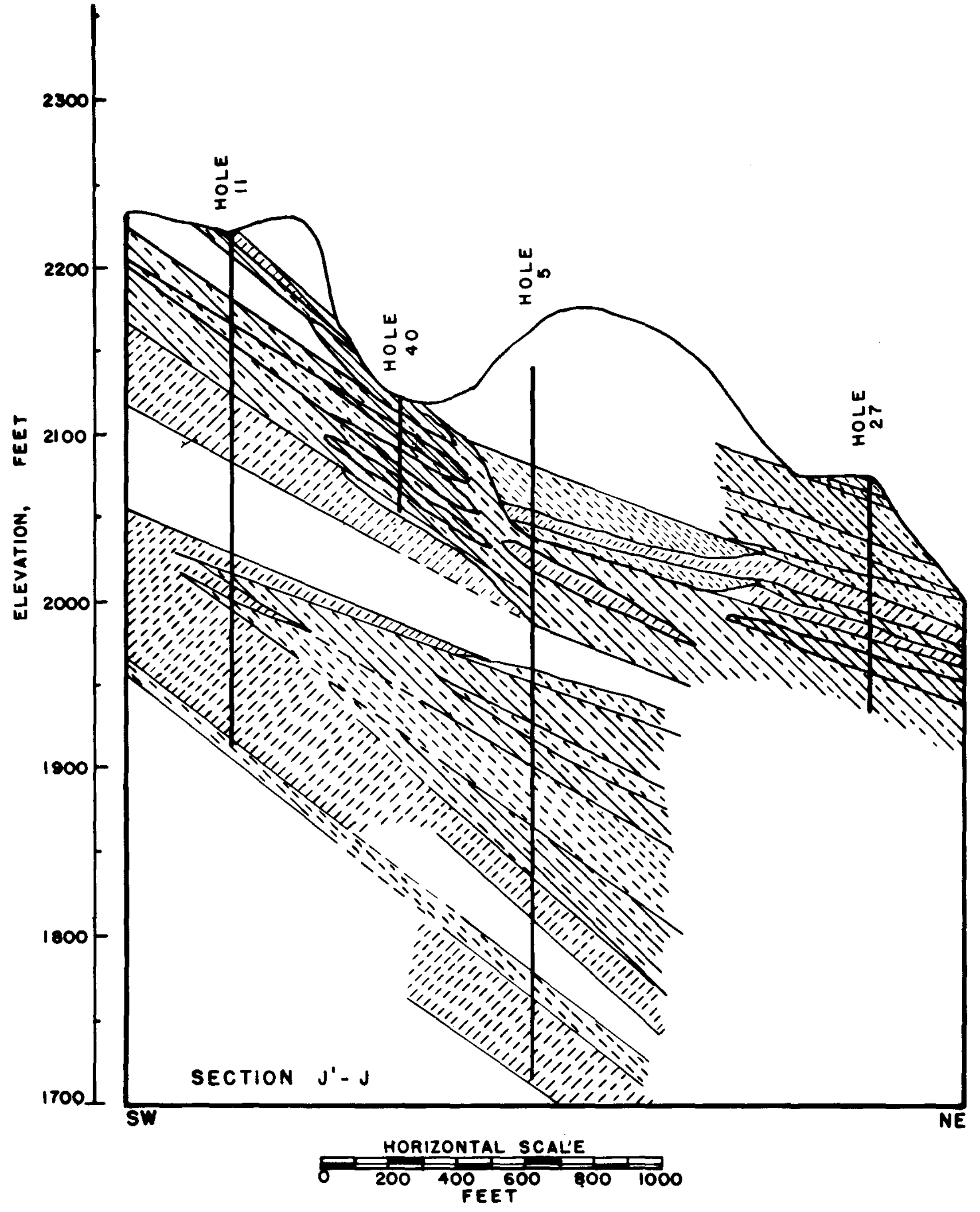

Figure 32. - Idealized sections showing the refractory classification of clay from Hobart Butte deposit, Lane and Douglas Counties, Oreg.

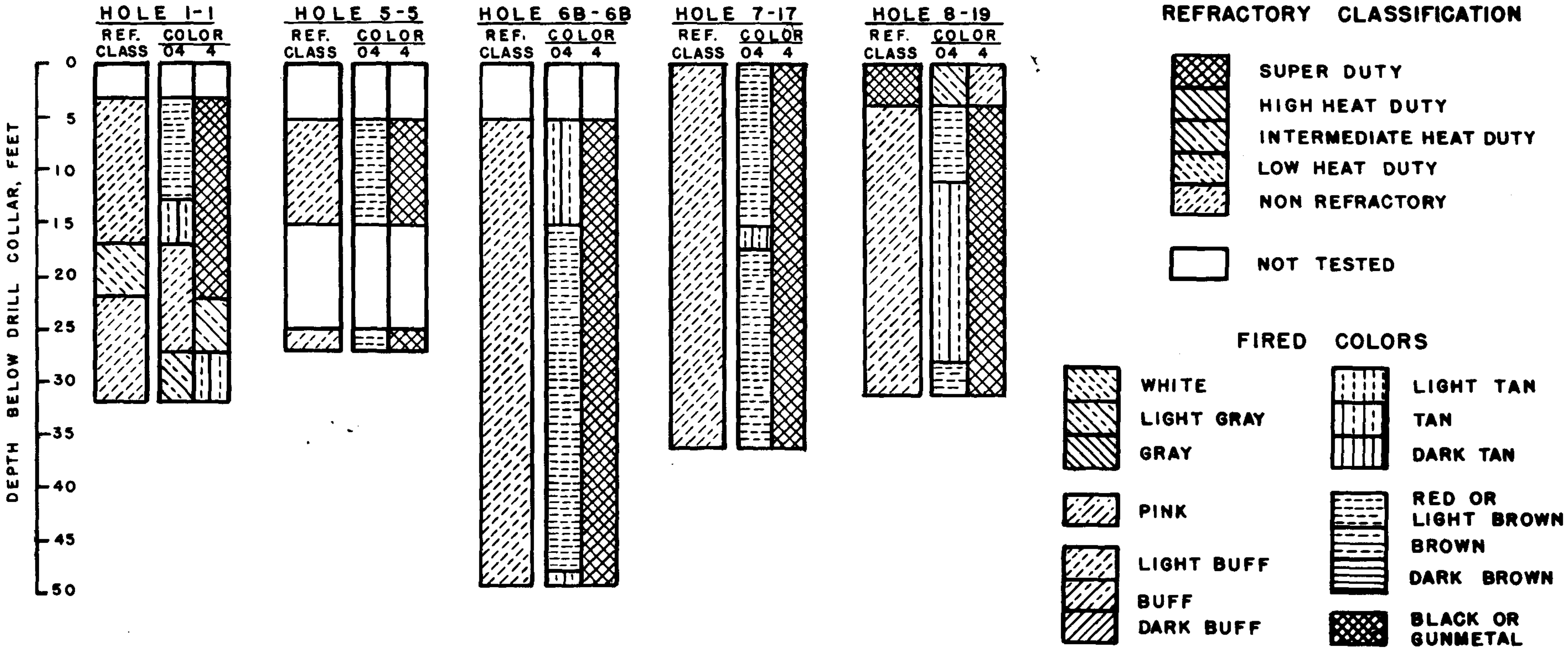

Figure 34. - Refractory classification and fired colors at cones 04 and 4 of clay samples from Five-Mile Prairie deposit, Spokane County, Wash.

P.C.E. values and fired colors. - Twenty-three drill holes out of a total of 40 drilled had samples showing sufficiently high ratio of available alumina to ferric oxide to warrant ceramic testing. A large irregular body of high heat-duty clay was found in holes 1, 3, 4, 7, 10, 13, and 21, shown along section line H'-H, figures 19 through 32. This section is projected along a line running approximately northeast from hole 13 along the crest of the butte. A similar high heat-duty clay bed is found in the holes along section line I'-I to the east, which roughly parallels section H'-H. In hole 26, at the northwest extremity of section I'-I, super-duty clay is found. Holes along section lines to the east do not, however, cut any of the higher-grade refractory clays. Immediately to the northwest of section H'-H, the high heat-duty bed is found in all holes on section line G'-G. Holes 6 and 8, in the extreme northwest corner of the drilled area, also expose high- and super-duty clay beds. Holes on the northeast-southwest consistently cut beds of high- and some super-duty clay at altitudes from 2,000 to 2,300 feet. Holes below 2,000 feet show little high heat-duty clay. Hole 6, which starts in high heat-duty clay just below 2,100 feet elevation, intersects super-duty clay at 2,050 feet. There are two super-duty beds in this hole, one 10 and the other 12 feet thick.

Colors of samples fired to cone 04 and 4 are consistently light; more than three-fourths of those fired to the latter cone are classified as light. About 25 percent are brown or darker. (See figs. 20 through 24 and table 8.)

Five-Mile Prairie, Wash., Deposit

The Five-Mile Prairie deposit is about 5 miles northwest of Spokane, Spokane County, Wash., between a U. S. highway on the east and the Spokane River on the west. The area is generally overlain with sediments, volcanics capping the hills. The clay is exposed along the western and southern flanks of a hill in sections 22, 25, and 26, T. 26 N., R. 42 E.

The predominant clay mineral is kaolin; however, most of the samples showed the presence of considerable montmorillonite, with resulting low available alumina compared to total alumina. An average of 14 samples contained 21.53 percent of total alumina and only 8.96 available alumina. The ratio of available iron to total iron was likewise low. The same samples showed 4.76 total Fe_2O_3 with an available analysis of only 2.73 Fe_2O_3.

Eleven holes were drilled by the Bureau of Mines in 1942, and 28 samples from five of the holes were taken for ceramic testing. The available-alumina content of these samples was low, averaging only 10.14 percent, and 4.19 percent of available Fe_2O_3. Overburden at the drill holes ranged from 2 to 5 feet.

P.C.E. values and fired colors. - Only one sample of those taken for ceramic testing had a PCE above cone 31. This was a 4-foot sample of surface material described as gray, gritty clay, which had only 12.9 percent of available alumina. The sample represented 3 percent of the total footage tested. Only 4 percent of the total footage was low heat-duty clay, and the remaining 93 percent was nonrefractory. The common fired color at cone 4 was gunmetal. (See figs. 33 and 34 and table 9.)

TABLE 8. - Test data for drill-core samples from the Hobart Butte deposit, Lane County, Oreg.

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.			Cone 04		Cone 4					
	Al_2O_3	Fe_2O_3		Range	Indicated clay type	Color	Hardness1/	Color	Hardness1/	Remarks	P.C.E., cone	Fired cone color	Refract classific
HOLE 1													
130.8-138.0	27.4	1.9	9.6	28-34	Flint	Gray	Fr	Tan	Fr	Brown specks at 4	31	Lt. gray, speckled	Intermedi
138.0-144.4	29.1	2.3	10.3	24-28	do.	do.	Fr	Buff	Fr	do.	26-31	Speckled tan	Do.
144.4-151.5	31.4	1.2	10.8	28-32	do.	Lt. gray	Fr	Gray	Fr	Tan specks at 4	32-	do.	High heat
151.5-159.0	31.4	5.1	10.7	17-24	do.	Buff	Fr	Lt. brown	SS	-	26+	Black	Intermedi
159.0-163.8	33.8	2.3	11.2	18-23	do.	Lt. gray	Fr	White	Fr	Brown specks at 4	26-31	Speckled tan	Do.
163.8-172.9	32.5	0.5	10.5	18-23	do.	White	SS	do.	Fr	-	32-	White, tan specks	High heat
172.9-180.3	34.5	0.5	11.8	16-21	do.	do.	Fr	do.	Fr	-	32-1/2-33	White	Do.
180.3-188.7	31.1	1.5	10.6	17-24	do.	Lt. gray	Fr	Gray	Fr	Tan specks at 4	31+	Lt. buff	Do.
188.7-195.4	32.0	6.9	11.4	16-22	do.	Tan	SS	Brown	SS	-	19-	Black	Nonrefract
195.4-202.0	30.2	7.7	10.4	15-23	do.	Brown	Fr	Brick-red	SS	-	19+	do.	Low heat
202.0-212.0	25.9	3.8	9.4	19-24	do.	Buff	SS	Lt. brown	SS	-	19-26	Dark brown	Do.
HOLE 2													
0.0-5.0	32.1	9.0	12.0	15-24	Flint	Red	Fr	Brown	Fr	-	26-	Black	Low heat
5-10	35.2	3.2	12.6	17-29	do.	Pink	Fr	Gray	Fr	-	32+	Speckled brown	High heat
10-15	33.2	7.0	12.0	16-27	do.	Dk. pink	Fr	Tan	Fr	-	26-31	Black	Intermedia
15-20	22.7	4.6	8.4	19-26	do.	Pink	SS	Buff	SS	-	19-26	Speckled brown	Low heat
20-28	24.7	3.7	9.0	21-29	do.	Lt. buff	Fr	Lt. tan	Fr	-	26-	Speckled tan	Do.
28-32	25.9	2.5	9.3	20-29	do.	Pink	SS	Buff	SS	Black specks at 4	26+	do.	Intermediat
32-40	26.5	6.7	10.6	17-29	do.	do.	Fr	Tan	Fr	White specks at 4	26-31	Dark brown	Do.
40-45	31.9	4.1	10.9	18-26	do.	do.	Fr	do.	Fr	do.	19-26	do.	Low heat
45-53	27.9	13.1	10.9	17-26	do.	Lt. red	Fr	Brown	Fr	Black specks at 4	19	Black	Nonrefract
53-59	29.0	21.0	11.4	17-22	do.	Red	Fr	Gunmetal	SS	-	-12	Gunmetal	Do.
59-69	35.6	2.7	12.2	17-26	do.	Lt. gray	SS	Lt. buff	Fr	Black specks at 4	31+	Speckled tan	High heat
69-80	25.5	6.2	9.4	17-24	do.	Lt. red	Fr	Brown	Fr	-	19-	Black	Nonrefract
80-90	24.5	2.6	8.7	16-25	do.	Lt. gray	SS	Buff	SS	Sandy at 4	26+	Speckled tan	Intermediat
HOLE 3													
0.0-2.0	27.6	3.4	10.3	18-26	Flint	Gray	SS	Lt. buff	SS	-	26+	Speckled brown	Intermedi
2-10	31.6	2.7	11.7	16-25	do.	Lt. gray	SS	do.	SS	-	31+	Speckled tan	High heat
10-20	18.1	3.7	8.0	19-26	do.	Gray	SS	Lt. gray	SS	-	19-26	do.	Low heat
20-27	29.1	1.6	11.2	19-28	do.	do.	SS	do.	SS	-	31+	do.	High heat
27-35	32.7	2.8	12.3	21-27	do.	do.	Fr	Gray	SS	-	31+	Speckled brown	Do.
35-43	26.1	8.5	14.5	21-25	do.	do.	Fr	Dk. gray	Fr	-	12-19	Dark brown	Nonrefrac
43-49	24.9	5.9	12.5	16-22	do.	Lavender	Fr	Brown	Fr	-	12-19	do.	Do.
49-58	17.5	2.3	8.7	21-27	do.	Gray	Fr	Lt. buff	Fr	-	26-	Speckled tan	Low heat
58-65	16.7	1.7	6.6	22-28	do.	Lt. gray	P	do.	Fr	-	19-26	Gray; brown specks	Do.
65-73	22.8	0.7	8.4	17-26	do.	White	Fr	White	Fr	-	26	White; tan specks	Do.
73-80	30.6	1.0	11.0	16-22	do.	Lt. gray	Fr	do.	Fr	-	31+	do.	High heat
80-88	27.3	10.5	15.7	16-22	do.	Gray	SS	Gray	SS	-	-12	Black	Nonrefrac
88-96	29.6	9.6	16.2	15-21	do.	Lavender	Fr	do.	SS	-	12-19	do.	Do.
96-102	30.3	5.6	14.0	15-23	do.	Gray	SS	do.	SS	-	19-	do.	Do.
102-109	28.5	5.9	12.8	16-25	do.	do.	Fr	do.	SS	-	12-19	Dark brown	Do.
109-117	31.0	3.9	12.4	15-25	do.	Lt. gray	Fr	Tan	Fr	-	26-31	Speckled brown	Intermedi
117-130	34.9	0.7	12.0	16-23	do.	do.	SS	White	SS	-	32+	White; tan specks	High he
130-138	34.4	1.1	12.2	15-24	do.	do.	SS	do.	SS	-	32	White	D
138-146.5	29.8	1.0	11.6	17-24	do.	do.	Fr	do.	SS	-	31+	White	D
146.5-153	28.4	1.0	11.0	17-24	do.	do.	Fr	do.	SS	-	31+	do.	D
153-160.5	29.5	1.9	11.2	16-25	do.	Gray	Fr	Lt. gray	SS	-	31-1/2	Gray; tan specks	D
HOLE 4													
0.0-10	25.5	7.6	9.7	18-27	Flint	Gray	Fr	Brown	SS	-	19-	Brown	Nonref
10-16	29.2	1.2	10.6	16-24	do.	White	Fr	White	Fr	-	31+	White; tan specks	High he
16-21	26.9	0.7	9.9	20-26	do.	do.	Fr	do.	Fr	Tan specks at 4	31	White	Interm
21-23	25.0	3.0	10.5	16-25	do.	Lt. gray	Fr	Tan	Fr	-	19-26	Speckled brown	Low he
23-36	31.9	1.7	11.7	15-25	do.	do.	Fr	Buff	Fr	-	31-1/2	Gray; brown specks	High he
36-44	28.5	11.7	16.7	13-20	do.	Lavender	Fr	Gunmetal	Fr	-	-12	Gunmetal	Nonref
44-52	30.5	2.4	12.1	16-22	do.	Lt. gray	Fr	Tan	Fr	Gray specks at 4	19-26	Gray; brown specks	Low he
52-59	30.5	5.2	12.4	16-22	do.	do.	Fr	do.	Fr	do.	19-26	Brown	
59-67.6	32.8	7.2	15.0	14-22	do.	Gray	Fr	Brown	SS	do.	12-19	do.	Nonref
67.6-75.6	25.8	10.3	15.6	16-24	do.	Lavender	Fr	do.	SS	-	12-	do.	
75.6-82.4	28.0	5.5	12.8	16-23	do.	do.	Powd	Tan	Powd	White specks at 4	19+	Dark brown	Low he
82.4-91.6	30.1	1.8	11.6	15-26	do.	White	Fr	White	Fr	Tan specks at 4	31-1/2	Gray; brown specks	High h
91.6-99	32.4	3.9	13.0	16-25	do.	Gray	Fr	Tan	Fr	-	31+	Lt. brown	
99-107	32.8	3.0	12.4	16-23	do.	Lt. gray	Fr	do.	Fr	-	26-31	Speckled tan	Interm
107-123	30.5	4.3	12.5	18-24	do.	Lt. pink	Fr	Lt. brown	SS	Black specks at 4	26-	do.	Low he
123-131	27.1	2.4	10.6	13-22	do.	White	Fr	Buff	Fr	Black specks at 04	26-31	do.	Interm
131-140	23.3	1.9	9.5	16-25	do.	do.	Fr	Tan	Fr	-	26-31	Gray, tan specks	
140-144	18.7	1.1	7.6	19-28	do.	Lt. gray	Fr	Lt. gray	SS	-	26+	White, tan specks	

See footnotes at end of table.

TABLE 8.- Test data for drill-core samples from the Hobart Butte deposit, Lane County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
								HOLE 5					
61-70	24.9	3.3	11.6	16-25	Flint	Gray	Fr	Lt. brown	Fr	-	19+	Brown, bloated	Low heat
70-78	26.7	3.2	22.1	15-23	do.	Tan	Fr	do.	Fr	-	19-26	do.	Do.
78-86	27.2	3.8	19.8	15-23	do.	Lt. brown	Fr	Brown	Fr	-	19-26	Dk. brown, bloated	Do.
86-94	24.1	1.9	11.4	16-26	do.	Gray	Fr	Tan	Fr	-	19	Brown	Nonrefractory
94-102	24.8	1.7	11.1	13-26	do.	do.	Fr	do.	Fr	-	19-26	do.	Low heat
102-108.5	26.8	2.4	11.9	16-26	do.	do.	Fr	Lt. brown	Fr	-	26-31	Speckled tan	Intermediate
108.5-119.8	28.0	2.2	15.4	20-29	Semi-flint	Brown	P	Brown	P	-	12-19	Gunmetal	Nonrefractory
119.8-128	27.9	3.2	15.0	21-31	do.	do.	P	do.	P	-	19-	Dark brown	Do.
128-134.5	22.9	1.4	10.1	18-30	do.	Gray	Fr	Tan	Fr	White specks at 4	26-31	Speckled tan	Intermediate
134.5-142	22.2	1.9	10.1	16-30	do.	do.	Fr	Gray	Fr	Tan specks at 4	26-31	do.	Do.
142-155	23.6	2.7	10.4	17-29	Flint	do.	Fr	Buff	SS	-	26-31	do.	Do.
185-191	21.3	2.2	8.5	21-32	Semi-flint	do.	SS	Tan	SS	-	19-26	do.	Low heat
191-199	20.5	1.3	8.2	26-36	do.	do.	SS	White	SS	Tan specks at 4	26-31	do.	Intermediate
199-207	22.8	1.7	8.7	27-35	do.	Lt. buff	Fr	Buff	Fr	-	26-31	do.	Do.
207-213.5	21.9	1.3	8.4	27-38	do.	do.	Fr	Buff	Fr	-	26-31	Gray; dark specks	Do.
213.5-224	20.1	1.9	11.7	21-32	do.	Tan	P	Red-brown	Fr	-	19-26	Dark brown	Low heat
224-233	27.0	2.8	11.3	27-36	do.	Gray	Fr	Tan	Fr	-	26-31	Brown	Intermediate
233-241.5	22.9	3.3	9.2	35-37	Kaolin	Lt. tan	Fr	do.	Fr	-	26-31	Speckled tan	Do.
241.5-250	20.2	2.2	8.1	25-36	Semi-flint	Buff	SS	do.	SS	-	19-26	Brown	Low heat
250-258	21.1	2.1	8.4	24-38	do.	Tan	Fr	do.	Fr	-	19-26	Speckled tan	Do.
258-266	23.0	3.2	9.2	26-37	do.	do.	Fr	do.	Fr	-	19-26	do.	Do.
266-274	23.5	1.3	10.7	28-37	do.	Gray	Fr	Brown	Fr	-	19-26	Brown	Do.
274-282	22.3	2.1	10.9	26-36	do.	do.	Fr	do.	Fr	-	19+	Dark brown	Do.
282-290	24.6	1.9	9.8	25-34	do.	Lt. buff	Fr	Lt. tan	Fr	-	26-31	Speckled tan	Intermediate
290-299	20.8	1.4	8.3	24-34	do.	Gray	Fr	White	Fr	Tan specks at 4	26-31	Gray; tan specks	Do.
299-307	27.4	2.2	11.0	25-35	do.	do.	Fr	Lt. tan	Fr	-	26-31	Speckled tan	Do.
307-315	20.8	7.6	12.6	20-34	do.	Lavender	P	Red-brown	SS	-	-12	Gunmetal	Nonrefractory
315-323	23.6	7.6	14.1	21-31	Flint	do.	P	do.	Fr	-	-12	do.	Do.
369-375	22.6	2.6	9.6	22-36	Semi-flint	Gray	P	Buff	P	-	19-26	Speckled tan	Low heat
375-384	20.0	3.5	9.4	20-33	do.	do.	P	Lt. tan	Fr	-	19-26	do.	Do.
384-393	24.4	11.8	9.9	21-34	do.	Red	Fr	Red	Fr	Light specks at 4	12-19	Gunmetal	Nonrefractory
393-401	27.2	9.8	10.8	20-31	Flint	do.	Fr	do.	Fr	-	12+	do.	Do.
401-409	26.8	12.2	10.4	23-35	Semi-flint	do.	Fr	do.	Fr	-	12-19	do.	Do.
409-419.5	25.9	7.8	9.8	24-36	do.	-	-	Brown	Fr	-	12-19	do.	Do.
419.5-428	23.5	12.2	9.5	26-40	do.	Tan	Fr	Red-brown	Fr	Gunmetal specks at 4	12-19	Brown	Do.
								HOLE 6					
0.0-5.0	32.7	2.2	10.8	20-26	Flint	Tan	Fr	Tan	Fr	-	31+	Speckled brown	High heat
5-11	27.3	1.4	9.3	18-26	do.	Lt. buff	Fr	White	Fr	Tan specks at 4	31+	White; tan specks	Do.
11-17	30.1	1.0	10.5	20-26	do.	do.	Fr	do.	Fr	-	32	Lt. gray; tan specks	Do.
17-20	31.1	1.8	10.8	16-23	do.	Lt. pink	Fr	Tan	Fr	-	32-	Speckled tan	Do.
20-30	29.1	1.1	10.1	18-24	do.	White	Fr	Lt. buff	Fr	-	32-	Lt. gray; tan specks	Do.
30-40	29.8	0.9	10.2	19-25	do.	do.	SS	White	SS	-	32-	White; tan specks	Do.
40-52	32.8	0.8	11.2	18-23	do.	do.	Fr	do.	Fr	-	33+	White	Super-duty
52-60	29.4	1.9	10.4	-	-	-	-	-	-	-	-	-	-
60-70	33.2	1.3	11.6	17-22	Flint	Lt. buff	Fr	Buff	Fr	White specks at 4	33	Light buff	High heat
70-80	36.5	1.0	12.6	15-24	do.	do.	Fr	Lt. buff	Fr	-	33+	Lt. gray; tan specks	Super-duty
80-87	35.1	1.0	12.2	17-24	do.	do.	Fr	Lt. gray	Fr	-	32+	White; tan specks	High heat
87-95	31.3	3.0	11.1	18-28	do.	Lt. pink	Fr	Tan	Fr	-	31+	Speckled tan	Do.
95-100	27.2	3.9	10.7	18-22	do.	Reddish-gray	SS	Lt. brown	SS	-	19-26	Dark brown	Low heat
100-110	26.0	5.4	10.7	17-24	do.	Pink	Fr	Brown	SS	Black specks at 4	19+	do.	Do.
110-116	25.9	2.3	9.4	19-24	do.	Lt. buff	SS	Lt. gray	SS	-	19-26	Speckled tan	Do.
116-123	23.4	5.9	9.1	16-23	do.	Lt. red	Fr	Brown	Fr	-	19-	Black	Nonrefractory
123-129	27.4	5.9	11.5	17-23	do.	Lt. lavender	Fr	do.	Fr	Gunmetal specks at 4	19-26	do.	Low heat
								HOLE 7					
0-5.8	25.2	4.1	9.5	21-26	Flint	Pink-gray	Fr	Tan	SS	White specks at 4	26+	Brown	Intermediate
5.8-15	28.7	8.7	11.2	21-26	do.	Pink	Fr	Brown	SS	Gunmetal specks at 4	12-19	Brown, bloated	Nonrefractory
15-27	29.9	9.2	14.6	14-21	do.	do.	Fr	do.	SS	Black specks at 4	19-	do.	Do.
27-32	29.7	2.3	10.6	16-26	do.	Lt. buff	Fr	Tan	Fr	-	31	Speckled brown	Intermediate
32-38.9	28.5	8.7	14.2	17-24	do.	Lavender	Fr	Brown	Fr	-	12+	Brown	Nonrefractory
38.9-49	29.3	9.0	14.1	15-23	do.	Lt. pink	SS	Gray	SS	-	12-19	Brown, bloated	Do.
49-54.2	27.9	10.3	15.6	17-21	do.	Pink	Fr	do.	SS	-	12-19	do.	Do.
54.2-61.6	29.9	8.0	15.4	19-24	do.	Gray	Fr	Brown	SS	Gray specks at 4	12+	Gunmetal	Do.
61.6-69.6	30.1	7.1	14.4	17-24	do.	Lavender	Fr	do.	SS	Tan specks at 4	12-19	Brown	Do.
69.6-78.7	30.2	3.9	11.7	20-27	do.	Lt. gray	Fr	Tan	SS	Gray specks at 4	19+	Dk. gray, bloated	Low heat
78.7-92	31.3	2.3	12.0	17-28	do.	do.	Fr	do.	Fr	-	31+	Speckled tan	High heat
92-97	34.2	2.0	12.6	20-27	do.	do.	Fr	do.	Fr	-	31-1/2	do.	Do.
97-108	34.2	1.8	12.3	17-25	do.	do.	Fr	do.	Fr	-	31+	do.	Do.
108-116.2	34.2	2.0	12.5	16-24	do.	do.	Fr	do.	Fr	-	31+	Gray; brown specks	Do.
116.2-124	34.0	0.8	11.7	18-25	do.	White	Fr	White	Fr	Brown specks at 4	31+	Lt. gray	Do.
124-132	32.6	0.7	11.8	16-24	do.	do.	Fr	do.	Fr	-	31+	White; tan specks	Do.
132-140	34.3	0.8	12.0	16-20	do.	do.	Fr	do.	Fr	-	31-1/2	do.	Do.
140-146.4	33.9	1.1	12.0	14-21	do.	Lt. gray	Fr	Gray	Fr	Tan specks at 4	31+	White; brown specks	Do.
146.4-153.4	34.7	1.3	12.2	16-22	do.	White	Fr	White	Fr	do.	31-1/2	do.	Do.
153.4-161.6	33.7	3.4	13.2	14-20	do.	do.	Fr	Tan	SS	-	31-	Tan; brown specks	Intermediate
161.6-169.6	28.6	3.0	11.8	16-25	do.	do.	Fr	do.	Fr	-	26	Speckled tan	Do.
169.6-173.5	21.6	2.5	8.4	22-29	do.	Lt. gray	Fr	do.	Fr	White specks at 4	26+	Tan; brown specks	Do.
173.5-186.2	21.5	4.9	8.8	16-24	do.	Pinkish gray	Fr	Lt. brown	SS	-	19-26	Speckled brown	Low heat

See footnotes at end of table.

TABLE 8. - Test data for drill-core samples from the Hobart Butte deposit, Lane County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
HOLE 8													
72-78	24.1	3.0	8.5	19-24	Flint	Lt. red	Fr	Tan	SS	-	19-26	Speckled tan	Low heat
78-86	28.9	3.0	10.2	16-23	do.	Salmon	Fr	do.	Fr	-	31+	do.	High heat
86-95	28.8	1.9	10.2	17-23	do.	Lt. buff	Fr	do.	Fr	-	31+	do.	Do.
95-100	23.8	1.8	8.7	17-23	do.	do.	Fr	Buff	Fr	-	26-31	Buff; tan specks	Intermediate
100-109	24.0	2.1	8.7	16-22	do.	do.	Fr	Lt. tan	Fr	-	26-	Speckled tan	Low heat
109-113	26.4	1.8	9.6	16-23	do.	Pink	Fr	Buff	Fr	-	31+	Gray; tan specks	High heat
113-120	23.5	4.3	9.0	19-26	do.	Lt. red	Fr	Brown	Fr	Tan specks at 4	19-26	Speckled brown	Low heat
HOLE 10													
63.6-68.0	26.3	3.0	9.9	20-26	Flint	Gray	SS	Buff	Fr	Mottled at 4	19-26	Speckled tan	Low heat
68.0-75.3	29.8	2.0	11.0	22-28	do.	Lt. gray	SS	Lt. gray	SS	Brown specks at 4	31+	Gray; tan specks	High heat
75.3-85.0	26.6	2.2	10.1	24-28	do.	do.	SS	do.	SS	do.	31+	do.	Do.
85.0-90.8	25.2	1.1	9.5	22-26	do.	do.	Fr	do.	Fr	do.	31+	Lt. gray; tan specks	Do.
90.8-98.8	28.5	1.3	10.2	24-28	do.	do.	Fr	do.	Fr	do.	31+	do.	Do.
98.8-105.2	25.9	2.1	9.8	22-28	do.	Gray	Fr	Buff	SS	-	19-26	Speckled tan	Low heat
105.2-114.0	24.0	1.2	9.2	20-26	do.	Lt. gray	SS	Lt. gray	Fr	Brown specks at 4	31-	do.	Intermediate
114.0-122.0	23.8	1.4	10.2	22-26	do.	do.	Fr	do.	SS	do.	26-31	Lt. gray; tan specks	Do.
122.0-130.0	19.8	2.1	8.4	22-28	do.	Gray	Fr	Tan	SS	-	19-26	Speckled brown	Low heat
130.0-139.0	25.0	0.9	9.0	20-26	do.	do.	SS	White	SS	Brown specks at 4	31-	Lt. gray; tan specks	Intermediate
139.0-146.8	31.9	0.9	11.1	22-28	do.	Lt. gray	Fr	do.	Fr	do.	31-32	do.	High heat
146.8-154.8	29.7	0.9	11.6	22-26	do.	do.	Fr	Lt. gray	Fr	do.	31-32	do.	Do.
154.8-162.8	32.5	1.6	11.7	18-28	do.	do.	Fr	do.	Fr	Tan specks at 4	31	Gray; brown specks	Intermediate
162.8-167.0	34.5	1.0	12.2	16-24	do.	do.	Fr	White	Fr	do.	31-1/2	Lt. gray; tan specks	High heat
167.0-174.6	35.4	0.7	12.6	18-24	do.	do.	Fr	do.	Fr	-	32+	White; tan specks	Do.
174.6-182.0	35.5	0.6	12.2	16-24	do.	White	Fr	do.	Fr	-	32+	do.	Do.
182.0-189.6	36.3	0.6	12.3	14-24	do.	Lt. gray	Fr	do.	Fr	-	32-1/2+	do.	Do.
189.6-194.0	34.4	0.6	11.5	14-24	do.	do.	Fr	Lt. gray	Fr	-	32	Lt. gray; tan specks	Do.
194.0-201.5	32.1	0.6	12.9	16-26	do.	do.	Fr	do.	Fr	-	32-	White	Do.
201.5-209.5	29.0	4.0	12.2	18-24	do.	Pink	Fr	Brown	Fr	Mottled at 4	19-26	Brown	Low heat
HOLE 11													
0.0-5.0	23.5	2.9	8.8	25-33	Semi-flint	Lavender	Fr	Brown	Fr	-	19-	Dark brown	Nonrefractory
5-13	21.5	2.5	9.4	22-33	do.	Lt. gray	P	Lt. tan	P	-	26+	Speckled tan	Intermediate
39-47	26.0	2.5	10.2	20-35	do.	Lt. tan	Fr	Gray	Fr	Tan specks at 4	26-31	do.	Do.
47-55	23.4	1.8	9.9	19-34	do.	Gray	P	Buff	Fr	White specks at 4	26+	do.	Do.
55-62	29.4	5.9	13.4	21-33	do.	Lavender	P	Brown	Fr	-	19-26	Black	Low heat
62-69	25.6	0.6	9.5	23-33	do.	White	Fr	White	Fr	Brown specks at 4	26-31	Lt. gray; tan specks	Intermediate
69-80	24.4	1.4	9.6	23-33	do.	Gray	Fr	do.	Fr	-	26-31	Speckled buff	Do.
80-88	22.8	3.0	9.1	21-34	do.	Lt. tan	Fr	Tan	Fr	-	26+	Light brown	Do.
88-96	24.1	1.5	9.0	29-40	do.	Lt. gray	Fr	Buff	Fr	-	26-31	Gray; tan specks	Do.
96-104	22.2	4.6	8.9	25-38	do.	Tan	Fr	Tan	Fr	-	19-	Dark brown	Nonrefractory
104-112	19.0	7.3	12.5	22-34	do.	Dk. gray	Fr	Gunmetal	Fr	Crumbled gray at 4	-12	Black	Do.
112-120	19.7	7.0	13.2	21-32	do.	do.	P	do.	Fr	Gray specks at 4	12-19	do.	Do.
120-128	23.8	4.3	11.0	26-36	do.	Gray	Fr	Tan	Fr	-	12-19	Dark brown	Do.
128-136	16.2	5.9	9.6	25-38	do.	do.	Fr	do.	SS	White specks at 4	19-	Black	Do.
136-144	18.1	6.0	10.5	-	-	-	-	-	-	-	-	-	-
194.5-205	27.9	10.6	16.5	24-34	Semi-flint	Lavender	P	Red	Fr	Gray specks at 4	-12	Black	Nonrefractory
205-210	22.2	4.0	9.0	25-37	do.	Red	Fr	Tan	Fr	-	26-31	Brown	Intermediate
210-218	20.7	13.3	13.3	19-30	do.	do.	Fr	Red	Fr	-	-12	Black	Nonrefractory
218-222	25.1	5.2	11.2	20-34	do.	Lt. red	P	do.	Fr	Gray specks at 4	19-26	Speckled brown	Low heat
222-230	22.1	8.5	12.4	20-34	do.	Red	Fr	Red-brown	Fr	-	-12	Black	Nonrefractory
230-239	24.2	7.6	13.0	16-28	do.	do.	SS	Red	SS	-	12-19	Dark brown	Do.
239-246.5	27.2	6.3	11.6	19-30	do.	do.	SS	do.	SS	-	12-19	do.	Do.
246.5-252	22.9	10.6	15.9	22-30	do.	Brick red	SS	Brick red	Fr	-	-12	Black	Do.
252-258.5	25.6	6.6	13.8	22-36	do.	Pink	Fr	Lavender	Fr	Gray specks at 4	12-19	Dark brown	Do.
258.5-263.5	29.2	5.8	13.8	20-35	do.	Red	SS	Lt. brown	SS	-	12-19	Black	Do.
263.5-275	27.3	7.4	14.6	19-35	do.	Gray	Fr	Gray	SS	-	12-	Dark brown	Do.
275-283	26.2	8.7	13.8	20-34	do.	Brick red	Fr	Dk. brown	SS	-	12-19	do.	Do.
283-291	26.0	7.7	12.9	24-38	do.	Red	Fr	Brick red	SS	-	12-19	do.	Do.
291-301	23.2	7.1	9.7	26-39	do.	Brick red	Fr	Red	Fr	-	19-	do.	Do.
301-308	25.4	5.2	10.2	21-40	do.	do.	Fr	Brick red	Fr	-	19+	Black	Low heat
HOLE 13													
0.0-10.0	25.2	1.5	8.9	22-28	Flint	White	SS	Lt. gray	Fr	Tan specks at 4	31+	Lt. gray; tan specks	High heat
10.0-20.0	27.0	1.1	9.5	20-26	do.	Lt. gray	Fr	do.	Fr	do.	32-	do.	Do.
20.0-24.0	26.0	0.8	9.4	18-26	do.	White	Fr	White	Fr	-	31+	White; tan specks	Do.
HOLE 16													
0-13.5	31.9	1.3	11.0	26-40	Flint	White	Fr	White	Powd	Powd on firing at 4	31+	Gray; brown specks	High heat
13.5-21	34.8	2.9	12.2	28-48	Semi-flint	Gray	Fr	Gray	Fr	Some kaolin	31-1/2	Speckled tan	Do.
21-29	32.2	1.4	11.3	29-42	do.	Lt. buff	Fr	White	Fr	do.	31-1/2	Speckled buff	Do.
29-34	33.6	1.0	12.0	26-40	do.	Buff	Fr	do.	Fr	-	31+	Speckled tan	Do.
34-44.8	31.1	8.2	12.0	28-42	do.	Lt. brown	Fr	Tan	Fr	Brown specks at 4	19+	Dark brown	Low heat

See footnotes at end of table.

TABLE 8. - Test data for drill-core samples from the Hobart Butte deposit, Lane County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification2/
	Al_2O_3	Fe_2O_3				Color	Hardness1/	Color	Hardness1/				
HOLE 16 (Cont'd)													
44.8-54.5	32.8	2.1	12.0	27-39	Semi-flint	Tan	Fr	Lt. gray	Fr	-	32+	Speckled tan	High heat
54.5-66	30.3	1.5	10.9	24-40	do.	Buff	Fr	do.	Fr	-	31+	Gray; brown specks	Do.
66-73.5	32.7	0.8	11.8	26-44	do.	White	Fr	White	Fr	Some kaolin	32	Gray; tan specks	Do.
73.5-77	30.4	1.7	10.9	30-43	do.	Buff	Fr	do.	Fr	do.	31+	Speckled tan	Do.
77-85	31.5	1.2	11.6	22-40	do.	do.	Fr	Lt. gray	Fr	-	31+	Gray; brown specks	Do.
85-93	32.5	1.5	11.4	14-22	Flint	do.	Fr	do.	Fr	-	31+	Speckled tan	Do.
93-101	33.2	1.6	12.0	15-23	do.	Gray	Fr	Lt. tan	Fr	White specks at 4	31+	Gray; brown specks	Do.
101-109	26.2	4.0	11.5	17-24	do.	do.	Fr	Tan	Fr	-	19+	Dark brown	Low heat
109-117	29.0	1.9	10.8	20-27	do.	Buff	Fr	Buff	Fr	-	26-31	Speckled tan	Intermediate
117-123.5	23.1	2.0	9.2	20-28	do.	do.	Fr	Lt. buff	Fr	Gray specks at 4	26-31	do.	Do.
HOLE 17													
0.0-2.0	29.9	1.1	10.5	19-25	Flint	White	Fr	White	Fr	-	31-1/2	Lt. gray; brown specks	High heat
2.0-11.6	31.3	1.5	11.7	17-23	do.	Gray	SS	Tan	Fr	-	32-	Speckled tan	Do.
11.6-20.0	31.7	1.3	12.0	17-24	do.	do.	SS	do.	Fr	-	31+	do.	Do.
20-27	29.7	1.1	11.7	16-23	do.	do.	SS	do.	SS	-	26+	do.	Intermediate
27-35	26.9	1.0	11.6	18-23	do.	do.	SS	Lt. brown	Fr	-	19-26	do.	Low heat
35-45	29.4	2.4	11.6	18-23	do.	do.	Fr	Lt. gray	Fr	-	31-	do.	Intermediate
45-50	29.2	1.1	10.4	18-24	do.	Lt. gray	Fr	do.	Fr	-	31-1/2	Lt. gray; tan specks	High heat
50-59	31.3	1.4	11.8	17-24	do.	Gray	Fr	White	Fr	-	31+	White; tan specks	Do.
59-67	31.8	3.3	13.1	17-21	do.	Pinkish-gray	Fr	Brown	Fr	-	19-26	Dark brown	Low heat
67-75	31.6	1.0	11.5	16-24	do.	Gray	Fr	Lt. gray	Fr	Porous at 4	31+	Lt. gray; brown specks	High heat
75-84	28.6	3.9	13.3	15-24	do.	Pinkish-buff	Fr	Brown	Fr	Mottled at 4	12-19	Dark brown	Nonrefractory
84-92	21.3	7.3	12.8	16-23	do.	Red-brown	Fr	Dark brown	SS	Gunmetal specks at 4	12+	do.	Do.
92-96	25.4	6.0	12.2	15-23	do.	Gray	Fr	Brown	Fr	-	19+	do.	Low heat
96-100	27.6	6.0	11.8	14-22	do.	Brick-red	Fr	Dark brown	Fr	-	19-26	do.	Do.
100-109	27.5	7.0	12.5	15-22	do.	do.	Fr	do.	Fr	-	12+	do.	Nonrefractory
HOLE 18													
0-9.5	33.6	2.0	11.9	18-23	Flint	Buff	Fr	Buff	Fr	-	32-32-1/2	Speckled brown	High heat
9.5-17.0	33.6	2.2	12.0	16-23	do.	do.	Fr	Brown	Fr	-	32-	Brown	Do.
17-20	33.4	0.6	11.8	18-24	do.	Lt. gray	Fr	Lt. gray	Fr	Brown specks at 4	33-	Speckled tan	Do.
20-24	33.9	1.5	11.9	16-23	do.	Lt. buff	Fr	Tan	Fr	-	32	do.	Do.
24-33	33.4	1.1	11.6	15-23	do.	White	Fr	White	Fr	Brown specks at 4	32-1/2	Gray; buff specks	Do.
33-41	35.4	0.9	12.5	15-22	do.	Gray	Fr	do.	Fr	Black specks at 4	32-	Gray; tan specks	Do.
41-49	35.2	0.8	12.2	16-22	do.	White	Fr	do.	Fr	-	31+	Lt. gray; tan specks	Do.
49-57	35.3	0.7	12.1	16-22	do.	do.	Fr	do.	Fr	-	32-1/2	White	Do.
57-65	34.0	0.5	11.7	17-22	do.	do.	Fr	do.	Fr	-	33-	do.	Do.
65-70	31.6	0.7	11.0	19-25	do.	do.	Fr	do.	Fr	-	31-1/2	White; tan specks	Do.
HOLE 20													
84-92	28.0	3.6	11.7	16-24	Flint	Gray	Fr	Gray	Fr	Buff specks at 4	31+	Speckled brown	High heat
92-100	26.9	1.6	10.5	16-24	do.	do.	Fr	Lt. gray	Fr	-	31+	Lt. gray; brown specks	Do.
100-110	31.6	1.8	11.9	18-24	do.	do.	Fr	Gray	Fr	Dark specks at 4	33	Speckled tan	Do.
110-120	32.7	2.1	11.6	18-24	do.	Reddish-gray	Fr	Buff	Fr	-	32-	do.	Do.
120-125	31.8	2.9	11.4	16-26	do.	Tan	Fr	Tan	Fr	-	31+	Speckled brown	Do.
125-132	31.0	1.0	12.2	16-24	do.	Lt. gray	Fr	White	Fr	-	32-32-1/2	Lt. gray; tan specks	Do.
132-140	33.4	2.0	12.4	14-22	do.	do.	Fr	Buff	Fr	-	32-1/2	Speckled tan	Do.
140-150	32.0	2.2	12.2	18-24	do.	Lt. pink	Fr	do.	Fr	Brown specks at 4	31-1/2	Speckled brown	Do.
150-160	20.8	13.4	9.6	16-22	do.	Rose	Fr	Brick red	SS	Fused in spots at 4	-12	Black	Nonrefractory
160-167	28.8	6.4	10.4	14-20	do.	Red	Fr	Dk. red	SS	-	19+	Brown	Low heat
HOLE 21													
27-35.5	26.2	4.6	9.7	22-30	Flint	Pink	Fr	Tan	Fr	-	19-26	Dark brown	Low heat
35.5-40.0	25.4	5.2	9.3	22-26	do.	do.	Fr	do.	Fr	-	19-26	do.	Do.
40-43	26.0	1.8	9.3	18-26	do.	Buff	Fr	Buff	Fr	White specks at 4	31+	Lt. gray; tan specks	High heat
43-50	28.6	2.3	10.0	20-26	do.	Pink	Fr	Lt. buff	Fr	-	31-1/2	Speckled tan	Do.
50-58	28.5	1.1	9.7	22-28	do.	White	Fr	Lt. gray	Fr	-	32	Lt. gray; tan specks	Do.
58-65	27.1	1.3	9.4	22-28	do.	do.	Fr	White	Fr	Brown specks at 4	32	White; tan specks	Do.
65-69	31.2	1.3	10.5	20-28	do.	do.	Fr	do.	Fr	do.	32	do.	Do.
69-77	27.2	0.8	9.3	21-28	do.	do.	Fr	do.	Fr	-	31-1/2	do.	Do.
77-83	22.6	0.5	8.1	22-26	do.	do.	Fr	do.	Fr	-	31+	White	Do.
83-88	26.6	2.4	9.4	16-23	do.	Buff	Fr	Tan	Fr	-	31+	Speckled tan	Do.
88-96.5	29.9	6.2	10.7	19-27	do.	Red	Fr	Dk. brown	Fr	White spots at 04	19-26	Brown	Low heat
96.5-99.5	22.9	3.6	8.9	16-24	do.	Pink	Fr	Tan	Fr	Black specks at 4	19-26	Speckled tan	Do.
99.5-103	25.9	4.7	10.0	16-24	do.	Lt. pink	Fr	Tan	SS	-	19-26	Brown	Do.
103-106	27.8	4.9	10.8	17-23	do.	Lt. red	Fr	Brown	Fr	-	26-	do.	Do.
106-110	23.1	9.4	10.4	13-21	do.	Lavender	Fr	Dk. brown	Fr	-	12-19	Dark brown	Nonrefractory
110-114	21.7	8.6	9.0	17-24	do.	Lt. red	Fr	Brown	Fr	-	19-	do.	Do.
114-118	22.3	3.1	8.6	21-25	do.	Lt. buff	Fr	Buff	Fr	-	19-26	Speckled tan	Low heat
118-125	23.4	3.4	8.8	18-23	do.	Pink	Fr	Dk. buff	Fr	-	26-	do.	Do.
125-134	19.4	6.0	9.6	17-24	do.	Gray	Fr	Brown	SS	Gunmetal specks at 4	12-19	Dark brown	Nonrefractory
134-142	24.3	2.8	9.6	16-23	do.	Lt. gray	Fr	Tan	Fr	-	26-	Speckled tan	Low heat
142-150	27.3	1.6	10.0	17-23	do.	do.	SS	Buff	Fr	-	31+	Lt. gray; tan specks	High heat
150-154	27.4	1.3	11.8	19-24	do.	White	SS	Lt. gray	Fr	Brown specks at 4	31+	do.	Do.
154-158	18.5	2.1	7.0	16-22	do.	Lt. gray	SS	Tan	SS	-	19-26	Speckled buff	Low heat
158-166	30.9	1.3	10.8	18-24	do.	Buff	Fr	Lt. buff	Fr	Tan specks at 4	32+	do.	High heat

See footnotes at end of table.

TABLE 8. - Test data for drill-core samples from the Hobart Butte deposit, Lane County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
								HOLE 22					
0-4.5	34.6	2.9	12.4	18-24	Flint	Buff	Fr	Tan	Fr	White specks at 4	32	Brown	High heat
4.5-10.5	34.3	1.1	12.4	14-20	do.	Lt. gray	Fr	White	Fr	Brown specks at 4	32+	Speckled brown	Do.
10.5-20	35.3	1.3	12.7	16-23	do.	White	Fr	do.	Fr	do.	32+	Lt. gray; brown specks	Do.
20-27	32.7	0.8	12.7	16-22	do.	do.	Fr	do.	Fr	do.	32-1/2	White; tan specks	Do.
27-33	34.4	0.8	12.4	16-21	do.	do.	Fr	do.	Fr	-	32-1/2	White	Do.
33-39	28.1	6.2	12.5	16-22	do.	Lt. brown	Fr	Lt. brown	Fr	Tan specks at 4	26-31	Dk. brown	Intermediate
39-44	25.3	9.9	14.9	16-23	do.	Rose	Fr	Dk. brown	SS	Gunmetal specks at 4	12-19	Black	Nonrefractory
44-55	25.7	8.1	12.8	16-21	do.	Brick red	Fr	Gunmetal	SS	Brown specks at 4	19+	do.	Low heat
55-64	25.8	6.8	11.8	17-22	do.	do.	Fr	do.	SS	do.	19-26	do.	Do.
64-75	25.2	8.8	9.4	16-20	do.	Dk. red	Fr	Red brown	Fr	-	12-19	do.	Nonrefractory
75-82	26.4	7.2	9.2	14-20	do.	Brick red	Fr	do.	Fr	-	12-19	do.	Do.
								HOLE 23					
0.0-6.0	21.8	15.6	8.8	18-24	Flint	Red	Fr	Red brown	SS	-	12-19	Dk. brown	Nonrefractory
6-11	19.3	8.2	7.6	21-27	do.	Salmon red	Fr	do.	SS	-	19+	Black	Low heat
11-16	24.9	3.7	9.2	19-28	do.	Dk. pink	Fr	Pinkish gray	SS	-	26-31	Gray; brown specks	Intermediate
16-20	26.9	4.5	10.0	22-29	do.	Pink	Fr	Pink gray	Fr	Mottled at 4	26-31	Brown	Do.
20-27	26.7	1.3	9.4	18-26	do.	White	Fr	White	Fr	-	31+	Lt. gray; brown specks	High heat
27-35	27.9	1.6	9.5	20-28	do.	Buff	Fr	Lt. buff	Fr	-	31-1/2	do.	Do.
35-40	28.2	1.4	9.8	19-26	do.	Lt. buff	Fr	do.	Fr	White specks at 4	31-1/2	Gray; tan specks	Do.
40-46	28.5	1.3	9.6	20-27	do.	Gray	Fr	White	Fr	-	31-1/2	do.	Do.
46-52	34.2	0.6	11.4	16-26	do.	Lt. gray	Fr	do.	Fr	-	33+	White	Super-duty
52-61	33.7	0.6	11.6	16-26	do.	do.	Fr	do.	Fr	-	33	do.	High heat
61-71	33.8	1.4	12.0	16-28	do.	do.	Fr	do.	Fr	-	33	White; brown specks	Do.
71-80	35.0	0.8	12.2	18-28	do.	Gray	Fr	do.	Fr	-	33	White; tan specks	Do.
80-90	29.7	4.2	10.5	16-25	do.	Tan	Fr	Lt. tan	Fr	-	26-31	Speckled brown	Intermediate
90-100	29.9	3.7	10.7	18-26	do.	Pink	Fr	Buff	SS	-	26-31	Speckled tan	Do.
100-103	27.7	3.5	10.8	17-26	do.	Buff	Fr	Tan	SS	-	26-31	do.	Do.
103-111	24.1	2.3	8.8	16-26	do.	Lt. gray	Fr	Buff	Fr	Gray specks at 4	26-31	do.	Do.
								HOLE 24					
0-11	34.5	3.3	12.6	22-28	Flint	Pink gray	Fr	Tan	SS	Gray specks at 4	31	Brown	Intermediate
11-20	33.8	3.3	12.1	18-25	do.	Gray	Fr	Brown	SS	do.	31-	Speckled brown	Do.
20-28	28.6	9.3	11.6	19-26	do.	Red	Fr	do.	SS	Dk. gray specks at 4	12-19	Black	Nonrefractory
28-36	26.4	21.0	11.4	18-32	do.	Brown	Fr	Dk. brown	SS	-	-12	do.	Do.
36-42	28.2	7.0	12.2	18-25	do.	Red gray	Fr	Lt. brown	Fr	-	19-	do.	Do.
42-43	31.0	2.4	11.6	19-26	do.	Grayed tan	Fr	Lt. gray	Fr	-	26-31	Speckled tan	Intermediate
43-47.5	28.9	4.1	11.0	20-24	do.	Lt. brown	Fr	Lt. buff	SS	-	19+	Brown	Low heat
47.5-50	24.8	3.9	9.2	17-24	do.	Lt. red	SS	Buff	SS	-	19-26	do.	Do.
50-60	24.7	1.0	9.0	17-27	do.	White	Fr	White	SS	-	31+	White; tan specks	High heat
60-70	30.3	1.1	11.3	18-27	do.	Lt. gray	Fr	Lt. gray	SS	Brown specks at 4	31+	White; brown specks	Do.
70-80	25.9	3.1	10.5	19-24	do.	Lt. buff	Fr	Lt. tan	SS	-	19-26	Speckled tan	Low heat
80-87	29.3	1.7	12.4	16-23	do.	Lt. gray	Fr	Lt. gray	SS	-	31	Gray; tan specks	Intermediate
87-91.5	30.4	4.8	12.8	17-24	do.	Gray	Fr	Lt. tan	SS	-	19-26	Dark brown	Low heat
91.5-100	31.3	2.4	12.1	17-24	do.	Gray	Fr	Buff	SS	-	31+	Speckled tan	High heat
100-108	31.3	2.5	12.2	17-26	do.	do.	Fr	Gray	SS	-	26-31	do.	Intermediate
108-116	30.5	1.9	11.7	18-24	do.	Lt. gray	Fr	do.	SS	-	31+	do.	High heat
116-124	27.7	3.1	11.4	18-23	do.	Lt. pink	Fr	Buff	SS	-	19-26	Speckled brown	Low heat
124-133	25.1	9.1	13.2	17-22	do.	Lt. red	Fr	Tan	SS	-	-12	Dark brown	Nonrefractory
133-141.2	33.0	3.6	12.6	16-22	do.	Gray	Fr	do.	SS	-	26-31	Brown	Intermediate
141.2-152.5	31.8	3.9	12.5	16-21	do.	do.	Fr	do.	SS	-	26-31	do.	Do.
152.5-158.7	27.1	2.8	10.3	16-23	do.	Pinkish gray	Fr	Buff	SS	-	26-31	Speckled brown	Do.
158.7-167	32.6	1.4	11.4	17-24	do.	White	Fr	White	SS	-	31+	Speckled tan	High heat
167-171.5	20.0	3.2	7.4	20-26	do.	Tan	Fr	Tan	Fr	-	19-26	do.	Low heat
171.5-179.5	34.4	1.9	12.4	22-28	do.	Gray	Fr	Gray	Fr	-	31-1/2	Speckled brown	High heat
179.5-187.5	35.6	1.9	12.5	17-25	do.	do.	Fr	do.	SS	-	31+	do.	Do.
187.5-195.5	34.0	3.2	12.8	16-24	do.	do.	Fr	do.	Fr	-	31+	do.	Do.
195.5-204	34.2	1.4	12.0	14-22	do.	do.	Fr	Lt. gray	SS	-	31+	Speckled tan	Do.
204-212	21.3	4.6	9.2	17-23	do.	do.	Fr	Gray	Fr	-	19-	Brown	Nonrefractory
212-220	24.1	1.6	8.8	15-23	do.	Pink	Fr	Lt. brown	SS	-	26-	Grayed tan	Low heat
								HOLE 25					
112-120	25.5	1.3	9.5	19-26	Flint	Lt. pink	Fr	White	Fr	Tan specks at 4	31-1/2	White	High heat
120-126	31.2	0.8	11.0	20-27	do.	White	Fr	do.	Fr	do.	32-1/2	do.	Do.
126-135	29.7	0.5	10.8	20-26	do.	do.	Fr	do.	Fr	-	32+	do.	Do.
135-142.5	26.8	0.7	10.3	18-25	do.	do.	Fr	do.	Fr	-	31	do.	Intermediate

See footnotes at end of table.

TABLE 8. - Test data for drill-core samples from the Hobart Butte deposit, Lane County, Oreg. (Cont'd)

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification2/
	Al_2O_3	Fe_2O_3				Color	Hardness1/	Color	Hardness1/				
								HOLE 26					
0.0-6	28.9	1.3	10.4	18-28	Flint	Lt. gray	SS	White	SS	-	32-32-1/2	Buff	High heat
6-11	32.1	1.3	11.4	17-25	do.	do.	Fr	do.	Fr	-	33+	White; tan specks	Super-duty
11-16	35.6	1.4	12.5	18-29	do.	do.	Fr	do.	Fr	Brown specks at 4	34	do.	Do.
16-20	31.3	3.4	11.2	21-31	do.	do.	SS	do.	SS	do.	31+	Speckled tan	High heat
20-28	34.8	1.8	12.1	18-29	do.	White	SS	do.	SS	do.	32-1/2	do.	Do.
28-35	35.5	1.3	11.7	24-31	do.	do.	SS	do.	SS	-	33-	do.	Do.
35-42	28.9	9.5	11.1	20-25	do.	Lt. red	Fr	Dk. brown	Fr	Speckled	19-26	Black	Low heat
42-45	28.3	4.3	11.0	20-29	do.	Lt. pink	Fr	Brown	Fr	White specks at 4	31-	Speckled brown	Intermediate
45-52	22.4	7.6	10.8	16-25	do.	Gray	Fr	do.	SS	Black specks	19-	Brown	Nonrefractory
52-60	24.6	6.8	9.1	19-26	do.	Lt. pink	SS	Lt. brown	SS	do.	19+	Black	Low heat
60-70	26.2	3.4	9.6	16-27	do.	Lt. gray	SS	Buff	SS	White specks at 4	26-31	Speckled tan	Intermediate
70-75	26.7	5.1	10.0	20-26	do.	Pink	SS	Tan	SS	-	26-31	Brown	Do.
75-85	30.5	2.3	10.6	16-23	do.	Buff	SS	Buff	Fr	-	32-1/2	Lt. gray; tan specks	High heat
85-95	29.3	1.3	15.5	18-25	do.	White	SS	Lt. gray	Fr	Speckled at 4	33	White; tan specks	Do.
95-105	25.1	1.9	10.6	19-26	do.	do.	SS	do.	SS	Brown specks at 4	31-	Lt. gray; tan specks	Intermediate
105-115	27.9	5.5	14.9	15-25	do.	Gray	SS	Brown	SS	Speckled at 4	19-26	Brown	Low heat
115-122	22.5	9.0	11.4	18-23	do.	Lavender	SS	Dk. brown	S	Gunmetal specks at 4	-12	Black, bloated	Nonrefractory
122-130	29.6	3.5	11.0	17-26	do.	Lt. lavender	Fr	Buff	Fr	-	31+	Speckled brown	High heat
130-135	32.4	2.9	16.0	15-24	do.	Lt. gray	SS	Lt. gray	SS	Speckled at 4	26-31	Speckled tan	Intermediate
								HOLE 27					
0-6	24.3	9.4	9.5	20-26	Flint	Lt. red	SS	Brown	SS	Black specks at 4	12-19	Black	Nonrefractory
6-11	24.1	4.3	8.9	18-25	do.	Lt. pink	SS	Buff	SS	do.	26-31	Brown	Intermediate
11-16	24.3	9.4	8.9	18-24	do.	do.	SS	Tan	SS	Speckled at 4	19-26	do.	Low heat
16-21	23.2	1.1	8.3	19-26	do.	White	SS	White	SS	-	26-31	White; tan specks	Intermediate
21-29	24.9	2.0	8.6	22-28	do.	do.	SS	do.	SS	Brown specks at 4	26-31	Speckled tan	Do.
29-38	27.4	1.8	9.4	18-27	do.	Gray	Fr	Lt. gray	Fr	do.	31-	do.	Do.
38-44	26.3	1.7	9.1	20-24	do.	Lt. buff	SS	do.	SS	do.	31	Lt. gray; tan specks	Do.
44-54	27.0	5.8	9.8	22-29	do.	Pink	SS	Brown	SS	Black specks at 4	19-26	Black	Low heat
54-62	30.5	4.5	10.7	17-26	do.	Tan	SS	Tan	SS	do.	26-31	Brown	Intermediate
62-70.5	23.1	3.6	8.4	17-23	do.	Buff	SS	do.	SS	do.	26-	Speckled brown	Low heat
70.5-78.5	20.5	10.6	8.4	19-25	do.	Red	SS	Dk. brown	SS	do.	12-19	Black	Nonrefractory
78.5-86.5	26.8	10.3	10.2	17-24	do.	do.	Fr	do.	SS	do.	12-19	do.	Do.
86.5-94	27.4	5.1	10.0	16-24	do.	Tan	Fr	Brown	Fr	-	26-31	Dk. brown	Intermediate
94-100	30.7	8.7	10.2	14-20	do.	Red	SS	Dk. brown	SS	-	19-	Black	Nonrefractory
100-111	32.3	5.1	11.6	14-23	do.	Pink	Fr	Tan	SS	-	31	Dk. brown	Intermediate
111-120	30.0	1.8	10.7	16-23	do.	Lt. pink	Fr	Lt. gray	Fr	Brown specks at 4	32-32-1/2	Buff; tan specks	High heat
120-128	25.3	3.2	9.4	18-24	do.	Gray	SS	Buff	SS	Tan specks at 4	26-31	Gray; brown specks	Intermediate
128-135.5	26.0	1.7	9.5	18-26	do.	White	SS	White	SS	Brown specks at 4	26-31	Lt. gray; tan specks	Do.
135.5-144.5	25.9	1.9	9.6	17-23	do.	Lt. gray	SS	do.	SS	do.	26-31	Lt. gray; brown specks	Do.
								HOLE 40					
0-9	35.8	1.7	12.9	10-18	Flint	Lt. gray	Fr	Buff	Fr	-	31+	Speckled brown	High heat
9-17.6	35.0	2.4	12.3	12-20	do.	do.	Fr	do.	Fr	Brown specks at 4	31	Brown	Intermediate
17.6-22	35.4	0.8	12.2	10-18	do.	do.	Fr	White	Fr	Tan specks at 4	32-32-1/2	Speckled buff	High heat
22-30	34.8	1.2	12.0	16-20	do.	do.	Fr	Buff	Fr	-	32+	Speckled tan	Do.
30-38	33.9	1.7	11.7	14-18	do.	do.	Fr	do.	Fr	-	31-	do.	Intermediate
38-46	34.0	1.4	12.0	14-18	do.	do.	Fr	do.	Fr	-	31+	Buff; tan specks	High heat
46-53	32.7	4.6	11.8	14-20	do.	Buff	Fr	Tan	Fr	-	19-26	Black	Low heat
53-60	32.9	1.9	11.9	18-24	do.	Lt. buff	Fr	Buff	Fr	-	31+	Speckled tan	High heat
60-67	28.7	1.3	10.4	18-22	do.	Lt. gray	Fr	do.	Fr	White specks at 4	26-31	Buff; tan specks	Intermediate
67-75	26.7	1.5	9.8	16-22	do.	do.	Fr	do.	Fr	Black specks at 4	31	Speckled tan	Do.
75-80	28.1	1.7	10.5	16-22	do.	Gray	Fr	Lt. gray	Fr	-	32	White; tan specks	High heat
80-85	29.6	2.6	11.4	16-23	do.	Pinkish gray	Fr	Buff	Fr	Tan specks at 4	31	Speckled brown	Intermediate
85-90	28.4	4.0	10.1	14-20	do.	Red	Fr	Tan	Fr	-	19-26	Dark brown	Low heat
90-95	27.0	7.2	11.6	16-20	do.	do.	Fr	do.	SS	Black specks at 4	12-19	Black	Nonrefractory

1/ SS = Softer than steel; S = Equal to steel; HS = Harder than steel; Fr = Friable; P = Punky; Powd = Powder.
2/ A.S.T.M. designation by P.C.E. only.

TABLE 9. - Test data for drill-core samples from the Five-Mile Prairie deposit, Spokane County, Wash.

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification[2]
	Al_2O_3	Fe_2O_3				Color	Hardness[1]	Color	Hardness[1]				
HOLE FM 1-1													
3-8	7.5	4.6	-	28-48	Shale	Rust	SS	Gunmetal	HS	-	12	Dk. red-brown	Nonrefractory
8-13	18.0	4.8	-	30-44	Kaolin	do.	SS	do.	HS	-	12-19	Black	Do.
13-17	9.2	2.0	-	29-49	do.	Tan	SS	do.	HS	-	12-19	Lt. brown	Do.
17-22	12.0	1.5	-	32-52	do.	Lt. buff	HS	do.	HS	-	19-26	Buff	Low heat
22-27	11.3	1.1	-	29-46	do.	do.	HS	Tan	HS	Green tint at 4	19-	Gray; bloated	Nonrefractory
27-32	9.7	0.9	-	27-44	do.	Lt. gray	SS	do.	HS	-	12-19	Buff; blistered	Do.
HOLE FM 5-5													
5-10	9.3	2.4	-	42-54	Kaolin	Rust	SS	Gunmetal	HS	-	12+	Brown; bloated	Nonrefractory
10-15	9.0	3.6	-	40-51	do.	do.	SS	do.	HS	-	-12	Black	Do.
25-27	7.8	3.5	-	46-53	do.	Lt. red	SS	do.	HS	-	-12	Dk. brown	Do.
HOLE FM 6B-6B													
5-15	15.0	4.7	-	59-68	M[3]	Tan	SS	Gunmetal	HS	-	-12	Brown, vesicular	Nonrefractory
15-17.5	12.5	5.0	-	57-64	do.	Rust	SS	do.	HS	-	-12	Brown, bloated	Do.
17.5-20	12.1	5.1	-	48-60	Kaolin	Lt. brown	SS	do.	HS	-	-12	do.	Do.
20-40	14.3	12.9	-	59-62	M	do.	SS	do.	HS	-	-12	Dk. brown; bloated	Do.
40-42	15.2	12.4	-	58-73	do.	Brick red	S	do.	S	Started to melt at 4	-12	Dk. red-brown; bloated	Do.
42-48	13.2	3.8	-	55-76	do.	Brown	HS	do.	HS	do.	-12	Black	Do.
48-49	12.2	3.1	-	36-58	Kaolin	Tan	HS	do.	HS	do.	12-	Brown; bloated	Do.
HOLE FM 7-17													
			800° C.										
0-10	13.6	7.1	5.7	47-66	Kaolin +M	Rust	HS	Gunmetal	HS	-	-12	Black	Nonrefractory
10-15	15.8	4.0	7.4	66-72	M	do.	HS	do.	HS	-	-12	Dk. brown; bloated	Do.
15-17-1/2	16.3	5.3	8.2	57-69	M	Tan	HS	do.	HS	-	-12	Brown, bloated	Do.
17-1/2-19	13.2	15.4	6.3	28-42	Shale	Brick red	HS	do.	HS	Started to melt at 4	-12	Black	Do.
19-23	7.8	6.2	4.0	27-37	do.	Red	SS	do.	HS	-	-12	do.	Do.
23-27-1/2	10.0	4.4	4.4	28-42	do.	Lt. brown	SS	do.	HS	-	-12	Dk. brown	Do.
27-1/2-33	9.7	3.3	4.4	34-50	Kaolin	Rust	SS	do.	HS	-	12-19	Brown	Do.
33-36-1/2	8.5	3.3	4.0	33-45	do.	Lt. brown	SS	do.	HS	-	12	do.	Do.
HOLE FM 8-19													
0-4	2.5	0.3	0.8	10-17	Nonclay	Lt. gray	Fr	Lt. buff	Fr	Sand	32-	White	High heat
4-11	12.8	7.4	4.9	39-53	Kaolin	Lt. red	SS	Gunmetal	HS	Cracked slightly at 4	-12	Black	Nonrefractory
11-28	9.7	2.9	5.3	37-50	do.	Tan	SS	do.	HS	-	-12	Dk. brown	Do.
28-31	9.1	3.4	5.2	41-52	do.	Rust	SS	do.	HS	-	-12	do.	Do.

[1] SS = Softer than steel; S = Equal to steel; HS = Harder than steel; Fr = Friable; P = Punky; Powd = Powder.
[2] A.S.T.M. designation by P.C.E. only.
[3] Montmorillonite.

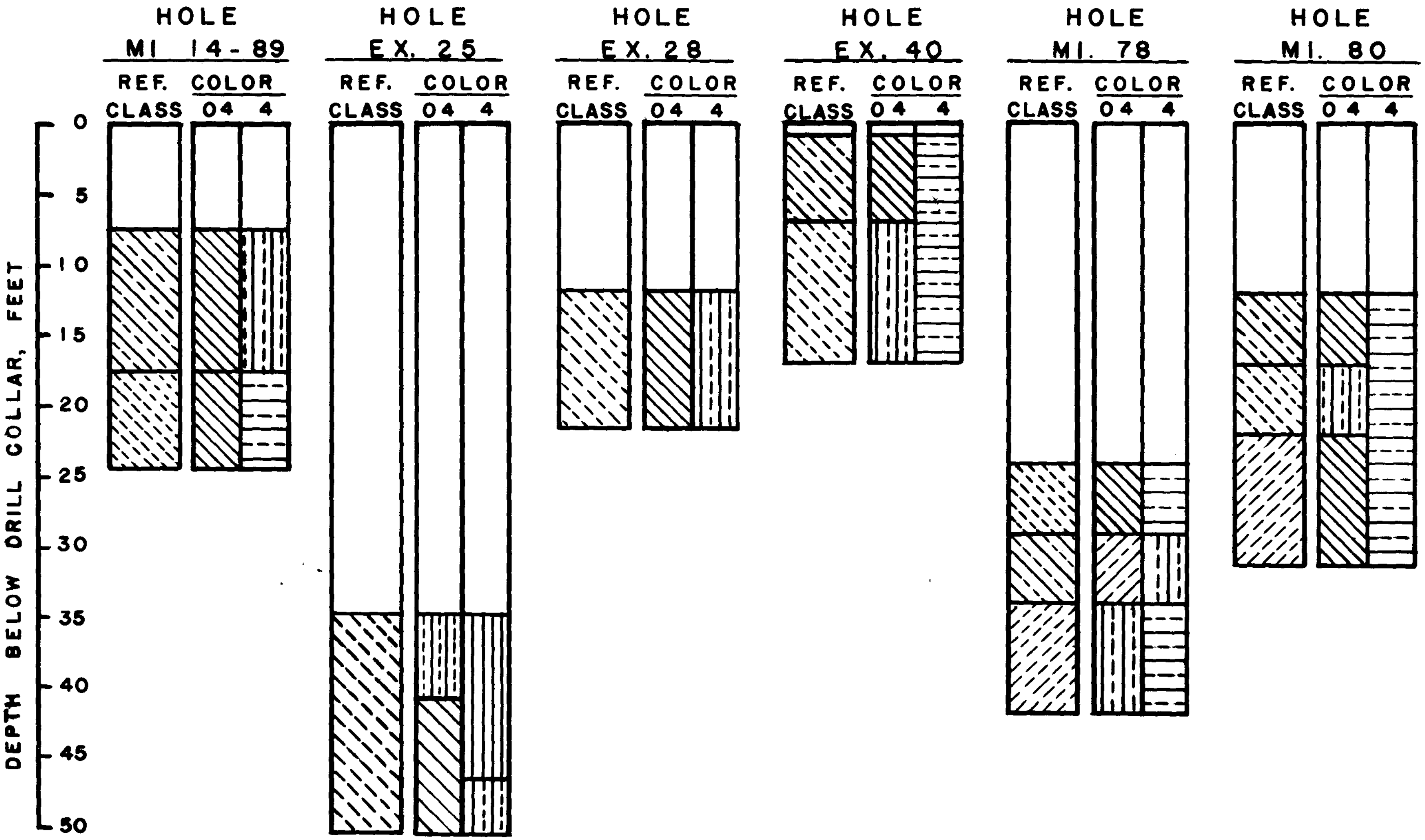

Figure 36. - Refractory classification and fired colors at cones 04 and 4 of clay samples from area I, Excelsior deposit, Spokane County, Wash. (See fig. 37 for legend.)

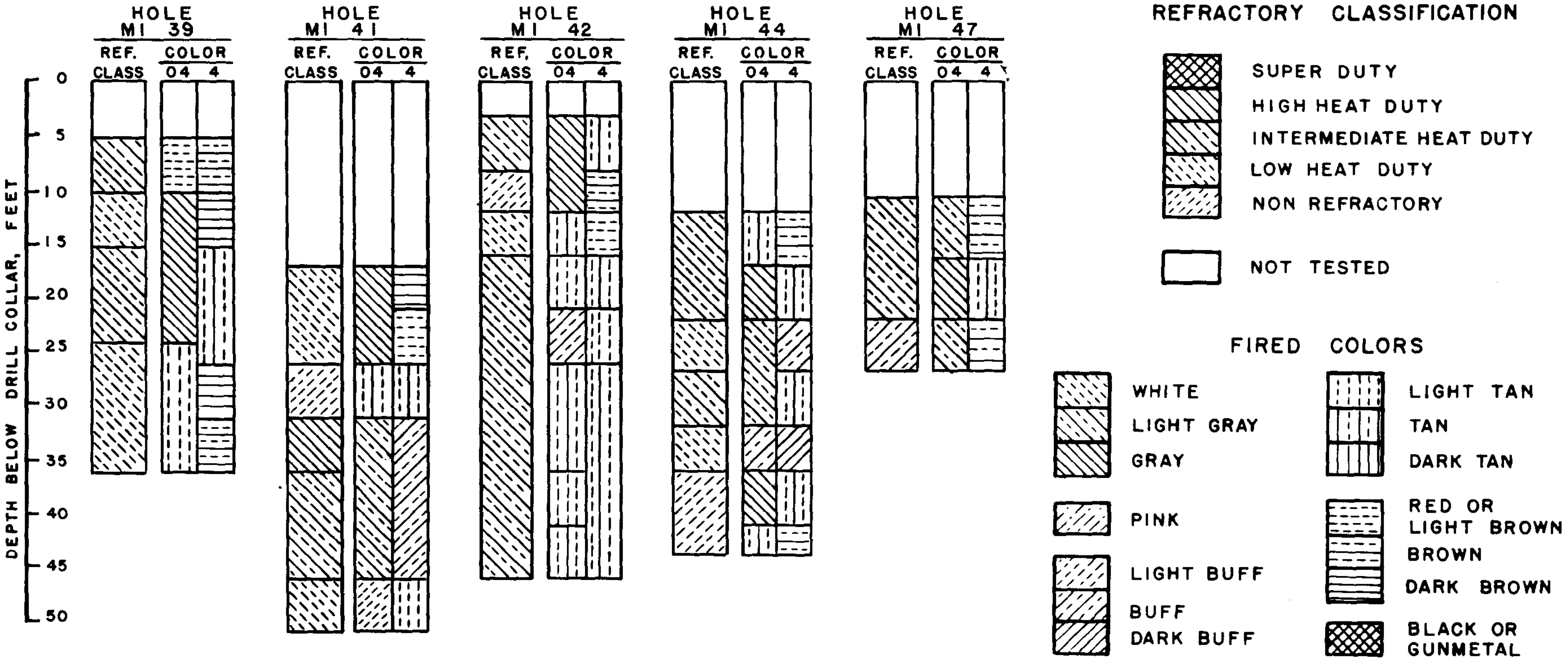

Figure 37. - Refractory classification and fired colors at cones 04 and 4 of clay samples from area 2, Excelsior deposit, Spokane County, Wash.

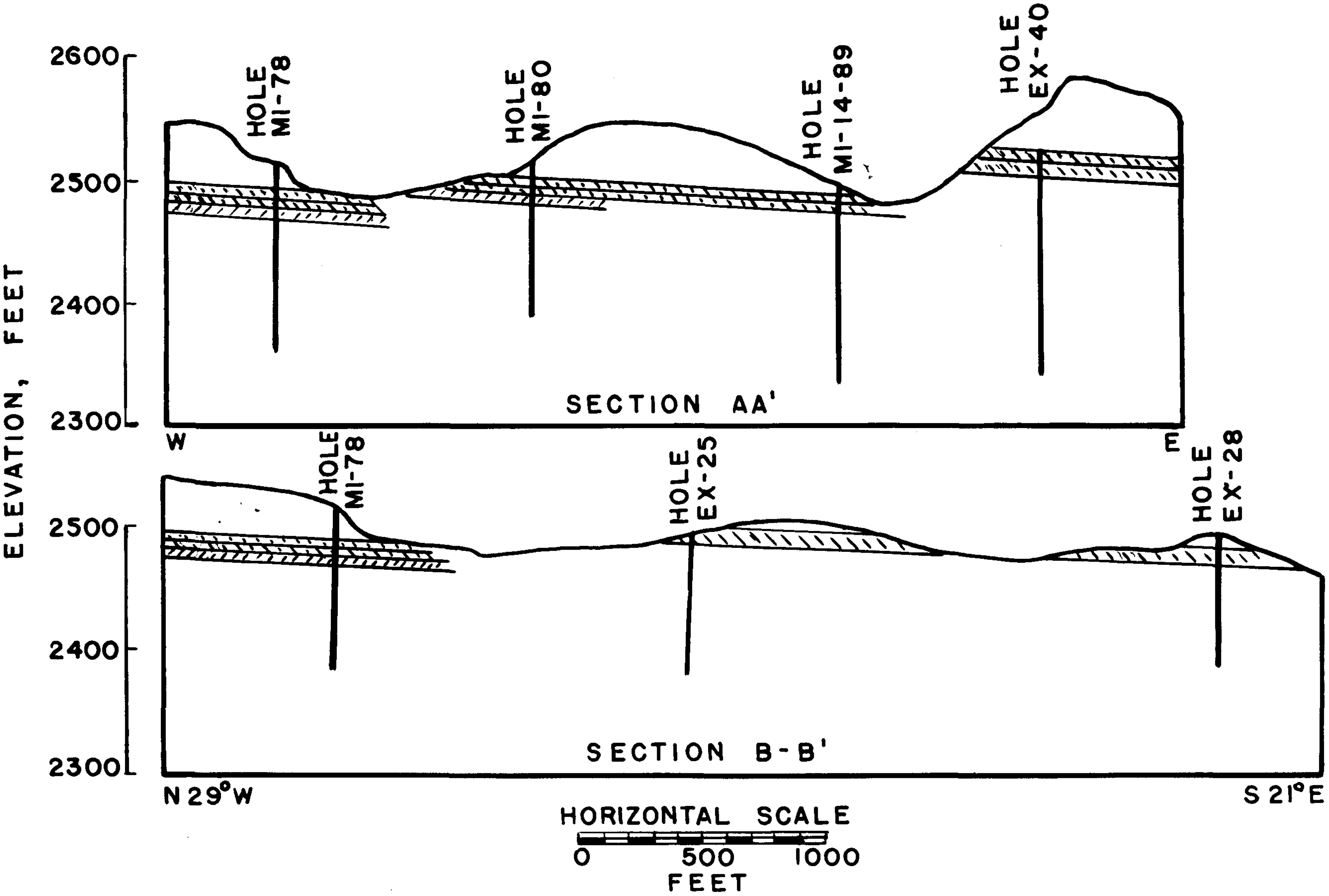

Figure 38. - Idealized sections showing the refractory classification of clay from area I, Excelsior deposit, Spokane County, Wash.

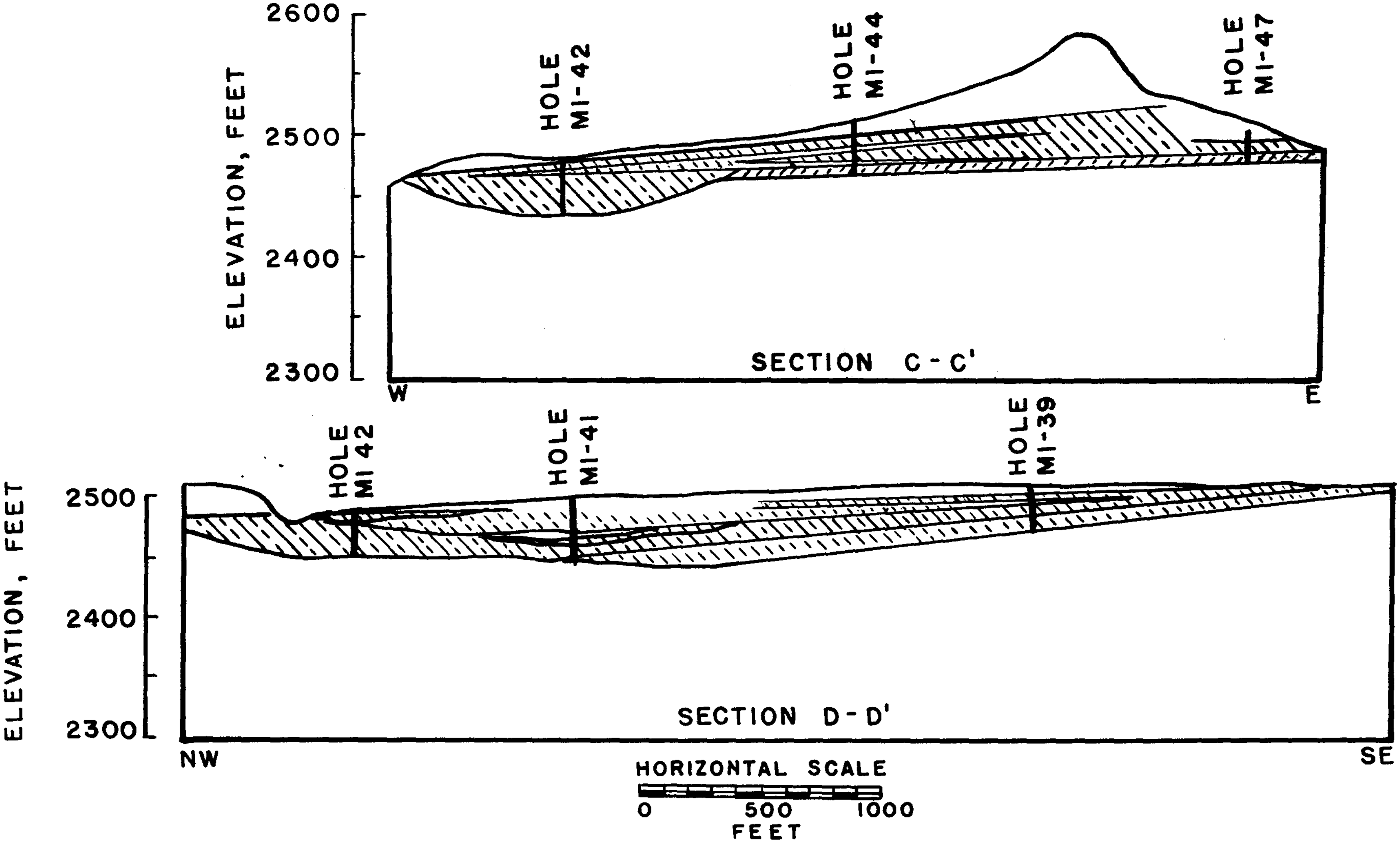

Figure 39. - Idealized sections showing the refractory classification of clay from area 2, Excelsior deposit, Spokane County, Wash.

No idealized sections were drawn for this deposit because the data were insufficient.

Excelsior, Wash., Deposit

The Excelsior deposit is in the Mica district of Washington, about 15 miles southeast of Spokane. Clays from this district have been used for making ceramics for many years. The district is served by both highway and railroad, which are but a few thousand feet from the Excelsior deposit.

Drilling was done by the Bureau of Mines in two principal areas. Area 1 is in sections 21 and 22 and area 2 in sections 14, 15, 22, and 23, T. 24 N., R. 44 E., W.M. More than 100 holes were drilled, but samples from only eleven were taken for testing. The average available alumina content of the samples was 30.6, with 3.4 percent of available Fe_2O_3. Overburden was somewhat deeper in area 1, averaging 15 feet, compared to an average of 9 feet in area 2. The depth of clay per hole was likewise greater in area 2 than area 1. Depth of clay averaged 32 feet in area 2 and 16.6 in area 1.

The bulk of the clay in this deposit has been formed by the decomposition of the basalt capping. It is disposed in flat-lying seams interbedded with white, sedimentary clay, quartz sand, and altered basalt. The beds are underlain with unaltered basalt.

P.C.E. values and fired colors. - The best refractory clay is a 5-foot bed of high heat-duty clay cut by hole MI-41 about 30 feet below the surface. However, considerable intermediate-duty clay is found often interbedded with low heat-duty and nonrefractory materials. These intermediate beds range from 5 to 30 feet in thickness and are covered with 1 to 10 feet of overburden. The most continuous strata is thirty feet of intermediate-duty clay cut by hole MI-42 about 15 feet below the surface. This bed is also found in holes MI-39, MI-41, MI-42, and MI-47. (See figs. 35 through 39 and table 10.)

Fired colors are gray, buff, and tan at cone 04, but at cone 4 they become tans and brown.

Olson, Idaho, Deposit

The Olson clay deposit is in Latah County, Idaho, about 8 miles northeast of Troy and 22 miles northeast of Moscow, Idaho. The deposit underlies some 928 acres in section 30, T. 40 N., R. 2 W., and section 24, T. 40 N., R. 3 W. It is disposed on a gently rolling plateau between Big Bear Creek and its west fork. The plateau is about 2,800 feet in elevation and rises 200 to 260 feet above the creek bottom. The Washington, Idaho & Montana Railroad is 2-3/4 miles from the deposit.

The clay beds range from a few inches to 126 feet in thickness and have an average thickness of 26.4 feet. Overburden is principally loess and averages 15.8 feet in thickness. The clay beds were believed to have been formed by weathering of the Thatuna mountain granites and subsequent transportation of the weathered products to its present site. Kaolin is the principal clay mineral, and it is associated with quartz, mica and iron oxide in varying amounts.

TABLE 10. - Test data for drill-core samples from the Excelsior area 1 deposit, Spokane County, Wash.

Interval, feet	Chemical analysis, percent			Plasticity test		Fired properties					Refractoriness		
	Available		Ign. loss, 700° C.	Range	Indicated clay type	Cone 04		Cone 4		Remarks	P.C.E., cone	Fired cone color	Refractory classification2/
	Al_2O_3	Fe_2O_3				Color	Hardness1/	Color	Hardness1/				
HOLE Ex. 25													
35-41	31.8	3.4	11.2	43-50	Kaolin	Tan	SS	Olive-drab	HS	Cracked	26-	Brown	Low heat
41-47	32.1	2.4	10.8	42-51	do.	Gray	SS	Dk. tan	HS	do.	19-26	do.	Do.
47-50.5	32.0	3.4	11.0	40-46	do.	do.	SS	Tan	SS	do.	19-26	do.	Do.
HOLE Ex. 28													
12-14	29.0	2.7	10.0	42-47	Kaolin	Gray	SS	Tan	HS	Cracked	19-26	Dark brown	Low heat
14-18	31.7	1.5	11.0	40-44	do.	do.	SS	do.	HS	do.	19-26	do.	Do.
18-22	32.3	1.6	11.1	34-48	do.	do.	SS	do.	SS	do.	26-	do.	Do.
HOLE Ex. 40													
1-7	31.6	3.25	11.4	43-53	Kaolin	Gray	S	Brown	HS	White specks	26-31	Brown	Intermediate
7-12	30.9	6.7	11.2	38-46	do.	Tan	SS	do.	HS	Brown specks at 4	19	Dark brown	Low heat
12-17	30.8	7.2	11.4	48-59	Kaolin +M3/	do.	SS	do.	HS	Cracked at 04	19+	Brown	Do.
HOLE MI 14-89													
7.5-17.5	31.0	2.0	11.0	34-42	Kaolin	Gray	SS	Tan	SS	-	26-31	Black	Intermediate
17.5-24.5	25.3	5.9	9.7	34-44	do.	do.	SS	Brown	HS	-	19-26	Brown	Low heat
HOLE MI-78													
24-29	30.2	2.4	10.9	36-42	Kaolin	Gray	SS	Brown	S	Black specks at 4	19-26	Dark brown	Low heat
29-34	31.5	1.8	11.1	32-40	do.	Buff	SS	Tan	HS	Badly cracked	26-31	Brown	Intermediate
34-42	29.9	2.2	10.6	34-38	do.	Tan	SS	Brown	HS	Cracked	12-19	Black	Nonrefractory
HOLE MI-80													
12-17	29.9	2.7	10.6	38-42	Kaolin	Gray	SS	Brown	HS	Cracked	26	Black	Intermediate
17-22	31.8	2.6	10.8	36-42	do.	Tan	SS	do.	HS	Badly cracked	19+	Dark brown	Low heat
22-31.5	30.2	2.2	10.1	38-44	do.	Gray	SS	Red-brown	HS	Cracked	12-19	do.	Nonrefractory
Area 2 - HOLE MI-39													
5-10	31.5	6.3	12.0	53-61	Kaolin +M	Lt. brown	S	Brown	HS	-	26-31	Black	Intermediate
10-15	30.2	4.2	11.1	56-66	do.	Gray	S	Dk. brown	HS	Cracked	19-26	Brown	Low heat
15-20	32.1	2.7	11.2	49-58	do.	do.	SS	Tan	HS	do. at 4	26-31	do.	Intermediate
20-24	31.4	3.4	11.2	48-57	do.	do.	SS	Green-tan	HS	-	26-31	do.	Do.
24-26	29.6	5.4	11.0	50-60	do.	Olive-green	S	do.	HS	-	19-26	Black	Low heat
26-31	29.8	4.8	10.0	50-58	do.	Tan	SS	Dk. brown	HS	Cracked	19-26	Dk. brown	Do.
31-36	28.6	7.1	10.6	42-48	Kaolin	do.	SS	Red-brown	HS	do.	19+	Brown	Do.
HOLE MI-41													
17-21	30.4	4.0	11.0	52-64	Kaolin +M	Dk. gray	HS	Dk. brown	HS	Cracked	19-26	Dk. brown	Low heat
21-26	32.2	2.2	11.0	44-52	Kaolin	Gray	S	Lt. brown	HS	Black specks	19-26	do.	Do.
26-31	27.5	7.8	10.7	40-46	do.	Tan	SS	Tan	SS	-	12-19	Black	Nonrefractory
31-36	32.8	1.2	11.7	38-46	do.	Lt. gray	SS	Buff	HS	Cracked	31+	do.	High heat
36-41	30.0	1.7	10.4	50-60	Kaolin +M	do.	SS	do.	S	White specks at 04	31	do.	Intermediate
41-46	29.3	1.3	10.2	52-60	Kaolin	do.	S	do.	HS	White specks at 4	31	do.	Do.
46-51	28.8	2.4	9.8	50-60	do.	Lt. buff	SS	Lt. tan	S	Fine cracks	19-26	do.	Low heat

See footnotes at end of table.

TABLE 10. - Test data for drill-core samples from the Excelsior area 2 deposit, Spokane County, Wash. (Cont'd)

Interval,
Chemical analysis, percent
Available
Ign. loss
Plasticity test
Fired properties
Cone 04
Cone 4

COPY

HOBART BUTTE DEPOSIT

Owner:

O. K. Edwards for 7 associates
Willamina Clay Products Company
1020 S.W. Taylor Street
Portland, Oregon

Quality:

Average P.C.E. of all clays in deposit is C/31-32

Highest P.C.E. of any clay sampled in pit. C/34

Lowest P.C.E. of any clay sampled in pit. C/27-28
(White granular material at grass roots)

Material is of flint clay variety and shows weak plasticity even when ground wet to pass 200 mesh.

Color is grey to white.

Unfired properties:

Water of plasticity - 27.8 per cent

Shrinkage water - 6.2 per cent

Pore water - 21.6 per cent

Dry volume shrinkage - 10.7 per cent

Dry linear shrinkage - 3.4 per cent

Fired properties:

	Shrinkage	
Cone	Volume per cent	Linear per cent
02 (2057° F.)	5.7	1.9
10 (2381° F.)	28.3	10.5
15 (2615° F.)	29.0	10.8
20 (2786° F.)	35.0	13.3
29 (2984° F.)	41.3	16.3

Absorption

Cone	Per cent Absorption
C/02	17.
C/10	11.2
C/15	9.4
C/20	6.4
C/29	0.6

The clay bars develop a fine cubical surface cracking characteristic of many commercial kaolins but the color remains white without specking until C/20 when a very light cream tint appears with a few light brown specks. A uniform light grey color and vitrified texture develops at C/29.

Chemical Analysis (Limits)

	High	Low
Al_2O_3	40.20	38.42
SiO_2	49.68	45.60
Fe_2O_3	0.74	0.37
TiO_2	.50	0.13
CaO	.50	0.37
MgO	.22	0.15
Na_2O	1.70	1.00
Loss on ignition	14.90	10.92

The material is of rather high purity with the exception of the large alkali content, 1.0 - 1.7 Na_2O. The ferric oxide content is less than other commercial kaolins except Georgia kaolin. Alumina content is low, but the silica content is not correspondingly high.

The calculated feldspar content is similar to that of ball clay rather than kaolin and this flux is undoubtedly the cause of the lower P.C.E., averaging for the best portions between C/33-34 and from one to two cones lower than the better kaolins.

Sufficient plasticity can be developed by wet-pan grinding for use in a brick auger. However, a better article can be produced more easily if a bond clay is added.

If a portion of the flint clay is given a high temperature calcine for grog, the product would show less volume change in original firing as well as less trouble in shrinkage and spalling in operation.

Sufficient plasticity can be developed by wet pan grinding for use in a brick auger. However, a better article can be produced more easily if a bond clay is added.

If a portion of the flint clay is given a high temperature calcine for grog, the product would show less volume change in original firing as well as less trouble in shrinkage and spalling in operation.

Cone fusion tests indicate that the 140 acres, controlled by Edwards and his associates, are underlain by clay of refractory quality with a minimum thickness of 200 feet. The average specific gravity of the material is 2.4; therefore 13.3 cubic feet per ton. On that basis the extimated quantity present is in the amount of approximately 40,000,000 tons.

The U.S. Bureau of Mines and the U.S. Geological Survey did exploration work on the Hobart Butte deposit during the war aimed at determining Al_2O_3 content for possible use as a source of alumina, but, probably they did not do any ceramic testing of samples.

United States Department of the Interior
Geological Survey

Strategic Minerals Investigation

PRELIMINARY REPORT AS OF JULY 23, 1943
on
THE HIGH-ALUMINA CLAY DEPOSIT AT HOBART BUTTE
Lane County, Oregon

Subject to revision when later drilling
results are released

by

John S. Loofbourow, Jr.

Prepared at Cottage Grove, Oregon
July 23, 1943

See geologic map in
pocket of bound copy
of this report

copy

SUMMARY

The Hobart Butte high-alumina clay deposit is located 16 miles by road south of the railroad at Cottage Grove, in Lane County, Oregon. This is a region of mild and humid climate. The deposit has been mined for refractory clay by the Willamina Clay Company. Since September, 1942, the Columbia Metals Corporation has had a lease on the property. In August, 1942, R. L. Nichols, of the Federal Geological Survey, mapped the deposit and recommended exploration by the Federal Bureau of Mines. Since January 26, 1943 the Bureau of Mines has put down 24 diamond drill holes, totaling 6896 feet. The purpose of this report is to summarise the economic geology revealed by this work.

The regional geology is presented in Bulletin 850 of the U. S. Geological Survey. The Hobart deposit is in the Calapooya formation of upper Eocene age, which is composed of more than 3500 feet of volcanic breccias, conglomerates, mudflows, and lava flows. The high-alumina deposits of kaolinite are found in beds ranging from conglomerate to fine shale or tuff. Generally the ore is conformable to the bedding. Structurally, Hobart Butte appears to be a faulted syncline. Dips are gentle but there is an abrupt change in attitude at the point where the fault is inferred, and the ore body is displaced. Kaolinite is practically the only clay mineral of importance, and this simplicity should favor the extraction of alumina. The sulphide minerals, realgar and stibnite, are widely distributed throughout the clay but in minor quantities.

The clay deposits have been divided into four areas. Two of these have been drilled sufficiently well to be classed as measured ore. These two bodies lie at the top of Hobart Butte and are separated by the cross fault. They are called ore bodies #1 and #2. The first is estimated to contain a total of 9,200,000 tons of dry ore with a grade of 29.9% available Al_2O_3 and 3% available Fe_2O_3. Of this amount it is estimated that 6,500,000 tons has no overburden. Ore body #2 contains 2,700,000 dry tons with nearly an equal amount of overburden. The average grade is 29.3% available Al_2O_3 and 3.6% available Fe_2O_3. The moisture content of both ore bodies has been approximately determined as 3%. These grade and tonnage estimates agree substantially with those of the U. S. Bureau of Mines.

Area #3 lies below ore body #1 on the south end of the Butte. Complete analyses have not yet been received but it is expected that roughly 2,500,000 tons averaging 25% available Al_2O_3 and 10% available Fe_2O_3 will be indicated. Area #4 is situated below ore body #2 at the northeast end of the Butte. The expected grade is 27% available Al_2O_3 but the overburden will be large. A program involving 3000 feet of drilling is just starting in this area.

When the current drilling program is completed it is recommended that no further intensive drilling be started at Hobart Butte until it becomes known definitely that Hobart clay can be used successfully as a source of alumina. Meanwhile, geologic efforts should be continued to locate other similar clay deposits in the surrounding area.

INTRODUCTION

Purpose and Scope

The investigation of high-alumina clay at Hobart Butte has been a joint project initiated by the Federal Geological Survey and drilled by the Federal Bureau of Mines. The purpose of the exploration work, as a part of the strategic mineral program, was to prove or disprove possible large tonnages of high-alumina clay. A report by R. L. Nichols 1/, dated August 28, 1942, estimated a possible reserve of 5,300,000 tons of indicated ore and 6,200,000 tons of inferred ore. This estimate has been substantiated by drilling.

The purpose of this report is to present a preliminary summary of the economic geology after six months exploration which cost approximately $35,000. The drilling has been renewed but it seems advisable to summarize present information now, because the writer may be transferred to another assignment and because the exploration of the most favorable ore areas has been essentially completed.

A total of 6896 feet of diamond drilling has completed the preliminary exploration of the upper portion of Hobart Butte. The writer logged all the core and sampled it. He also designated sites for 130 test pits and sampled them. In addition he took 122 samples from pre-existing exposures. With the help of D. L. Snyder, of the U. S. Bureau of Mines as rodman, a topographic map of the Butte was prepared. Surface geology and assays were posted on the map. During the latter half of the drilling the writer also located the drill holes by transit survey. Sections and maps were drawn up contemporaneously with the drilling, as the basis for suggesting additional drill hole locations.

During this field work microscopic studies were not attempted for lack of time. However, specimens of core were taken at an average of 8-foot intervals and were preserved for future reference. These should be valuable in laboratory investigations of structure and origin, but it would have been preferable to have kept a complete file of split core.

Location and Access

Hobart Butte is located in the Calapooya Mountains of southwestern Oregon about 16 miles south of Cottage Grove. The greater part of the area lies in southern Lane County although a small part extends into northern Douglas County. The base of the Butte is reached by driving approximately 13 miles from Cottage Grove over a hard-surfaced road of low gradient from there it is 3 miles along a narrow mountain road of perhaps 10% grade. Cottage Grove is on the Siskiyou line of the Southern Pacific Railroad, 144 miles from Portland, Oregon.

Topography, Vegetation and Climate

Hobart Butte is a prominent, elongate, topographic feature which rises more than 1500 feet from the valley of the Coast Fork of the Willamette River to a summit elevation of 2459 feet. Its summit area is narrow, extending about 1/2 mile in a northeast-southwest direction and terminating sharply in all directions. The sides of the Butte slope for the most part over 30° and are heavily timbered on the north side. The areas free from dense timber are covered either by a second growth timber or by heavy brush. This, in addition to a pervasive colluvial mantle, limits outcrops. Artificial cuts give the best exposures of the rocks.

The average annual total precipitation is over 50 inches, based on a comparison with figures for adjacent areas. Precipitation is mainly in the form of rain, although snow occasionally accumulates to a depth of a foot or two.

History

According to Wilson and Treasher 2/ Robert Phillips discovered this clay deposit in 1930 while prospecting for cinnabar. Samples were submitted to Hewitt Wilson, of the University of Washington, and he proved them to be a high-grade, refractory clay. In the spring of 1933 the Willamina Clay Products Company obtained a lease on the property and later purchased it. A road was completed to the property and 12,000 to 15,000 tons have since been mined and shipped to the ceramics plant of the Willamina Company for use in the manufacture of refractory materials. In September, 1942 the Columbia Metals Corporation, of Seattle, Washington, secured a lease on the property with the object of using this clay as a source of alumina.

Previous Investigations and Acknowledgments

Wells and Waters 3/ in 1930 investigated the quicksilver deposits of the nearby Blackbutte and Elkhead mines and gave an excellent account of the regional geology. They briefly mention Hobart Butte. The first published reference to Hobart Butte as a clay deposit was made by Wilson and Treasher in 1938 in their survey of refractory clays for the State of Oregon. 2/ This paper included 6 chemical analyses showing total alumina from 38% to 40%. It was these analyses that led Robert L. Nichols of the United States Geological Survey to investigate Hobart Butte as a possible source of high-alumina clay in the summer of 1942. In the course of several weeks field work numerous test-pits and surface samples were taken by Nichols and analysed by the U. S. Bureau of Mines for available alumina. As a result Nichols recommended Hobart Butte in a report dated August 28, 1942, as a deposit of sufficient size and grade to warrant drilling by the U. S. Bureau of Mines. Subsequent to Nichols' examination the U. S. Bureau of Mines examined the deposits and their analyses appear in War Minerals Report No. 175. 4/ In January 1938 Hodge published a compendium on Northwest Clays which describes Hobart Butte. 5/

Throughout the present investigation the writer has benefited by numerous field conferences with Robert L. Nichols under whose supervision the work was undertaken. He also gratefully acknowledges the help of Mr. Nichols and the Northwest Regional Office of the Geological Survey in the preparation of this report. The writer also wishes to express his appreciation to George H. Coughlin, Project Engineer of the U. S. Bureau of Mines, and H. G. Iverson, District Engineer of the U. S. Bureau of Mines, for their cooperation in having samples analysed, in furnishing assay data, and in extending many courtesies. In particular, Mr. Coughlin is to be thanked for contributing the section on mining to be appended to this geological report. Thanks are also due D. L. Snyder, also of the Bureau of Mines, for his assistance as a rodman and also for his help on mineral identifications in the field.

Bibliography

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5/ Hodge, Edwin T., Market for Columbia River Hydroelectric Power Using Northwest Minerals. Section IV - Northwest Clays, Vol. IV, pp. 873-883, part 3, 1938.

GENERAL GEOLOGY

U.S.G.S. Bulletin 850 by Wells and Waters 3/ is the basis for this summary of the regional geology and Figure 2 is a reproduction of their geologic map.

Hobart Butte is in the upper Eocene Calapooya formation, which is composed primarily of volcanic material in the form of volcanic breccias, tuffs, conglomerates, lava flows, and mud flows. The rocks do not vary greatly in composition but they are strikingly dissimilar in appearance. This characteristic prevails throughout the formation, and even its individual members show marked local variations. In the vicinity of Hobart Butte these sedimentary rocks attain a total thickness of at least 3500 feet, with the top not exposed. East of Hobart Butte lavas predominate while west of the Butte tuff predominates. Fossil leaves date this formation. Wood and charcoal are also common.

Underlying the Calapooya formation, and separated by an angular unconformity, is the Umpqua formation which consists of a thick series of marine sandstones, shales, conglomerates, and interbedded basalt flows. A study of dips on the geologic map of Wells and Waters 2/ indicates an anticline to the northwest of Hobart Butte, and a syncline extending through Hobart Butte. The anticline is best developed in the lower Eocene Umpqua formation but it is also slightly developed in the upper Eocene Calapooya formation, which comprises the clay deposits of Hobart Butte. Faults that have been mapped in the Black Butte and other mining areas are normal, with a northeast strike and show displacements up to a few hundred feet. In the adjacent Black Butte and Elkhead mining district hydrothermal mineralization is characterized by cinnabar, realgar, and stibnite deposits in the Eocene rocks.

ORE DEPOSITS

General Features

At Hobart Butte the high-alumina clay occurrences have been divided into four areas. Ore bodies #1 and #2 are at the top of the Butte and are separated by a fault. Area #3 occurs below ore body #1 at the south end of the Butte and Area #4 crops out at the north end of the Butte below ore body #2. Ore bodies #1 and #2 have been sufficiently well defined by drilling and test-pitting to be classed as measured ore. The other areas are not sufficiently well-known to permit an estimation of reserves. Most of ore body #1 has no overburden. Ore body #2 has almost as much overburden as ore. All the high-alumina clay at Hobart has been found to occur at fairly well defined horizons, generally parallel with the bedding, and terminating against the hillside, or by lensing out or faulting. In only a few cases does the ore body cross the bedding.

Lithologic Features

Nearly all the rocks on Hobart Butte contain appreciable amounts of available alumina but only a relatively small quantity of the rocks are of a high enough grade to merit economic interest. Most of the rock material is of volcanic origin that has been deposited as breccias, conglomerates, sandstones, shales or tuff. The relative amounts of fluvial and subaerial deposits have not been determined. There is no evidence of marine deposition. Bedding is generally obscure and only in a few drill holes is it well developed. Throughout the section fragments of carbonized wood are common and some logs were found up to a foot in diameter and several feet in length. Leaf imprints have been noted in several widely separated localities.

The rocks comprising ore bodies #1 and #2 are mainly gray, but in some places they are white, which may be a result of hydrothermal bleaching. Red and reddish purple beds are common in ore bodies #3 and #4, and these colors occur occasionally in the upper ore bodies. Surface alteration changes the gray beds to a yellowish tint but the red beds are apparently but little affected.

A conspicuous feature of some portions of ore body #1 are white rounded to angular, and often ovoid pellets of nearly pure kaolinite. They range from microscopic size to over 1/4" in diameter and occur in a gray argillaceous matrix. They often constitute as much as 75% of the rock and form high-grade areas. According to V. T. Allen* microscopic studies show that these pellets are made up of kaolinite that was soft at the time of deposition and was molded around grains of quartz and rock fragments. These are interpreted as being of sedimentary origin.

In the high-alumina rocks most of the grains can be easily scratched by a knife, often by the fingernail, but there are some fine-grained rock fragments of non-clayey material that are generally harder than steel or are quite difficult to scratch with it. Many of the rocks relatively low in alumina may be scratched by a knife but this is mainly the result of tearing apart of poorly cemented grains, and a definite grittiness usually results.

High-grade material nearly always exhibits a conchoidal fracture. This property is one of the most reliable guides. The fracture always breaks across all the grains to produce a smooth curved surface. The low-grade material breaks with an irregular, rough surface that has been developed by pulling apart of most of the grains.

The luster of the high-alumina rocks is commonly porcelainous. These features of hardness, fracture and luster, as described above, are found to apply not only to the gray and white beds but also to the red beds.

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* Commodity Geologist, High-Alumina Clay, U. S. Geological Survey, Personal Communication, February 5, 1943.

Mineralogy

Kaolinite ($Al_2O_3.2SiO_2.2H_2O$)

Kaolinite is the only clay mineral as yet described at Hobart Butte. This statement is based on the results of thermal analyses by Dr. Joseph A. Pask, of the University of Washington and the Northwest Experiment Station of the U. S. Bureau of Mines, and on petrographic examinations by Victor T. Allen, of the Geological Survey. This simplicity of mineralogy should facilitate the extraction of alumina from the clay.

Among the other minerals distributed throughout many of the beds at Hobart Butte are the hydrothermal sulphides. Most abundant are realgar and stibnite. These minerals commonly occur in close association with the high-alumina rocks. Realgar was nearly always found associated with rocks assaying more than 20% available alumina. In only about 5% of the occurrences was the grade of alumina less than 20%. The same is true of stibnite. These two minerals occur in very minor quantities, probably not more than a pound to the ton, but they volatilize readily, and the arsenic and antimony might be recovered at an early stage in the metallurgical process.

Realgar (As S) and Orpiment (AS_2S_3)

Realgar has two principal modes of occurrence: (1) as irregularly distributed flecks scattered through the host rock; and (2) as concentrations along fractures. In the latter case the mineral is often found coating over 90% of the fracture surface, and where there are slickensides the realgar gives emphasis to the grooved structure. In neither case does the mineral occur in concentrations sufficiently large to be of economic importance in itself. It is nearly always massive, but a few instances have been noted where it occurs as crystals in small cavities. Small amounts of orpiment were seen but it appears to be limited to near surface occurrences.

Stibnite

Stibnite is characteristically found scattered in the host rock. It is always crystalline, and is found either as clusters of radiating prismatic needles, or as groups of needles irregularly oriented. In some places isolated needles of stibnite are seen. As in the case of realgar, stibnite is sometimes found on fracture surfaces. Here the crystals are generally very fine and occur in random orientation. The longest stibnite needles are rarely over 1/8 inch in length. Several unidentified alteration products of stibnite were noted.

Pyrite (FeS_2) Arsenopyrite (FeAsS)

Pyrite and arsenopyrite are occasionally found associated with realgar and stibnite. These two minerals are often found together although their characteristically small size sometimes makes them difficult to differentiate. In many cases, however, they are found in sufficiently large crystals to be identified with certainty. They are commonly found distributed at random in the host rock, but occasionally are concentrated in veinlets.

There are probably several other sulphide minerals, both metallic and non-metallic, at Hobart Butte but they were not identified during this investigation. A. C. Waters* has recognised cinnabar (HgS) and calomel (HgCl) crystals.

Some minerals were found whose origin may be either hypogene or supergene:

Siderite ($FeCO_3$)

Siderite is a common mineral at Hobart Butte though small in quantity. It characteristically occurs in tiny, honey-colored globules but occasionally in small barrel-shape forms. These occur as disseminated grains or in clusters. Siderite is somewhat more common in the rocks of intermediate alumina content.

Calcite ($CaCO_3$)

Calcite is not often seen but in the core of hole #10 it was found filling interstices of the host rock. One vein nearly 1/4 inch in width was noted. The mineral was not found in any of the high-alumina rocks.

Several minerals were found of definite supergene origin:

- **Limonite** ($2Fe_2O_3 \cdot 3H_2O$)

Limonite occurs as ribs and stainings in nearly all of the rocks near the surface of the Butte. It is also common at considerable depth where it is thought surface waters have penetrated. Often, the rock is so profoundly oxidized and stained by limonite that it is difficult to determine the original nature of the specimen. In the oxidized areas casts were found of what were once radiating needles of stibnite. Also small globular-shaped limonite forms occur which probably were originally siderite or pyrite. Hematite (Fe_2O_3) has a similar occurrence but is rare.

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* Personal communication.

Scorodite ($FeAsO_4.2H_2O$)

Scorodite was previously determined by Reynolds M. Denning, of Stanford University and confirmed by A. F. Rogers and A. C. Waters*. Scorodite is common in the clay quarry and appears as green noncrystalline crusts especially near crevices in the rock. A. F. Rogers and A. C. Waters also recognized pitticite ($FeAsSH_2O$) with the scorodite.

Structure

Hobart Butte is thought to be a faulted syncline. The evidence for the structural interpretations is not completely satisfactory as it depends on only one accurate dip reading on the surface; and a dozen others of questionable accuracy. In addition the drill core shows bedding in several dozen instances but the orientations are of course indefinite. However, the evidence does combine to form the picture presented on the nine accompanying cross-sections. These sections show the evidence for a gentle syncline pitching at a low angle to the northeast. The syncline is poorly exposed, especially as its northwest flank is mostly eroded. However, there does seem to be enough evidence to outline its trend as approximately north 65° east with a plunge of 5 or 10 degrees in that direction.

Near the northeast end of the Butte there is an abrupt change in the dip of the beds and in the location of the ore body. This is taken to indicate the presence of a fault though no evidence was directly observable on the surface. On the south side of the supposed fault the beds appear to form a gentle syncline pitching to the northeast, whereas on the north side of the fault the bedding appears to dip to the northwest as a homocline. Probably the fault strikes northwest and dips southwest on the basis of the drill hole data and a correlation of assay data on each side of it on the surface.

A great many of the diamond drill cores and much of the material in the test pits showed a considerable degree of slickensiding and fracturing. This could be the result of slight deformational movements or of volume changes by hydrothermal alteration.

Ore Body #1

Ore body No. 1 lies along the summit of Hobart Butte and extends from it southwest and northeastward to the cross fault. It is composed mainly of gray and white beds. It has been penetrated by 11 diamond drill holes, numbered 13, 18, 10, 25, 7, 17, 16, 3, 22, and 4. It is terminated in all directions by the hillsides except to the northeast where it

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* Personal communication, March 28, 1943

may be faulted against low-grade rock and except to the west where the available alumina content is below 27%. The total outcrop length of ore body #1 is nearly 1600 feet and the average width of its base is over 500 feet. Its greatest stratigraphic thickness is at least 200 feet.

Ore Body #2

Ore body No. 2 lies to the northeast of ore body #1, extending from the cross fault to the northeast side of the Butte. It is lithologically similar to ore body #1, but correlation is not certain. It is terminated in all directions by the hillside except to the southwest where it is offset by the fault. It is covered by nearly an equal quantity of low-grade material forming a ratio of overburden to ore of nearly 1 to 1. Based on a 45° slope only a small peripheral area would have a mining ratio of less than 1 to 1. The ore body is about 80 feet in thickness and dips about 20° to the northwest. It has been prospected by 8 diamond drill holes numbered: 2, 1, 20, 8, 6, 23, 21 and 26.

Area #3

Area #3 lies under the southerly end of ore body #1 several hundred feet stratigraphically and topographically below ore body #1. It has a maximum thickness of about 100 feet and is composed mainly of red beds. It has been prospected by 4 diamond drill holes numbered: 11, 14, 12 and 19, for which all assay returns have not yet been received.

Area #4

Area #4 lies to the northeast of ore body #2 and several hundred feet lower both stratigraphically and topographically. It is composed of varicolored beds. Under the renewed exploration program this area will be prospected by some 3000 feet of drilling.

Origin

- The problem relating to the origin of the kaolinite must of necessity be treated in a perfunctory manner because time has not been available during this field work to study the rocks microscopically. Four principal hypotheses have been considered: first, the clay is a result of residual weathering in situ; second, the deposit consists of transported clays; third, the clay is the result of hydrothermal alteration of sedimentary rocks in situ; fourth, the deposit consists of both transported and hydrothermal clay.

Recent drilling suggests that the theory of residual weathering is unsatisfactory, for the clay is too thick and no profile of weathering is apparent, neither conformable with the present topography nor with any pre-existing topography.

That the kaolinite is of sedimentary origin is favored by the petrographic studies of V. T. Allen, who states that flattened pellets of kaolinite, which are common in certain ore beds, are originally sedimentary structures. Moreover, if the pellets were originally kaolinite, some of the matrix must also have been originally kaolinite. Similar pellets occur in the clays at Castle Rock, Washington, and in the Mississippi Valley, and in both cases they are considered as being of sedimentary origin.

That some of the kaolinite is of hydrothermal origin is suggested by the occurrence of the hydrothermal sulphide minerals, chiefly realgar and stibnite. Not only do these sulphides occur in general association with the ore, but it can be said that in many cases the quantity of realgar or stibnite. Exceptions have been noted in the section on mineralogy, but it would not be unusual to have erratic deposition from hydrothermal solutions. Another point in favor of a hydrothermal origin of some of the kaolinite is that on sections D-D' and E-E' the ore body is shown to cross the bedding at a sharp angle.

In view of apparently valid arguments in favor of both the sedimentary and hydrothermal origin for the clay mineral at Hobart Butte, this field investigation can only conclude that both may have been operative and suggest that at some convenient time detailed microscopic and field studies be made in an attempt to decide the relative effect of the two processes.

RESERVES

Method of Calculation

The methods used are not detailed because the deposit is in general uniform and because this is only a preliminary field estimate. Also, by definition, measured ore permits a maximum error of 20%, and these estimates are believed to be within this limit.

For calculating tonnages the ore bodies were divided into easily measurable geometric shapes, which were calculated and added to obtain a total volume figure. This was divided by 14.5, the number of cubic feet per ton of crude ore, based on specific gravity determinations by the U. S. Bureau of Mines. From within the ore bodies 39 specific gravity samples of drill core were found to have an average density of 2.2 and the maximum variation was only 14%. These figures apply to natural rock. The Bureau's moisture determination on 32 samples from within the ore bodies indicate an average of 3% H_2O. These also were drill core samples and hence are subject to some question, but no important discrepancy is expected.

Average grades were obtained from U. S. Bureau of Mines' assays by using a cut-off of 27% available Al_2O_3 as a minimum, with available Fe_2O_3 unrestricted. The ore interval in each hole was averaged and then the holes in each ore body were combined to reach the average grade of the deposit. The holes were not weighted by their area of influence because the grades are so uniform. The maximum deviation from the average was only 14%. The distance between holes ranges from 200 to 500 feet, but again the uniform grade is the compensating factor.

The District Engineer of the U. S. Bureau of Mines used different shapes in preliminary measurements of the deposit but the results are in substantial agreement with the figures in this report. The differences are expected to be well within the 20% error permitted in the definition of measured ore.

Ore Body #1

Ore body #1 is described in general on page 14. It is thought to have been drilled sufficiently well to be considered as measured ore. A total of approximately 137,800,000 cu. ft. was calculated. On a basis of 14.5 cu. ft. to the ton there should be approximately 9,500,000 wet tons, or slightly over 9,200,000 tons of dry ore. Of this amount at least 6,500,000 tons could be mined without stripping any overburden. Another 1,500,000 tons might have a ratio of overburden to ore of less than 1 to 1. The remaining tonnage has a ratio greater than 1 to 1. The average grades in 11 drill holes range from 27.8% to 34.1% available alumina. The average grade is 29.9% available Al_2O_3 and 3.0% available Fe_2O_3.

Ore Body #2

Ore body #2 has also been drilled sufficiently to be considered as measured ore. The average grades in 8 holes range from 27.1% to 32.2% available Al_2O_3. The average grade is 29.3% available Al_2O_3 and 3.6% available Fe_2O_3. The greatest extreme in grade is only 10% from the average. The total volume has been calculated as approximately 42,000,000 cu. ft. On a basis of 14.5 cu. ft. to the ton this would equal approximately 2,750,000 wet tons or 2,700,000 dry tons roughly. The maximum thickness of overburden is about 100 ft. and the total tonnage of overburden is nearly equal to the tonnage of ore. On the north side of the Butte some ore is available at less than a 1 to 1 stripping ratio but it amounts to only a few hundred thousand tons.

Area #3

Area #3 has not been calculated as assay data are not complete. However, it can be said tentatively that the drilling may indicate about 2,500,000 tons averaging 25% available Al_2O_3 and 10% available Fe_2O_3 with a large amount of overburden. The high iron content also makes this area of secondary interest at present, but overburden may be excessive.

Area #4

Area #4 has not been drilled but on the basis of a few surface assays available and a knowledge of the geology, it can be inferred that the proposed drilling program would define several million tons averaging greater than 27% available alumina.

Other areas

On the basis of present exposure no additional ore bodies are apparent on Hobart Butte. However, it is intended to make a geologic reconnaissance of the region in the hope of finding other deposits similar to Hobart Butte. The most promising area is the group of hills lying east of the Cottage Grove Dam extending from Cottage Grove to London (figure 1) and possibly the area of altered rocks surrounding the Elkhead mine (figure 1 and figure 2). The Blackbutte quicksilver mine appears unfavorable as only 4 out of 29 samples showed more than 27% available alumina, and no particular part of the mine looked promising as a possible location for future development (figures 1 and 2).

CONCLUSIONS AND RECOMMENDATIONS

The Hobart Butte clay deposit is being considered as a source of alumina under the War Minerals Program. The points in favor of this deposit are:

1. A total of 10,700,000 dry tons averaging 29% available Al_2O_3 and 3% available Fe_2O_3 with a maximum ratio of overburden to ore of 1 to 1.

2. 6,500,000 dry tons of the above grade with no overburden.

3. The moisture content of the crude ore is only 3%.

4. The available Fe_2O_3 content is only 3%.

5. The grade in the various drill holes deviates from the average grade of the ore bodies by a maximum of 14%.

6. Kaolinite is practically the only clay mineral which should make the extraction of alumina comparatively simple.

7. The rock is non-plastic and homogenous. It should be easy to mine in wet weather and should have uniform grinding properties.

8. Topographic relief is adequate to obviate any problem of draining an open pit mine.

The points against the Hobart Butte clay deposit as a source of alumina are:

1. Transportation. It is 14 miles from the nearest railroad station at Cottage Grove which is 144 miles by rail from Portland.

2. It is dubious that high-grade reserves can be increased substantially.

3. The rock is hard enough so that some blasting will be necessary.

When the present drilling program is completed, it is recommended that there be no further intensive drilling at Hobart until it becomes known definitely that Hobart clay can be used successfully as a source of alumina. Meanwhile, geologic efforts and possibly reconnaissance drilling should be continued to locate other similar clay deposits in the surrounding area.

Respectfully submitted,

John S. Loofbourow, Jr.
Field Geologist
High-Alumina Clay

Cottage Grove, Oregon
July 23, 1943

Minor elements, as determined by a complete spectrographic analysis (E. W. Miller, department spectroscopist) are as follows:

Over 10%

- Silicon
- Aluminum

10% to 1%

- Titanium
- Strontium
- Sulphur

1% to 0.1%

- Iron
- Calcium
- Barium

0.1% to 0.01%

- Zirconium
- Chromium
- Vanadium
- Lithium
- Boron

0.01% to 0.001%

- Magnesium
- Manganese