Bureau of Mines
Information Circular 7752

CERAMIC INDUSTRY DEVELOPMENT
AND RAW-MATERIAL RESOURCES OF OREGON,
WASHINGTON, IDAHO, AND MONTANA

BY HAL J. KELLY, KARLE G. STRANDBERG,
AND JAMES I. MUELLER
CERAMIC INDUSTRY DEVELOPMENT
AND RAW-MATERIAL RESOURCES OF OREGON,
WASHINGTON, IDAHO, AND MONTANA

BY HAL J. KELLY, KARLE G. STRANDBERG,
AND JAMES I. MUELLER

Information Circular 7752
CERAMIC INDUSTRY DEVELOPMENT AND RAW-MATERIAL RESOURCES OF OREGON, WASHINGTON, IDAHO, AND MONTANA

by

Hal J. Kelly,¹ Karle G. Strandberg,² and James I. Mueller³

CONTENTS

Summary .......................................................... 1
Introduction ...................................................... 1
Purpose ............................................................ 1
Scope ............................................................... 1
Acknowledgments ................................................. 2
Ceramic industry review ....................................... 2
Economic review and outlook .................................. 2
Plant locations and products .................................. 4
Trends and development ....................................... 5
Deficiencies and future demands ............................. 5
Ceramic raw-material-resources review ..................... 6
Clay ..................................................................... 6
Feldspar .................................................................. 6
Talc ......................................................................... 7
Kyanite-type minerals ........................................... 7
Expanding clays ................................................... 7
Other materials .................................................... 7
Oregon ceramic raw-material resources and industries ... 8
Industrial review .................................................. 8
Firing ...................................................................... 8
Raw-material resources - summary .......................... 8

¹/ Metallurgical engineer, Bureau of Mines, Region I, Seattle, Wash.
³/ Associate professor, School of Mineral Engineering, University of Washington and ceramic engineer, Bureau of Mines, Region I, Seattle, Wash.

Information Circular 7752
## CONTENTS (Con.)

<table>
<thead>
<tr>
<th>Review by counties</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker</td>
<td>10</td>
</tr>
<tr>
<td>Benton</td>
<td>10</td>
</tr>
<tr>
<td>Clackamas</td>
<td>12</td>
</tr>
<tr>
<td>Clatsop</td>
<td>13</td>
</tr>
<tr>
<td>Columbia</td>
<td>14</td>
</tr>
<tr>
<td>Crook and Deschutes</td>
<td>14</td>
</tr>
<tr>
<td>Douglas</td>
<td>14</td>
</tr>
<tr>
<td>Jackson</td>
<td>15</td>
</tr>
<tr>
<td>Josephine</td>
<td>16</td>
</tr>
<tr>
<td>Klamath</td>
<td>16</td>
</tr>
<tr>
<td>Lane</td>
<td>16</td>
</tr>
<tr>
<td>Linn</td>
<td>17</td>
</tr>
<tr>
<td>Malheur</td>
<td>18</td>
</tr>
<tr>
<td>Marion</td>
<td>18</td>
</tr>
<tr>
<td>Morrow</td>
<td>19</td>
</tr>
<tr>
<td>Multnomah</td>
<td>19</td>
</tr>
<tr>
<td>Polk</td>
<td>21</td>
</tr>
<tr>
<td>Tillamook</td>
<td>21</td>
</tr>
<tr>
<td>Union</td>
<td>22</td>
</tr>
<tr>
<td>Washington</td>
<td>22</td>
</tr>
<tr>
<td>Yamhill</td>
<td>22</td>
</tr>
<tr>
<td>Washington ceramic raw-material resources and industries</td>
<td>23</td>
</tr>
<tr>
<td>Industrial review</td>
<td>23</td>
</tr>
<tr>
<td>Raw-material resources - summary</td>
<td>25</td>
</tr>
<tr>
<td>Review by counties</td>
<td>26</td>
</tr>
<tr>
<td>Chelan</td>
<td>26</td>
</tr>
<tr>
<td>Clark</td>
<td>28</td>
</tr>
<tr>
<td>Cowlitz</td>
<td>29</td>
</tr>
<tr>
<td>Douglas</td>
<td>29</td>
</tr>
<tr>
<td>Ferry</td>
<td>29</td>
</tr>
<tr>
<td>King</td>
<td>30</td>
</tr>
<tr>
<td>Kitsap</td>
<td>35</td>
</tr>
<tr>
<td>Klickitat</td>
<td>35</td>
</tr>
<tr>
<td>Lewis</td>
<td>35</td>
</tr>
<tr>
<td>Lincoln</td>
<td>36</td>
</tr>
<tr>
<td>Okanogan</td>
<td>36</td>
</tr>
<tr>
<td>Pend Oreille</td>
<td>37</td>
</tr>
<tr>
<td>Pierce</td>
<td>37</td>
</tr>
<tr>
<td>San Juan</td>
<td>37</td>
</tr>
<tr>
<td>Skagit</td>
<td>38</td>
</tr>
<tr>
<td>Skamania</td>
<td>39</td>
</tr>
<tr>
<td>Snohomish</td>
<td>39</td>
</tr>
<tr>
<td>Spokane</td>
<td>40</td>
</tr>
<tr>
<td>Stevens</td>
<td>43</td>
</tr>
<tr>
<td>Whatcom</td>
<td>47</td>
</tr>
<tr>
<td>Whitman</td>
<td>48</td>
</tr>
<tr>
<td>Yakima</td>
<td>48</td>
</tr>
</tbody>
</table>


## CONTENTS (Con.)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idaho ceramic raw-material resources and industries</td>
<td>49</td>
</tr>
<tr>
<td>Industrial review</td>
<td>49</td>
</tr>
<tr>
<td>Raw-material resources - summary</td>
<td>51</td>
</tr>
<tr>
<td>Review by counties</td>
<td>51</td>
</tr>
<tr>
<td>Ada</td>
<td>51</td>
</tr>
<tr>
<td>Adams</td>
<td>51</td>
</tr>
<tr>
<td>Benewah</td>
<td>51</td>
</tr>
<tr>
<td>Boise</td>
<td>52</td>
</tr>
<tr>
<td>Bonneville</td>
<td>53</td>
</tr>
<tr>
<td>Cassia</td>
<td>53</td>
</tr>
<tr>
<td>Clearwater</td>
<td>53</td>
</tr>
<tr>
<td>Gem</td>
<td>54</td>
</tr>
<tr>
<td>Idaho</td>
<td>54</td>
</tr>
<tr>
<td>Kootenai</td>
<td>56</td>
</tr>
<tr>
<td>Latah</td>
<td>57</td>
</tr>
<tr>
<td>Lewis</td>
<td>62</td>
</tr>
<tr>
<td>Payette</td>
<td>62</td>
</tr>
<tr>
<td>Shoshone</td>
<td>62</td>
</tr>
<tr>
<td>Valley</td>
<td>63</td>
</tr>
<tr>
<td>Washington</td>
<td>63</td>
</tr>
<tr>
<td>Montana ceramic raw-material resources and industries</td>
<td>63</td>
</tr>
<tr>
<td>Industrial review</td>
<td>63</td>
</tr>
<tr>
<td>Raw-material resources - summary</td>
<td>63</td>
</tr>
<tr>
<td>Review by counties</td>
<td>65</td>
</tr>
<tr>
<td>Beaverhead</td>
<td>65</td>
</tr>
<tr>
<td>Cascade</td>
<td>67</td>
</tr>
<tr>
<td>Fergus</td>
<td>67</td>
</tr>
<tr>
<td>Lewis and Clark</td>
<td>68</td>
</tr>
<tr>
<td>Lincoln</td>
<td>69</td>
</tr>
<tr>
<td>Madison</td>
<td>69</td>
</tr>
<tr>
<td>Powell</td>
<td>70</td>
</tr>
<tr>
<td>Silver Bow</td>
<td>70</td>
</tr>
<tr>
<td>Sheridan</td>
<td>70</td>
</tr>
<tr>
<td>Yellowstone</td>
<td>71</td>
</tr>
<tr>
<td>Appendix</td>
<td>72</td>
</tr>
<tr>
<td>Glossary</td>
<td>74</td>
</tr>
<tr>
<td>Bibliography</td>
<td>76</td>
</tr>
</tbody>
</table>
TABLES

1. Major sources of income in the Pacific Northwest, 1952 .......................... 3
2. Per capita income in the Pacific Northwest, 1952 ............................... 3
3. Hydroelectric power, developed and undeveloped, in the Pacific Northwest, January 1952 ............................... 3
5. Clay localities near Kings deposit ....................................................... 18
6. Summary, ceramic plants - Oregon and Idaho ........................................ 72
7. Summary, ceramic plants - Montana and Washington .................................. 73

ILLUSTRATIONS

1. Map of Oregon, showing certain nonmetallic deposits and ceramic plants .................................................. 9
2. Outcrop of white rock near Baker, Oreg. .................................................. 11
3. Occurrence of white clay in the Silver Creek Falls recreational area, Marion County, Oreg. .................................. 20
4. Map of Washington showing certain nonmetallic deposits and ceramic plants .................................. 24
5. Map showing certain nonmetallic deposits in Chelan County, Wash. .................................. 27
6. Map showing certain nonmetallic deposits and ceramic plants in King County, Wash. .................................. 31
7. Map showing certain nonmetallic deposits and ceramic plants in Spokane County, Wash. .................................. 41
8. A pit of the Mica, Wash., plant, Gladding McBean & Co., showing white clay underlying red basaltic clay .................................. 44
9. An adjoining pit at Mica, Wash., showing white clay from which overburden of basaltic clay has been removed by erosion .................................. 45
10. Map of Stevens County, Wash., showing certain nonmetallic mineral deposits and ceramic plants .................................. 46
11. Map of Idaho, showing certain nonmetallic deposits and ceramic plants .................................. 50
12. Hills of silica sand, feldspar, and clay from which Gem Silica Co., Emmett, Idaho, mines silica .................................. 55
13. Map showing certain nonmetallic deposits in Latah County, Idaho .................................. 58
14. Benson pit, near Troy, Idaho, mined by the Troy Firebrick Co. .................................. 60
15. Map of Montana showing certain nonmetallic deposits and ceramic plants .................................. 64
16. Map of Beaverhead and Madison Counties, Mont., showing talc, feldspar, and sillimanite deposits .................................. 66
SUMMARY

A picture of the ceramic industrial potential of the Pacific Northwest States is presented by reviewing the present ceramic industries, raw-material resources, and current market demands. A resume is given of the industrial plants manufacturing ceramic ware as well as available information on raw-material resources. No attempt was made to prospect for new deposits but rather to evaluate, insofar as possible, those already known. Since much of the industry is concentrated on the Pacific coast, most of the information available on resources concerns deposits in that area. Large, undeveloped districts in Montana and Idaho, however, offer promise of larger reserves of ceramic raw materials.

Average annual production, some operating costs, and annual power consumption are given for each of the plants. Production and some cost figures are listed to show the limited nature of the present industry and to suggest fields open for new development.

INTRODUCTION

Purpose

Expanding potentials in Pacific coast ceramic markets, especially in the fields of electrical porcelain and refractories, have made necessary a review of present knowledge of raw-material resources, present industrial status, and possible future development. A constantly increasing population, wartime-stimulated heavy industry, and unparalleled development of hydroelectric power in the area have contributed to an increasing market for ceramic products. All of the whiteware and all refractories, except clay refractories, are being shipped from the East, Midwest, or California. As a result, very few of the ceramic resources have been developed, and not much prospecting has been done.

This survey was undertaken to guide intelligently a program of development of raw-material resources, to offer inducement for industrial development, and to present the situation, both economic and geographic, of complimentary ceramic raw materials.

Scope

The survey covers ceramic raw-material resources and production in the four Pacific Northwest States (Oregon, Washington, Idaho, and Montana). Of special interest are the higher grade clays from which whiteware or refractories can be made; clays and shales that can be used for expanded aggregate; and those clay deposits that are now being used in the manufacturing of structural clay products. All of the wide variety of materials from which building brick can be made will not be described; only those now being mined are listed.
Feldspar, talc, kyanite-type, and other high-alumina minerals also are covered in this survey.

Acknowledgments

Not all sources of information can be acknowledged individually in this survey, but literature sources from which much of the information is taken are listed at the conclusion of this report.

The assistance of Sheldon S. Glover, supervisor, Washington State Department of Mines and Geology, Olympia, Wash., and F. W. Libby, former director, Oregon State Department of Geology and Mineral Industries, Portland, Oreg., is acknowledged.

CERAMIC INDUSTRY REVIEW

Economic Review and Outlook

During World War II the Pacific Northwest experienced a rapid increase in industrial activity, principally in aircraft and shipbuilding, lumber and paper-pulp-products manufacturing, metals refining and fabricating, and food processing. The greatest expansion of industry occurred in western Washington and Oregon, particularly in the metropolitan centers of Seattle, Portland, and Tacoma. This area attracted great numbers of people from the inland portions of the region and from the Midwest. After the war, work in defense plants declined, but business continued at a high level in the region as demand throughout the Nation for consumer goods stimulated production. Owing to the availability of large blocks of firm low-cost power generated at the hydroelectric projects of the Federal Government, the postwar expansion of electrometallurgical and electrochemical industries was a major growth factor in the Northwest. In 1952 the region supplied 40 percent of the production of primary aluminum in the United States. Fabrication of aluminum products also increased substantially. Electrochemical plants to process raw materials imported from outside the region were built in the major coastal cities. Production of elemental phosphorus at plants erected near large phosphate-rock deposits in southern Montana became of growing importance.

The Federal Government continued public works programs in the Northwest to provide power, irrigation, and flood-control benefits. At the end of 1953 major construction at Hungry Horse and McNary Dams was completed, and work was in progress at The Dalles, Chief Joseph, Albeni Falls, and Palisades projects. In central Washington the Bureau of Reclamation proceeded with construction of the canals and laterals of the Columbia Basin project, the Nation's largest reclamation project. Water obtained from the Columbia River at Grand Coulee Dam was made available to 920 farms in 1952. Ultimately, 1,029,000 acres will be irrigated. A $7,000,000 sugar refinery was placed in operation in 1953 to process beets from the project.

The growth of service and retail trades based on the tourist industry also was a factor in maintaining income at a high level in the Northwest. After 1950 military requirements brought about increased production of materials for defense.

The major sources of income and the per capita income in the Pacific Northwest for 1952 are given in tables 1 and 2.
TABLE 1. - Major sources of income in the Pacific Northwest, 1952
(Selected components as percentage of total income)

<table>
<thead>
<tr>
<th>State</th>
<th>Agricultural income</th>
<th>Government and service income</th>
<th>Manufacturing payrolls</th>
<th>Trade and service income</th>
<th>Construction payrolls</th>
<th>Mining payrolls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montana</td>
<td>21.2</td>
<td>17.4</td>
<td>7.2</td>
<td>24.2</td>
<td>4.7</td>
<td>5.4</td>
</tr>
<tr>
<td>Idaho</td>
<td>22.5</td>
<td>15.9</td>
<td>10.9</td>
<td>22.5</td>
<td>5.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Washington</td>
<td>6.7</td>
<td>21.1</td>
<td>18.6</td>
<td>26.3</td>
<td>5.2</td>
<td>.9</td>
</tr>
<tr>
<td>Oregon</td>
<td>8.7</td>
<td>16.2</td>
<td>22.0</td>
<td>26.5</td>
<td>4.0</td>
<td>.2</td>
</tr>
<tr>
<td>United States</td>
<td>6.7</td>
<td>15.9</td>
<td>24.5</td>
<td>25.6</td>
<td>4.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>


TABLE 2. - Per capita income in the Pacific Northwest, 1952

<table>
<thead>
<tr>
<th>State</th>
<th>Per capita income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montana</td>
<td>$1,697</td>
</tr>
<tr>
<td>Idaho</td>
<td>1,438</td>
</tr>
<tr>
<td>Washington</td>
<td>1,810</td>
</tr>
<tr>
<td>Oregon</td>
<td>1,733</td>
</tr>
<tr>
<td>United States</td>
<td>1,639</td>
</tr>
</tbody>
</table>


The region has 46 percent of the saw timber in the United States and has within its boundaries 25 percent of the country's irrigated acres. Generators installed at Federal and non-Federal hydroelectric projects have a capacity equal to approximately one-fourth of the total capacity of all hydroelectric installations in the United States. In addition, the Northwest contains 40 percent of the Nation's undeveloped waterpower resources. If fully developed, the rivers of the region, principally the Columbia and its tributaries, could generate over 42 million kw. (table 3).

TABLE 3. - Hydroelectric power, developed and undeveloped, in the Pacific Northwest, January 1952
(Thousand kilowatts)

<table>
<thead>
<tr>
<th>State</th>
<th>Estimated undeveloped hydroelectric power</th>
<th>Developed hydroelectric power (capacity of actual installations)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Electric utilities</td>
</tr>
<tr>
<td>Montana</td>
<td>6,935</td>
<td>462</td>
</tr>
<tr>
<td>Idaho</td>
<td>8,849</td>
<td>454</td>
</tr>
<tr>
<td>Washington</td>
<td>15,516</td>
<td>2,932</td>
</tr>
<tr>
<td>Oregon</td>
<td>6,723</td>
<td>800</td>
</tr>
<tr>
<td>Total Pacific Northwest</td>
<td>38,023</td>
<td>4,648</td>
</tr>
</tbody>
</table>


The census of 1950 disclosed that Oregon advanced nearly 40 percent in population from 1940 to 1950 and that Washington increased 37 percent, compared with a national increase of 14.5 percent. The high rate of population increase in these States resulted more from immigration than from natural increases. In percent increase of population, Oregon was exceeded only by California, Arizona, Florida, and...
Nevada, Idaho and Montana experienced increases of approximately 12 and 6 percent, respectively, from 1940 to 1950. Both States lost population through outmigration of people to work in defense plants, and the net gains resulted from natural increases. Estimates have indicated that since 1950 the Pacific Northwest has continued to increase in population, although at a slower rate than during the decade 1940–50. Oregon and Washington ranked higher than the national average in percentage increase in population. Idaho and Montana grew in numbers at a rate well below the national rate (table 4).

**TABLE 4. - Population of the Pacific Northwest**

<table>
<thead>
<tr>
<th>State</th>
<th>1940</th>
<th>1950</th>
<th>Increase, 1940-50, percent</th>
<th>1953</th>
<th>Increase, 1950-53, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montana</td>
<td>559,456</td>
<td>591,024</td>
<td>5.6</td>
<td>618,000</td>
<td>4.5</td>
</tr>
<tr>
<td>Idaho</td>
<td>524,873</td>
<td>588,637</td>
<td>12.1</td>
<td>598,000</td>
<td>1.6</td>
</tr>
<tr>
<td>Washington</td>
<td>1,736,191</td>
<td>2,378,963</td>
<td>37.0</td>
<td>2,520,000</td>
<td>5.9</td>
</tr>
<tr>
<td>Oregon</td>
<td>1,089,684</td>
<td>1,521,341</td>
<td>39.6</td>
<td>1,630,000</td>
<td>7.1</td>
</tr>
<tr>
<td>Total Pacific</td>
<td>3,910,204</td>
<td>5,079,965</td>
<td>29.1</td>
<td>5,366,000</td>
<td>5.6</td>
</tr>
<tr>
<td>United States</td>
<td>131,669,275</td>
<td>150,697,361</td>
<td>14.5</td>
<td>158,375,000</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Source: United States Bureau of the Census reports. 1953 figures are provisional estimates.

Despite recent growth the Pacific Northwest is sparsely settled. The 4 States comprise 13.2 percent of the area and only 3.4 percent of the people of the United States. Washington, Oregon, Idaho, and Montana rank 33d, 39th, 44th, and 47th, respectively, according to population per square mile of land area. Only 4 cities - Seattle, Portland, Tacoma, and Spokane - exceed 100,000 in population.

If economic development continues in the Pacific Northwest as expected, population will continue to increase at a more rapid rate than in the United States as a whole. A median estimate by the Columbia Basin Interagency Committee places the population of Washington, Oregon, Idaho, and the 11 counties in Montana west of the Continental Divide at 7 million by 1975. This figure compares with a census count of 4 million persons in the area in 1950.

**Plant Locations and Products**

The ceramic industry of the region is principally that of manufacturing structural clay products and refractories. There are 41 structural and 4 refractory plants (2 of which also make structural clay products) within the 4-State region. Of the 4 refractory plants, 2 are operated by Gladding, McBean & Co. at Renton and Mica, Wash.; 1 by Washington Brick and Lime Co., Spokane, Wash., at Troy, Idaho; and the fourth, a captive operation, at Anaconda, Mont., makes clay and silica refractories for the Washoe smelter of the Anaconda Copper Mining Co. The structural-clay-products plants are concentrated largely in the coastal area of the region, where the population density is greatest. There are 26 plants west of the Cascade Mountains - 17 in Oregon and 9 in Washington. Of the 15 plants east of the mountains, 4 are in Idaho, 4 in Montana, 2 in Oregon, and 5 in Washington.

Two modern plants for expanding shale are operating in the Portland area to supply the Pacific Northwest with expanded-clay aggregates. A plant operated a short time in the Seattle area near Woodenville, Wash., but was dismantled several years ago.
Other ceramic industries in the region include 2 flowerpot plants, a glass-container plant, and 3 producing talc mines. Numerous small potteries, mostly studio-type shops, are scattered throughout the region; many of them have developed from hobby interests. Since these potteries have little effect on utilization of regional ceramic resources, they are not included in this survey. Much of their raw material is purchased in prepared form from suppliers, and the total output is relatively small. The same situation exists in regard to porcelain-enamel plants; only three such plants are found in the region, all enameling small-size products.

**Trends and Development**

The number of structural-clay-product plants in operation has been decreasing for many years. Within the last 5 years, 6 plants have ceased operation in the region, and only 2 new ones have begun. In the 20 years before, reduction in the number of clay plants was even more marked. The decrease resulted from improved roads and transportation facilities and increased labor costs. These factors allowed the larger plants with more efficient labor to compete with the smaller plants in the latter's market area. The present trend of increasing transportation costs, however, is limiting the markets of the region's larger plants.

Notable developments in the industry have been the erection of 2 new tunnel kilns, 1 by the Washington Brick & Lime Co. at its Spokane plant, and the other by the Lowell Brick & Tile, Lowell, Wash. A modernization program at the Renton plant of Gladding, McBean & Co. and reconstruction of the Clay City plant of Builders Brick Co., Seattle, also represent progress in the Pacific Northwest ceramic industry. Gladding, McBean & Co. recently began producing a superduty refractory, the first to be made in the Pacific Northwest. At the Troy, Idaho, plant of Washington Brick & Lime Co., which formerly specialized in hand-molded shapes, repress equipment has been installed recently to improve tailoring of the brick.

The possibility of natural gas being made available to a large portion of the region perhaps promises most for future development of present ceramic producers. Four plants in Montana now are using natural gas, and they report fuel costs of $1.50 to $3.00 per 1,000 brick compared with $4.50 to $10.00 for plants using other fuels. Typical rates for natural gas in the State range from 59 cents per 1,000 cubic feet when less than 99,000 cubic feet is used to 25 cents for consumption of 4 million cubic feet or more. Comparative ease of firing and reduction in supervision during firing are further advantages not considered in the above figures for fuel costs. One plant, the Washington Brick & Lime Co., Spokane, Wash., is using butane, and several other smaller plants are using propane experimentally, at least for the water-smoking period. Oil is the fuel most used, with coal next, and wood least used.

**Deficiencies and Future Demands**

The region has no whiteware industry, does not produce refractories other than clay, and is a net importer of most ceramic products and materials. Foreign imports of ceramic wares into Washington in 1952 were valued at $700,000 and imports of dinnerware at $517,000. Waterborne freight into Seattle included 1,800 tons of foreign-made clay products, 560 tons of imported clay, 570 tons of domestic clay, 910 tons of domestic brick and tile, and 940 tons of other domestic clay products. Rail shipments into the region in 1950 included 90,000 tons of clay (including bentonite) and 12,800 tons of common brick. In addition, 25,000 tons of face brick and building tile and 50,000 tons of refractories were shipped by rail into Idaho, Oregon, and Washington from outside the region; sewer pipe and drainage tile totaling 12,000 tons were brought into the Washington-Oregon area; and 3,100 tons of china, earthenware, and crockery was brought into Oregon, 980 tons into Idaho, and 180 tons into Montana. Imports of clay refractories were principally from Canada and the Midwest.
With the extensive development of hydroelectric power in the four States of the region, a large electrical porcelain market has developed. Within this region an estimated $2,500,000 annual market exists for insulators alone. At present all electrical porcelains are being shipped into the area from eastern plants. Japanese-made ware, however, will probably enter the Pacific coast market. Development of raw-material resources suitable for such use is the remaining unsatisfied requirement for establishing such an industry in the Pacific Northwest.

The demand for coating and filler clays continues to grow as more wood-pulping plants are built in the Pacific Northwest. Although most of the pulp made in the region goes into other products, an estimated 50,000 tons of clay is shipped into the region for use in papermaking. Future requirements will exceed the current demands as more pulp is made and a greater percentage of the pulp goes into paper.

The construction of petroleum refineries near Ferndale and Anacortes, Wash., was to be completed in 1955. Continued prospecting for oil in the coastal areas and expanded major oil-company facilities indicate another growing future market for ceramic products.

**CERAMIC RAW-MATERIAL-RESOURCES REVIEW**

Development of ceramic raw-material resources of the region has been limited. No feldspar, sillimanite, or other high-alumina minerals are now being mined for ceramic uses. Development of the better grades of clay has been confined to the work of Gladding, McBean & Co., Washington Brick & Lime Co., and that done during World War II by the Bureau of Mines (28) and the Geological Survey in searching for high-alumina clays as a potential source of aluminum. This work was regionwide and was the most extensive development of clay resources ever undertaken in the Pacific Northwest. Since high iron content was not considered to preclude the use of clays in extracting alumina from the clays, many deposits were drilled that could not be used in the better grades of ceramic ware. The minimum limit of 10 million tons eliminated from consideration many deposits that might be used for ceramics. As a result, not all of the work done under this program was of value in estimating ceramic raw-material reserves.

A detailed review of potential sources of ceramic materials by State and county is made in the following pages of this report. The regional outlook with respect to different ceramic materials can be summarized as follows:

**Clay**

Large deposits of kaolin in the Spokane, Wash., and Moscow-Troy, Idaho, areas, have been exploited to a limited degree. Further exploration and beneficiation studies are needed to evaluate the potential of these deposits for ceramic, paper, and other uses. Economic feasibility may depend upon finding outlets for the feldspar and mica fractions separated during preparation of suitable kaolin products. Other possible sources of kaolin are the Lewiston and Townsend, Mont., and Cascade, Idaho, districts.

**Feldspar**

Adequate reserves of feldspar of probable ceramic grade can be found in Madison and Beaverhead Counties, Mont., and in the Gem Silica Co. deposit, Emmett, Idaho. Other probable sources are the Grimes Pass district, Idaho County, Idaho, and deposits on Orcas Island, Wash. Until substantial demand exists in the Pacific Northwest, no commercial development is anticipated.

4/ Underlined numbers in parentheses refer to terms in bibliography at the end of this report.
Talc

The Montana talc deposits are a source of high-grade talc. Reserves are adequate, and the deposits are amenable to low-cost mining. As a result, the deposits are being mined despite the distance from consuming centers.

Kyanite-Type Minerals

Large reserves of kyanite and andalusite have been reported in Shoshone and Idaho Counties, Idaho, and of sillimanite in Beaverhead and Madison Counties, Mont. The Idaho deposits have not been investigated owing to their recent discovery and inaccessible location. Only preliminary examinations have been made of the Montana occurrences. The quality and extent of these deposits would have to be investigated more thoroughly before their commercial value could be evaluated.

Expanding Clays

Data on expanding clays of the region are almost entirely lacking. Adequate reserves of shale exist in northwestern Oregon for the two plants operating there. Promising shales have been found in King and Kitsap Counties, Wash., and in Cascade and Yellowstone Counties, Mont. Shales associated with coal measures in western Washington offer good possibilities for further investigation.

Other Materials

Although chromite, olivine, magnesite, and silica are not included in this survey, a brief and generalized mention of the occurrences of these refractory materials is warranted.

Chromite was mined in 1952 in Josephine, Curry, Douglas, and Jackson Counties, southwestern Oregon, and in Grant County, Oreg., near John Day. Shipments were made to the General Services Administration stockpile at Grants Pass. A major occurrence of chromite is in Stillwater County, Mont., near Nye. During World War II development of two properties, the Mount and Benbow, proved large reserves of submetallurgical-grade chromite. American Chrome Co., a subsidiary of Goldfield Consolidated Mines Co., is producing chromite concentrates averaging about 38 percent Cr₂O₃ under terms of a United States Government loan and purchase contract. Substantial chromite reserves occur in ancient beach sands near Coos Bay, Coos County, Oreg. Deposits of less importance are found in Washington in the Twin Sisters Mountains, Whatcom and Skagit Counties, and on Cypress Island, Skagit County.

The olivine deposits of the Twin Sisters Mountains in northeastern Washington provide a vast reserve of comparatively high grade olivine. The refractory properties of this material have been the subject of numerous investigations. The olivine is being used to a limited extent as a foundry sand.

A large deposit of magnesite occurs near Chewelah, Stevens County, Wash. The deposit is mined by open-pit methods and concentrated by heavy mediums and flotation methods. The concentrates then are trammed to the plant at Chewelah and dead-burned in a rotary kiln to produce refractory MgO. This product is shipped east for use in refractory products.

Massive silica deposits are found throughout the region, but few are being worked. Silica is being produced from such deposits in Josephine and Jackson Counties, Oreg., in Skagit and Spokane Counties, Wash., and in Bonner County, Idaho. Silica sand is being mined in Stevens County, Wash., and in Gem County, Idaho.
Oregon's ceramic industry, except for numerous small studio-type potteries and one flowerpot plant, is engaged in manufacturing structural clay products. Certain nonmetallic deposits and ceramic plants in Oregon are shown in figure 1. There are 21 plants in the State, of which 3 produce only drain tile; 2, expanded clay aggregates; and the others, brick and all types of hollowware. Most of the industry is concentrated in the Willamette River Valley, where the alluvial valley is suitable for drain-tile production and the rich farming land needs drainage. Eleven of the 18 plants that make drain tile account for an annual production of over 4 million feet. This output is marketed readily in the Willamette Valley. The sale and use of drain tiles have been stimulated by the program of the Production Marketing Administration of the United States Department of Agriculture, which will pay up to 50 percent of the raw-materials cost for new drainage systems. In the Portland area there are two large brick plants that produce a total of over 13 million of all types of building brick annually. Two expanded-clay-aggregate plants, the only ones in the region, and one flowerpot plant also operate in or near Portland. The State's 7 largest plants produce 93 percent of all brick made in the State; the 4 largest produce 76.5 percent of the total. Production of all other types of hollowware amounts to 10,950 tons per year. No refractories, sewer pipe, or flue linings are made in Oregon. Construction of a glass-container plant in Portland has been announced.

Virtually all plants have nearly unlimited reserves of clay, and nearly all of them obtain the clay from adjacent pits. A few use clay from distant sources which increases their raw-material costs above the $1.00 to $2.00 a yard usually quoted.

Raw materials used to make expanded clay aggregate are obtained from similar shale deposits, one near Vernonia and the other near Banks.

Firing

Most structural ware is produced in downdraft kilns, which are either semicontinuous or periodic. A few scove kilns are used, but there are no continuous kilns in the State. Wood is the most used fuel; oil is second; and coal is third choice. Many of the smaller operators use wood for the water-smoking period but change to oil for firing. The wide variety of kilns, fuel, and firing methods is reflected in a wide difference in costs, from a high of over $10.00 per thousand brick to a low of $4.25 per thousand. The expanded-clay-aggregate plants use oil-burning rotary kilns to boost the shale.

Raw-Material Resources - Summary

Little information is available on deposits of feldspar, talc, kyanite-type, or other high-alumina minerals. None is produced in the State. The ferruginous bauxite deposits of the Salem-Eugene area are considered to be too high in iron for ceramic use. There are, however, three general areas of well-known clay occurrences: One in northwestern Oregon, from Willamina on the south to Rainier on the north; another in the Salem area from Mehama on the south to Molalla on the north; and the third in and near Eugene in west-central Oregon. Other deposits of clay suitable for better grade ware are reported, but little is known of their extent or value.

The light-color clays of the Northwest district usually are high in alkali content, which results in comparatively low fusing temperatures. The soft, white to gray clays widely distributed east of the Salem district appear to have been formed.
Figure 1. Map of Oregon, showing certain nonmetallic deposits and ceramic plants.
by alteration of tuffaceous rock, and they are intermixed characteristically with high-iron clays. Kaolinite and montmorillonite are present.

Clays of the Eugene, Oreg., district include a type similar to clay of the Salem, Oreg., district; a highly siliceous clay near Eugene; and the hard, nonplastic, high kaolinite clays (tuffs altered in place) at Hobart and Black Buttes southeast of Eugene.

The genesis and mineralogy of many clays of western Oregon warrant further investigation. Present information, however, indicates that Oregon has fewer potentially valuable clay deposits than the other States of the region.

Additional information regarding individual deposits and industries is presented in the review by counties. Counties having no known deposits of ceramic minerals are not listed. Deposits of clay suitable only for structural clay products and not now being used are omitted.

Review by Counties

Baker County

Clay

A deposit (see fig. 2) 20 miles from Baker, in the Blue Mountains at the foot of the Elkhorn Range, is described as a white kaolin containing 49 to 55.9 percent SiO₂, 17 to 23 percent Al₂O₃, and about 5 percent Fe₂O₃. The bed is 1 to 15 feet thick. Jess Edwards of Baker was reported to own the deposit, but he could not be located for confirmation.

The Schroeder claims, 6 miles southeast of Baker, were visited, and a sample was taken. Differential thermal analysis showed a very low clay content, and the clay mineral was of the montmorillonite group.

Feldspar

Large, massive dikes of feldspar porphyry are reported to occur on the Harney deposit in Baker and Union Counties along the axis of the Pueblo Mountains.

Summary

Although there is no ceramic industry in Baker County and the county is remote from population centers, the possibility of finding deposits of feldspar and silica is good because of extensive igneous activity.

Benton County

Clay

No deposits of ceramic raw materials concerned in this survey are known in Benton County, except clay used for structural products.

Ceramic industry. - There are two structural-clay plants in Benton County, one at Corvallis and the other at Monroe.

The Corvallis Brick & Tile Works is on the Crystal Lake Cemetery Road south of Corvallis. The production is primarily drain tile but common and face brick and
Figure 2. - Outcrop of white rock near Baker, Oreg. This is described as clay on the Schroeder claims. Differential thermal analysis indicated a very low clay content.
building tile are made. Clay is mined from recent deposits of the flood stages of the Willamette River. Estimated life of the deposit is 25 years. Annual production is about 85 thousand brick, 200 thousand feet of drain tile, and a small number of building tile. Products are extruded, air-dried, and fired in two 30-foot, round, downdraft kilns and one smaller kiln. Fifteen cords of wood is required for each firing of the larger kilns. Drain tile is sold in Yamhill, Polk, Benton, and Linn Counties and roman brick in the Roseberg area. H. W. and Myrtle M. Albright own the plant.

The Monroe Brick & Tile Co. is one of the larger ceramic plants of the State and produces 4,500 thousand brick and 2,800 tons of drain and building tile a year. Extrusion forming is used. Drying is by air and waste heat in drier sheds. Three rectangular, downdraft kilns are used; the largest has a capacity of 100 thousand brick and the other two 65 thousand brick each. The plant recently changed from oil to wood for firing. This was done as an economy move because oil costs are high, due in part to transportation charges. Fuel requirements are about 9-1/2 cords per firing for the largest kiln.

Clackamas County

Clay

The most extensive exploration of clay deposits in this county was that made by the Federal Bureau of Mines and the Federal Geological Survey in 1943, when nearly 1,200 feet of drilling was done during a search for high-alumina clays (10, 28). Ceramic tests of selected samples were reported in 1949 by Skinner and Kelly (20). Previous work in this area was done by Wilson and Treasher (27), and by Hodge (13).

Molalla deposit. - The Molalla clay deposit is south of Molalla and 28 miles south of Portland. Drilling was done in secs. 22 and 27, T. 5 S., R. 2 E., Willamette Meridian (W. M.), and outlined over 32 million tons of clay occurring in 2 horizons. The average Al₂O₃ content ranged from 25 to 27 percent, with 7 to 8 percent Fe₂O₃. None of the 180 samples tested was light colored after firing to pyrometric cone 4 (1,165° C.). Some high- and intermediate-duty fire clay occurs in the deposit, but the intermediate is probably the best that could be mined. The intermixture of kaolinite and montmorillonite results in high drying and firing shrinkage. Drilling was done on clay deposits known as the Ellis, Vincent, Miller, and some of the Molalla Reservoir deposits.

Dibble deposit. - This deposit lies in the SE₁/₄SW₁/₄ sec. 1, T. 6 S., R. 2 E., W. M., southeast of Molalla. The clay is light bluish gray. Two samples taken by Wilson (24) contained 2.8 and 14.1 percent Fe₂O₃. The pyrometric cone equivalents (p.c.e.) of the samples were 33 (1,745° C.) and 29 (1,640° C.). No estimate of quantity is available.

Zahar deposit. - This deposit also is in sec. 1 and is a continuation of the Ellis deposit (Molalla deposit). Some development on a pit was done many years ago. Hodge (13) gives the following section:

<table>
<thead>
<tr>
<th>Soil and terrace gravel overburden</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine-grained to yellow-stained clay</td>
<td>5</td>
</tr>
<tr>
<td>White kaolinite clay</td>
<td>15</td>
</tr>
<tr>
<td>Bluish, uniform, hard clay, fine silt</td>
<td>40</td>
</tr>
</tbody>
</table>

This clay is believed to be Pliocene or Pleistocene series and is interbedded with tuffs and water-worked pyroclastic material and andesitic flows. Chemical
analyses range from 30.4 to 37.6 percent $\text{Al}_2\text{O}_3$, 44.4 to 54.2 percent $\text{SiO}_2$, and from 1.96 to 4.4 percent $\text{Fe}_2\text{O}_3$. Depth of clay is reported to be up to 160 feet.

Ceramic industry. - Three small structural-clay plants use clay mined in the county: The Molalla Brick & Tile Co. between Molalla and Liberal; The Needy Brick & Tile Co. 9 miles west of Molalla; and the Hubbard Clay Works 3 miles east of Hubbard in adjoining Marion County.

The Molalla Brick & Tile Co. produces 150 thousand feet of drain tile and about 25 thousand roman brick and 80 tons of building tile per year. Clay is obtained from a local pit and is a plastic, gray clay, which is silt from the Willamette River. Power for the clay-workings machinery is furnished by a 50-hp, gasoline engine and firing is in a 24-foot, circular, downdraft kiln. Wood is used for fuel. Operators of the plant are A. F. Schoenborn and Charles Vincenzi.

The Needy Brick & Tile Co. plant produces building brick and drain tile by extrusion. Annual production is 75 thousand brick and 2,900 tons of drain and building tile. Clay is mined locally from the Molalla alluvial fan exposed by Rock Creek. The clay is fired in two 25-foot, round, downdraft kilns using wood for water-smoking and oil for the finish firing. Plant operators are Edward Kenagy and Kenneth Berkey, Hubbard, Oreg.

Hubbard Clay Works 3 miles east of Hubbard produces drain tile only, averaging 480 thousand feet per year. The clay is mined from a pit on Rock Creek and is a gray, plastic Willamette River silt. The tile is formed by extrusion, dried with hot air, and fired in round, downdraft kilns. Oil is used as fuel. S. D. Hostetler & Sons operate the plant.

Summary. - The clays of Clackamas County probably will not be of value except for structural-clay products because of the heterogeneous mixture of high- and low-iron clays and the intermixture of montmorillonite and kaolinite would make selective mining of high-grade clay difficult, if not impossible. High shrinkage, due partly to the bentonitic nature of these clays, would make it difficult to manufacture ceramic ware using these clays without prefiring. All reported samples from the Molalla area fired to dark colors at high temperatures.

Clatsop County

Clay

Several deposits of clay are known in the county, but owing to high-iron content and soluble salts they probably can be used only for structural-clay products.

P. M. West deposit. - This clay was reported by Wilson and Treasher (27) to be 2 miles south of Seaside and 1/2 mile west of the Seaside-Tillamook road. The clay produced a light-gray glass at pyrometric cone 20 (1,520° C.). Analysis showed 23.4 percent $\text{Al}_2\text{O}_3$, 63.2 percent $\text{SiO}_2$, and 1.86 percent $\text{Fe}_2\text{O}_3$. High salt content probably would cause short firing range and may account for the relatively low fusing temperature.

Summary. - The P. M. West deposit offers a possibility for use as a plastic bond clay in a whiteware body. There is no industrial utilization of ceramic raw materials in the county.
Columbia County

Clay

Only one deposit of good clay is known in the county. Little development or systematic prospecting has been done in the area.

**Sig Fransen deposit.** - This refractory-grade clay is in the NE1/4 sec. 33, T. 8 N., R. 3 W., W. M., 6 miles west of Rainier. A pit 80 to 100 feet wide and 40 feet front to back was maintained at one time, but little production was reported. Three types of clay were reported by Wilson and Treasher - (27) a gray, plastic clay; a light-colored, moderately plastic clay; and a conglomerate of quartzite and tuffs, with the tuffs altered to kaolinite. The p.c.e. of all of these samples was near cone 32. The clay is believed to be the product of the weathering of the tuffaceous conglomerate of the gravel. Kaolinization has produced a white, soft, plastic clay that retains the original shape of the gravel as the kaolinite bonds together the quartz and mica. Estimated tonnage of clay is 430 to 1,720 thousand short tons. The clay fires buff to brown. Gray clay is reported in SE1/4 sec. 20, T. 6 N., R. 4 W., W. M., 3 miles from Mist (2).

Ceramic industry. - A gray, sandy shale is mined by Smithwick Concrete Products Co. near Veronia as the source of raw material for an expanded-shale-aggregate plant in Portland, Multnomah County. There is no other ceramic industry in the county.

Summary. - Clay of the Sig Fransen deposit has potential commercial value but, like many Oregon clays, fires to a darker color than is desirable for many classes of ceramic ware.

Crook and Deschutes Counties

Clay

Several day deposits of unknown size or quality are reported at Prineville, Crook County, and Redmond and Bend, Deschutes County (2).

Douglas County

Clay

The only reported occurrence of good-grade clay was from the C. C. Fristo claims in Sec. 13, T. 32 S., R. 7 W., W. M., on the north flank of Grayback Mountain. It is reported to be refractory grade (2). The Hobart Butte deposit is in Lane and Douglas Counties, and is described under Lane County.

Talc

There are four reported occurrences of talc in Douglas County, Oreg., as follows: (2, 3, 13)

1. A band of talc 6 feet wide is reported 1-1/2 miles south of Canyonville, north of the Levens claims. Iron oxide content is 1 percent.

2. A 4-foot talc vein is reported on Starveout Creek 12 miles south of Azalea. This material is said to be white when ground.
3. A 12-foot vein of high-iron talc occurs near Tiller, 2 miles southeast of Milo.

4. A 4-foot vein, described as fairly good quality, is reported northeast of Canyonville on the Umpqua River.

Ceramic Industry.

There is no ceramic industry using any of the raw materials included in this survey.

Summary.

The four talc deposits of the Riddle district have not been tested to determine if they are ceramic grade. There are reportedly deposits of clay suitable for structural-clay products, and a structural-clay-products plant is planned for construction in Roseburg.

Jackson County

Clay

Only a few widely scattered deposits are reported in Jackson County. None has been developed, and none is being worked.

Dead Indian Road deposit. - There is a large mass of altered rhyolite that has been partly kaolinized in sec. 19, T. 38 S., R. 3 E., W. M. The quarry, which is being mined for road ballast by the county, exposes 50 to 75 feet of extremely variable, partly kaolinized flow rock. Irregular distribution of iron silica and unaltered volcamics makes the ceramic value of this deposit doubtful. A sample of the light-color material had a p.c.e. of 31+. Samples taken earlier had p.c.e. of 28 to 31. Other similar exposures are found nearby.

Brownsboro clay. - A deposit 6 miles east of Eagle Point in sec. 3 or 4, T. 36 S., R. 1 E., W. M., was reported by Wilcox (3). He described the clay as highly variable in iron content and ranging from cone 32 to below refractory grade. Other clay deposits are reported near Evans Creek, 25 miles northwest of Medford, that have p.c.e. of 28 to 32 (3). A low-alumina, high-silica clay is reported to occur in sec. 9, T. 38 S., R. 3 E. W. M. No confirming information is available.

Other deposits. - Other deposits of doubtful value are found in SW1/4 sec. 20, T. 33 S., R. 1 W., W. M., on the Gaines property and in SE1/4 sec. 25 and NE1/4 sec. 36, T. 33 S., R. 1 W., W. M. (3).

Feldspar

There is a feldspar dike in the Sparks mine in the NE1/4 and SE1/4 sec. 2, T. 35 S., R. 4 W., W. M., 1.1 miles up Evans and Wimer Creeks. The dike, over 15 feet wide, strikes N. 60° W. and dips about 70° SE. It is composed of quartz, microcline, and albite, with tourmaline as an accessory mineral, and is described as being white to glassy. The owner is H. W. Sparks, Rogue River.

Summary.

No clays of commercial value are known in this county, but the possibility of finding other feldspar deposits is good.
Josephine County

Feldspar

The Hugo silica property 3 miles southwest of Hugo is reported to have feldspar dikes up to 18 inches wide cutting the quartz. No feldspar is produced.

Ceramic industry. - One small brick plant operates intermittently near Grants Pass.

Klamath County

Clay

There are no deposits of good-quality clay, feldspar, talc, or kyanite-type minerals in the county.

Ceramic industry. - The Klamath Falls Brick & Tile Co. is one of Oregon's largest producers of structural-clay products. A wide range of light and dark face brick are produced from local clays mixed with clays from Lincoln, Calif. Production is 2 million of all types of brick, 50 thousand building tile, and 35 tons of drain tile per year. The products are formed by extrusion, dried in a batch humidity drier, and fired in 1 rectangular and 1 circular downdraft kiln. Oil is used as fuel. Connected electrical load is 145 kilowatts. Ralph Smith, Klamath Falls, is owner of the plant.

Lane County

Clay

The Bureau of Mines drilled the Hobart Butte deposit during World War II. Other clay deposits are known in the area, but they have not been explored as thoroughly as the Hobart Butte. During World War II clay was washed from the Eugene silica sands, and the silica was sold for foundry use. An insufficient market was developed to continue operation after the war, although the quality of the sand for foundry use was reported to be acceptable. No use was made of the clay washed from the sand.

Hobart Butte clay. - The deposit is in secs. 1, 6, 31 and 36, T. 22 S., R. 3 and 4 W., W. M., in Lane and Douglas Counties. The extensive drilling by the Bureau of Mines, in which 40 holes were drilled, indicated nearly 29 million tons of clay averaging 26.9 percent available $\text{Al}_2\text{O}_3$ and 4.5 $\text{Fe}_2\text{O}_3$. Samples from 23 holes were taken for ceramic tests, and of the 330 samples tested 125 were high or super-duty clay and only 63 were nonrefractory (20). The clay mineral is kaolinite, and it was formed by the decomposition of volcanic tuffs. Three distinct clay types are exposed in the pit near the crest and on the southeast side of the butte. Near the top of the pit is a hard, white to light-gray clay that contains extremely white spots; below it is a fine-grained tan to brown clay; and at the bottom of the pit is a dark-gray clay that also contains white spots. The dark-gray type also appears to contain a higher percentage of sulfides. Differential thermal analyses and X-ray diffraction patterns show a high kaolinite content in all three clays. When heated at 1,330° C., an unorthodox expansion occurs, probably owing to the exfoliation along bedding planes. This expansion is more marked in some of the clay types than in

\[\text{Letter from F. W. Libbey, director, Oregon Department of Geology and Mineral Industries.}\]
others. The result of the expansion is a cracked, structurally weak product if fired to 1,330° C. or higher. The magnitude of this expansion can be reduced by grinding the clay to minus-48-mesh. Extremely fine grinding (minus-325-mesh) results in a net fired shrinkage and structurally competent ware if fired to 1,500° C. Despite fine grinding the clay does not develop plasticity when worked with water and in such sizes it is strongly dilatent. These factors would make the use of the clay in ceramic ware difficult unless a more plastic clay is added. Less refractory clays of similar origin are found at Black Butte 2-1/2 miles southeast of Hobart Butte in NW1/4 sec. 16, T. 23 S., R. 3 W., W. M. Hydrothermal alteration of andesitic flows has produced less extensive kaolinization than has occurred at Hobart Butte.

Mabel clay. - A deposit of hard, white clay northeast of Mabel, which is northeast of Springfield, was reported by Wilcox (23). A sample taken 100 yards west of the Mabel-Holley road was reported to have a p.c.e. of 32. The clay is in the SW1/4 of sec. 15 and the NE1/4 of sec. 22, T. 15 S., R. 1 W., W. M. The quantity or quality of this clay has not been evaluated.

Fall Creek Ranch clay. - This clay, an altered tuff, is exposed in a bluff across Fall Creek from the Fall Creek ranch, in the SW1/4 SE1/4 sec. 31 T. 18 S., R. 1 E., W. M. The ranch, formerly owned by Henry Page, now is owned by Glenn Thompson. The material is highly siliceous, and a recent sample fused to a dark-gray glass below pyrometric cone 26. The clay mineral is kaolinite.

Eugene Fire clay. - A highly argillaceous sand is found in the NE1/4 NW1/4 sec. 2, T. 18 S., R. 4 W., W. M., 2 miles southwest of Eugene. The sand contains an estimated 25 percent of kaolin and considerable mica. Similar deposits are found in T. 17 S., R. 4 W. W. M.

Ceramic industry. - There are no operating ceramic plants or producers of ceramic raw materials in the county. The Eugene sands were mined during World War II for foundry use but have not been mined since that time. The clay washed from the sand was not utilized.

Summary. - The Hobart Butte clay deposit offers the best source of refractory clay known in the county. The Mabel clay may warrant further investigation. Other known deposits appear to have less value.

Linn County

Clay

Only one occurrence of clay other than those suitable for structural ware has been reported in Linn County. A white clay or shale is reported by Hodge (13) as occurring in sec. 11, T. 14 S., R. 1 W., W. M., 1.9 miles southeast of Sweet Home. Three feet of coarse, plastic, gritty clay overlies 10 feet of white clay or shale. Overburden is 2 to 3 feet of basaltic soil. The shale is reported to be low-fusing and nonplastic. No estimate of quantity is available.

Ceramic industry. - The Albany Brick & Tile Co. plant at Albany produces about 900 thousand building brick, 69 thousand feet of drain tile, and 250 tons of building tile per year. Alluvial clay is obtained from a nearby pit. The products are formed by extrusion, dried by waste heat, and fired in three rectangular, downdraft kilns. Slab wood is used for fuel. The plant operator is Jack V. Berry.
Malheur County

Clay

Only one deposit of clay better than structural grade is known in the county and is 28 miles north of Huntington. No information other than the location of the deposit is available (13). No deposits of the other ceramic materials of this survey are known in the county.

Ceramic industry. - The Oregon Clay Products Co., Inc., operates a structural-clay-products plant at Vale. The company produces only common and face brick. About 1,500 thousand brick is made annually. Alluvial clay is obtained locally. The ware is air-dried and fired in scove kilns. Slack coal is used as fuel. Consumption of fuel is 700 pounds per thousand brick and power 34,320 kw.-hr. per year.

Marion County

Clay

Clay deposits of Marion County are similar to those found to the north and east in Clackamas County. None of the many occurrences of clay reported in the county have been developed. Wilson and Treasher (27) and Hodge (13) described exposures of clay near Scotts Mill, Silverton, Macleay, Silver Creek Falls, and Sublimity, an area about 10 miles wide and 13 miles long. In general, the clays of this area are alteration products of rhyolitic and andesitic tuffs. The clay is underlain with basalt and overlain with iron-stained clay and tuffs. Wilson and Treasher (27) described samples taken from 19 different localities in this area. The following information is taken from their work and that of Wilcox (23).

Kings clay. - This deposit is a few miles northeast of Sublimity in SW1/4 SE1/4 sec. 18, T. 8 S., R. 1 E., W. M. The clay is chalky white and fine-grained and contains clear quartz grains. It is iron-stained near the surface, probably due to meteoric waters percolating through the overlying tuffs. A channel cut and several auger holes showed clay with p.c.e. ranging from 19 to 33. The channel samples had a p.c.e. of 32-1/2 and contained 32.5 percent Al2O3, 46.2 percent SiO2, and 3.8 percent Fe2O3. When fired, the clay was dark brown and severely cracked. An estimated 330,000 tons of clay, in a 15-foot bed, is believed to be high-heat-duty. Other exposures are tabulated below.

<table>
<thead>
<tr>
<th>Location1/</th>
<th>Color</th>
<th>Pyrometric cone equivalent</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE1/4NW1/4 sec. 18 T8S R1E</td>
<td>White to pink</td>
<td>20 and 27-28</td>
<td>7 1/2-ft. bed.</td>
</tr>
<tr>
<td>SE1/4SW1/4 sec. 18 T8S R1E</td>
<td>Gray</td>
<td>30-31</td>
<td>2 1/2-ft. bed.</td>
</tr>
<tr>
<td>SE1/4SW1/4 sec. 18 T8S R1E</td>
<td>Iron-stained</td>
<td>18</td>
<td>Unknown</td>
</tr>
<tr>
<td>NW1/4 sec. 19 T8S R1E</td>
<td>White</td>
<td>30+ to 33</td>
<td>14 1/2-ft. bed.</td>
</tr>
<tr>
<td>SW1/4SE1/4 sec. 13 T8S R1E</td>
<td>White, iron-stained</td>
<td>30-</td>
<td>2 1/2-ft. bed.</td>
</tr>
<tr>
<td>NE1/4NE1/4 sec. 21 T8S R1E</td>
<td>White</td>
<td>33-34</td>
<td>Unknown</td>
</tr>
<tr>
<td>NW1/4SE1/4 sec. 21 T8S R1E</td>
<td>Blue, yellow white</td>
<td>28-30</td>
<td>9 ft. exposed.</td>
</tr>
<tr>
<td>SW1/4SW1/4 sec. 3 T8S R1E</td>
<td>Buff</td>
<td>32 1/2</td>
<td>Small</td>
</tr>
<tr>
<td>SW1/4SW1/4 sec. 3 T8S R1E</td>
<td>do.</td>
<td>34</td>
<td>Do.</td>
</tr>
</tbody>
</table>

1/ Willamette Meridian base used for all locations.
Silverton clays. - Seven exposures of clay were sampled by Wilcox (23) on the Silverton-Victor Point road. The p.c.e. of these samples ranged from 27 to 31-32. No information as to quantity is available. The exposures extend about 4.9 miles along the Silverton-Victor Point road. P.c.e. range from 19 to 32. All of the clays appear to be decomposition products of tuffs with varying quantities of iron oxide. An exposure in a road cut 6 miles south of Silverton in SE1/4 SW1/4 sec. 25, T. 7 S., R. 1 W., W. M., appears to be the best. The clay had a p.c.e. of 31-32 and contained 31.1 percent Al2O3, 51.7 percent SiO2, and 2.9 percent Fe2O3. Samples taken by H. J. Kelly in road cuts just inside the Silver Creek Falls recreational area (see fig. 3) had p.c.e. values higher than 31. The test cones were tan to brown. Halloysite is the principal clay mineral.

Other deposits. - Weathered gravel is deposited in the SW1/4SE1/4 sec. 27, T. 8 S., R. 1 W. W. M. A p.c.e. of 30 is reported by Wilson and Treasher (24). Other occurrences of similar clay have been reported in the county, but all show the same characteristics — dark-colored fusions, widely variable iron content, and high fired shrinkage.

Ceramic industry. - The Donald Brick & Tile Co. plant at Donald obtains river alluvium clay from a local pit. Products are extruded, and drying is by air and waste heat. The products are fired in 3 round, downdraft kilns 22 feet in diameter and 1 rectangular kiln 20 by 40 feet. The water-smoking fuel is wood, and oil is used to complete the firing. J. S. Fisher & Sons, Donald, operate the plant. The Hubbard Clay Works, 3 miles east of Hubbard, uses clay from adjoining Clackamas County.

Summary. - The clay deposits of Marion County are similar to those of Clackamas County. Although a wide distribution of clay is known, no development has been done. The clays are generally high in iron and fire to dark colors. Investigation of deeper seated clays might be warranted, but similarity to the Molalla clays discourages optimistic predictions as to future value.

Morrow County

Clay

A small deposit of refractory clay in Morrow County southeast of Heppner. It is reported to be too small for commercial use.6/

Multnomah County

Clay

No deposits of ceramic raw materials other than those suitable for structural clay products are known in the county.

Ceramic industry. - Two of the Oregon's largest brick plants are near Portland in Multnomah County, and 1 of the State's 2 expanded-aggregate plants is in the city. The Sylvan Brick Co., east of Sylvan, produces common and face brick. Annual production is 8 million brick of all types. Clay is mined locally from a 50-foot section exposed in a pit. The deposit is underlain by basalt and is believed to be water-laid. The brick are formed by extrusion and fired in a semiperiodic kiln of

6/ Letter from F. W. Libbey, director, Oregon Department of Geology and Mineral Industry.
Figure 3. - Occurrence of white clay in the Silver Creek Falls recreational area, Marion County, Ore. White halloysite underlies red clays formed from alteration of tuffs.
11 chambers, each 11 by 40 by 12 feet. Crude oil is used as fuel, and 35 barrels are required per chamber per firing. Power requirements are 680,000 kw.-hr. a year. Charles E. Jensen is general manager.

The Columbias Brick Works is at Gresham. Annual production is 5,300,000 of face and common brick and 6,600 tons of structural tile. Clay is obtained nearby where 40 feet of mining depth is available in an alluvial deposit. The brick are formed by extrusion, dried in waste-heat tunnel driers, and fired in a semicontinuous Hoffman kiln. The 22 chambers of the kiln are fired with coal. Each chamber holds 24,000 brick. Franze Olbrick is the president of the company.

The Smithwick Haydite plant, operated by the Smithwick Concrete Products Co., is at 1750 NE. Lombard Place, Portland. The gray, sandy shale is received by railroad at the plant and stored in steel bins. The shale is fired in an 8 by 100-foot rotary kiln at 1,900° to 2,200° F. Fuel is Bunker C oil. The fired product passes through a rotary cooler and is elevated to a crushing and screening plant. The plant handles 200 cubic yards of raw materials a day. The market area is from southern Oregon to Vancouver, B. C.

The Pacific Stoneware Co. plant is at 9217 North Peninsular Avenue, Portland. The principal product is flowerpots, which are formed by pressing and molding. Three flowerpot machines plus hand molding are used to form about 4 million pots per year. The pots are dried in steam-heated drying rooms. Two round, down-draft kilns 20 feet in diameter are oil-fired. Clay is obtained near Vancouver, Wash., and from Willamina Clay Products Co. L. S. M. Scott is the owner.

Polk County

Clay

The only clays known in Polk County are sediments of the Willamette River that are used in manufacturing structural-clay products throughout the river valley. No other ceramic materials are known in the county.

Ceramic industry. - Monmouth Brick & Tile Co., Monmouth, annually produces 300 thousand feet of drain tile, 80 thousand building brick, and 200 tons of building tile. Clay is obtained from a 10-foot bed of tan sediments deposited on the Willamette Plain. Forming is by extrusion, and air and waste heat are used for drying. Firing is done in a 20- by 30-foot rectangular-kiln and in a 20-foot round kiln; both are downdraft. One thousand gallons of oil is used for each firing in either kiln. Connected electrical load is 18 hp. Phillip Partridge operates the plant.

Tillamook County

Clay

Only one deposit, of unknown value, has been reported from this county. Hodge (13) describes 2 exposures of whitish clay 6.5 miles from Tillamook about 1/4 mile from the ocean in sec. 5 T. 2 S., R. 10 W., W. M. The exposures are 160 and 200 feet long and show a maximum depth of 12 feet. No estimate of quality is given.

Ceramic industry. - One small drain-tile plant, 7 miles southeast of Tillamook mines a plastic blue to yellow alluvial clay. About 90 thousand feet of drain tile each year is formed by extrusion. The product is air-dried and fired in one circular, downdraft kiln. Wood is used for fuel, and about 9 cords is required per kiln of 19 thousand 4-inch tile. The plant is operated by R. G. Krebs.
Union County

Feldspar

Porphyritic dikes are reported to occur on the Harney deposit in Union and Baker Counties.

Ceramic industry. - A small brick plant at La Grande produces 500 thousand building brick a year. The deposit at the plant appears to be a remnant of basaltic clay. Potential reserves occur over an area of 17 acres. The brick are extruded, air-dried, and fired in a scove kiln. Fuel used is propane, a recent change from coal. Power consumption is 24,120 kw.-hr. a year.

Washington County

Clay

One deposit of gray clay was reported by Wilson and Tressler (27) as being northwest of Cherry Grove. Glassy, gray fusions at p.c.e. 16 to 20 classified the clay as nonrefractory. The alluvial clays of the river terraces are used for structural-clay products. Expanded clay aggregate is made at Banks.

Ceramic industry. - The McCormak Clay Products Co., Forest Grove, did not operate in 1952, but in 6 months of 1953 and 1954 then produced 18 thousand drain tile and 10 thousand roman brick. The ware was formed by extrusion from clay mined from a pit at the plant and was fired in a 40-foot, round, downdraft kiln. Oil was used as fuel. The products are sold locally. Elmer McCormak, Forest Grove, is the owner.

The Scholls Tile Co. is 1/2 mile north of Scholls. The clay is obtained from a recent silt and transported clay deposited on basalt by the Tualatin River. The plant extrudes 250 thousand feet of drain tile a year. The product is air-dried and fired in two 20-foot, round, downdraft kilns. Oil is used as fuel, and the connected electrical load is 50 hp. J. C. Snyder & Son are the plant owners.

The O. K. Brickyard, just south of a junction on U. S. Highway 99W known as Six Corners, produces 200 thousand brick annually. The brick are formed by extrusion and air-dried. A scove kiln with a capacity of 90 thousand brick is fired with slabwood.

The largest ceramic plant in the county is that of the Empire Building Materials Co., Portland. The shale mine and expanding plant are near Banks. The shale is mined by open-pit methods, using a ripping tool on a bulldozer blade. The product is crushed and stored in surge bins. The shale is expanded in two rotary kilns. One is 6 by 70 feet and has a preheater; the other is 7 feet in diameter and 70 feet in length. The kilns use a common cooler. The combined capacity of the kilns is 300 cubic yards of raw shale a day. The expanded shale is screened through 3/8-inch. The raw shale is similar to that mined by Smithwick Concrete Products Co. in Columbia County, about 20 miles north.

Yamhill County

Clay

Deposits of structural-grade clay are distributed widely throughout the county, but little is known of their qualities. No refractory clay has been found.
Peavine Ridge clay. - A white, plastic clay deposit of unknown depth 9 miles southwest of McMinnville has been used for stoneware. The analysis given by Hodge (13) is as follows: \( \text{SiO}_2 \), 58.12 percent; \( \text{Al}_2\text{O}_3 \), 28.74 percent; \( \text{Fe}_2\text{O}_3 \), 2.75 percent, and \( \text{CaO} \) and \( \text{MgO} \), 1.55 percent.

Grande Ronde clay. - The deposit is in SE1/4 sec. 5, T. 6 S., R. 7 W., W. M. Three pits were worked about 30 years ago but were flooded and are inaccessible, according to Wilcox (23). The clay was used in Portland for firebrick. No additional information is available.

Willa1mina pit. - The pit of the Willamina Clay Products Co. at Willamina contains clays that fire from white to deep red. A white-firing carbonaceous shale and a similar dark, carbonaceous, soft clay are found in the pit. The soft clay fires to a white color, is highly plastic, and has been used as a ball clay. The Pacific Stoneware Co., Portland, uses it for that purpose. The pit bottom is a white clay of unknown depth on which a dark-gray, carbonaceous shale rests. Above it occur beds of tuff and shale. The cap is altered basalt. The p.c.e. of the shale is about 12; that of the softer, plastic, carbonaceous clay, 8 to 9; and that of the gray clay, 26. Landslides have obscured the exact relationship of the various clay types.

Ceramic industry. - The Willamina Clay Products Co. produces 3,000,000 face and common brick per year. A range of colors from white to dark red is produced in all shapes. Several types of clay are mined and blended to get desired colors. The brick are formed by extrusion and dried in tunnel dryers fired with sawdust. They are fired in 8 chambers of an 18-chambered, semicontinuous kiln, using sawdust for fuel. This is the only plant in the State that uses sawdust as fuel. Power requirements are about 400,000 kw.-hr. a year.

The McMinnville Brick & Tile Co. produces 800,000 to 1 million building brick and 700,000 drain and building tile. Clay is obtained locally from sediments deposited by the Willamette River, which are 10 to 14 feet deep over 12 acres. Ware is extruded and dried by air and waste heat and is fired in 2 round, downdraft kilns and 1 double-chambered 40-foot-square kiln. Wood is used for the water-smoking period, and oil is used for the finish firing. One and one-half cords of wood and 1,000 gallons of oil are required per firing. Connected power is 180 hp. S. B. and L. S. Nichols are the owners.

Summary. - The sediments of the Willamette River Valley provide excellent and abundant plastic clay for drain tile and other structural products. The white-firing plastic clay from the Willamina pit affords the only source of ball-type clay in the region. Further investigation of the low-fusing, white-firing clays of the county is warranted.

WASHINGTON - CERAMIC-RAW-MATERIAL RESOURCES AND INDUSTRIES

Industrial Review

Washington's ceramic industry is somewhat more varied than Oregon's. There are two principal producing areas in the State. One is on the coast in and near Seattle where a line of structural-clay products and clay refractories is made. The other area is centered in eastern Washington around Spokane, where structural-clay products and intermediate-heat-duty refractories are made. There are 19 ceramic plants in the State 2 of which produce refractories and structural-clay products. Of the remaining 17, 1 makes hand-molded brick only, and the others extrude most types of structural-clay products. Certain nonmetallic deposits and ceramic plants in Washington are shown in figure 4.
Figure 4. - Map of Washington showing certain nonmetallic deposits and ceramic plants.
Forming

Stiff-mud products are the most common, but repressing is practiced in two Eastern Washington plants. The Renton refractory plant forms refractory brick by dry pressing and structural-clay products by extrusion.

Firing

Scove, periodic and semiperiodic, downdraft, and tunnel kilns are used to fire ware made in Washington. The type of kiln most used is the round, downdraft kiln. Two plants use scove kilns for all or part of their firing. Three plants are using tunnel kilns - 1 for refractories and 2 for structural-clay products. The most used fuel is oil, although coal and wood are used also.

Market areas

Virtually all ceramic products are marketed within the region. Refractories and sewer pipe are shipped from Washington into Oregon, Idaho, and Montana, where none is made. Gladding, McBean & Co.; Builders Brick Co.; Washington Brick & Lime Co.; Chehalis Brick & Tile Co.; and Granger Clay Products Co. ship some other structural-clay products into Oregon, Montana, and Idaho. Northern Idaho is supplied almost entirely by Washington products.

Outlook

The Washington area offers a market for additional locally made clay refractories because an estimated 50 thousand tons is imported annually. With the continued growth of heavy industry there appears to be a constantly increasing market. The wood-pulping and paper-manufacturing industry is expanding, and two oil refineries - the first in the region - have been built. This continued growth and the prospect of natural-gas availability indicate an increasing need for more refractories.

Demand for kyanite-type and other high-alumina minerals and feldspar would be stimulated by whiteware manufacture. A potential limited demand exists for kyanite-type minerals as an additive to refractories, but there is no demand in the region for feldspar. None of these minerals is produced in the region.

The outlook for ceramic products is good. Further development and evaluation of ceramic resources remain as additional steps needed to encourage industry.

Raw-Material Resources

Summary

Raw-material resources of Washington are outlined fairly well, but several areas warrant further investigation. The most extensive clay area is around Spokane, where further prospecting for white clay is warranted. Operating brick manufacturers in the Spokane area are well supplied with suitable and adequate reserves of clay. Development of new ceramic industries will depend upon knowledge of available resources. This is especially true of a porcelain insulator or other whiteware operation. The white clays of the Spokane district would require beneficiation because of high quartz and mica content.

Investigation of the carbonaceous shales of the coal-mining and other districts in western Washington promises to develop an adequate supply of shale for manufacturing expanded clay aggregate.
The mineralogical and geological relationship of the carbonaceous shale deposits of the Cowlitz, Toledo, and Enumclaw districts needs to be established. Further prospeecting may reveal deposits of the quality of the Kummer shale.

Investigations of the ceramic raw materials of Washington, other than for structural-clay products, have been for refractory purposes or as a source of aluminum. Drilling by the Bureau of Mines, during World War II, of the Cowlitz, Blum, Durham, Green River, Kansaket, and Kangley deposits in western Washington and the Five Mile Prairie and Excelsior deposits in eastern Washington and investigation of other deposits in the Spokane area was the most extensive exploration for clay yet undertaken in Washington. Gladding, McBean & Co. and the Washington Brick & Lime Co. have carried on exploratory and development programs on clay deposits.

Review by Counties

Chelan County

Figure 5 shows certain nonmetallic deposits in Chelan County. Some refractory shales have been mined near Wenatchee, and other occurrences are known. Pegmatite dikes are distributed widely throughout the county, and the feldspar content of many is high. No ceramic tests have been made to evaluate them. There are two reported occurrences of kyanite, but neither is considered to be commercial. Soapstone is found in many locations, but no investigations have been made to determine the value of the occurrences.

Clay

**Dry Gulch shale deposit.** - A carbonaceous shale bed is exposed in Dry Gulch in NE1/4 sec. 21, T. 22 N., R. 20 E., W. M. Samples taken of the shales on the north side of the Gulch had a p.c.e. of 26 (1,595° C.). A sample of iron-stained shale had a p.c.e. of less than 19.

**Stemilt Canyon.** - A deposit of shale in Stemilt Canyon in the E1/2, sec. 11, T. 21 N., R. 20 E., W. M., was reported by Valentine (22). Refractory tests were made on this deposit, and the reports were favorable.

**Squaw Saddle.** - The Squaw Saddle deposit in the west center of sec. 16 T. 22 N., R. 20 E., W. M., is of doubtful value, according to Valentine (22).

**Other deposits.** - No other deposits of clay of better than structural grade are known in the county. A small deposit of unknown value is reported on Cedar Creek near Midway.

**Kyanite-Type Minerals**

A deposit of kyanite-type minerals in secs. 21 and 22, T. 30 N., R. 16 E., W. W. M., in the Trinity tunnel of the Royal Development Co. was reported by Valentine (22). Another deposit, also reported by Valentine, occurs in NW1/4 sec. 33, T. 31 N., R. 16 E., W. M. The deposit is on Railroad Creek and is described as kyanite veins 1/2 to 1-1/2 inches wide in Swakane gneiss.

**Feldspar**

A pegmatite dike in sec. 20 T. 27 N., R. 17 E., W. M., is exposed by a road cut along the north shore of Wenatchee Lake. A sample taken recently has a p.c.e. of 7
Figure 5. - Map showing certain nonmetallic deposits in Chelan County, Wash.
The fired cone was a gray glass. The dike is traceably by small exposures for over 100 feet. Quartz and biotite are accessory minerals.

Chelan Tunnel. - Segregations of feldspar occur in the Swakane gneiss near the highway in sec. 20, T. 27 N., R. 21 E., W. M. The feldspar dikes are distributed widely, and a workable concentration may occur, according to Valentine (22).

Winsap deposit. - At the Dick Nickel prospect, in secs. 1, 2 and 11, T. 26 N., R. 21 E., W. M., pegmatite dikes containing pink feldspar are reported.

Talc and Soapstone

Although 8 occurrences of soapstone have been reported in Chelan County none is of talc quality. The possibility of using any of the material for ceramics is remote.

Ceramic industry

One small building-brick plant is operating in the county. Plants formerly operated at Chelan and Oroville but have been shut down in recent years.

Wenatchee Brick & Tile Co. makes about 500 thousand building brick per year. Clay is mined from a Columbia River alluvial deposit near the plant. The ware is air-dried and fired in a scove kiln. Oil is used for fuel. Oil consumption is 50 to 60 gallons per thousand brick and power cost is $1.00 per thousand brick.

Summary

The most promising nonmetallic resource of the county is feldspar. It is unlikely that the shales of the Wenatchee area are consistent enough to furnish a continuing supply of high-grade refractory clay. One possible exception is the deposit in Stilmet Canyon, although not enough data on that deposit are available. No commercial occurrences of talc or kyanite-type minerals are known.

Clark County

Clay

The only known deposits of better than structural-grade clay are the Fly Creek and Boardman deposits. Both are high in iron and alumina. The Boardman deposit is in sec. 16, T. 5 N., R. 4 E., W. M. (22), and the Fly Creek deposit is in sec. 16, T. 5 N., R. 4 E., W. M., 25 miles E. of Woodland. The alumina content of the Fly Creek deposit is 30 to 32 percent, and the ferric oxide content is 12 to 14 percent (2). Use of either in ceramic products is unlikely. No other ceramic raw materials of concern in this survey are known.

Ceramic industry. - Two structural-clay plants operate in the county. The Muffet Brick & Tile Co. north of Vancouver makes roman brick and drain tile. The deposit is a hard, plastic, alluvial clay and is mined with a shale planer. The machine was made at the brick plant. Production is 400 thousand roman brick and 85 thousand drain tile per year. The ware is formed by a plunger-type extrusion machine, air-dried, and fired in a round, downdraft kiln. Wood is used for the water-smoking period and oil for finishing. Propane has been used for the watersmoking period, but wood is considered to be a more satisfactory fuel. Fuel costs are about $6.00 per thousand. Power consumption is 38,160 kw.-hr. a year.
The Hidden Brick Co., Vancouver, is the only handmold-brick plant in the region. Clay is obtained from a pit at the plant or from excavations in Vancouver. The clay is air-dried and fired in scove kilns. Annual production is about 350 thousand brick. Wood is used as fuel, and electrical power consumption is 2,160 kw.-hr. a year.

Cowlitz County

Clay

A bauxitic laterite similar to that found in Oregon occurs in Cowlitz County. The high iron content makes this material unsuitable for ceramic use.

Cowlitz deposit. - The Cowlitz deposit of high-alumina clay in secs. 7, 16, 17, 18, 19, and 20, T. 10 N., R. 1 W., W. M., and sec. 24, T. 10 N., R. 2 W., W. M., was drilled by the Bureau of Mines in 1943 (10, 28). Eight separate clay areas were drilled, four of which had clay of favorable alumina - ferric oxide ratio. Over 190 samples from 19 holes were tested. Area 2 in sections 17 and 18 offered the best opportunity for mining high-heat-duty clays. Fired colors of 29 of the 44 samples tested from area 2 were light after firing to cone 4 (1,165° C.); 25 were high-heat-duty or better. Montmorillonite and kaolinite are the clay minerals, with the former consistently present in the nonrefractory samples. The fired shrinkage of these clays is very high, and calcination is required before the clay is used (20). High-heat-duty clays were mined from the deposit by Gladding, McBean & Co. up to 1950. Operations were discontinued because of highly variable iron content of the deposit.

Other deposits. - High-alumina clays and bauxites high in iron are known to occur in El/2 sec. 32 and W1/2 sec. 33, T. 9 N., R. 4 W. and N1/2 sec. 4, T. 8 N., R. 2 W., and in SE1/4 sec. 21, T. 9 N., R. 1 W., W. M. (2).

Summary. - Similar occurrences of clay north of the Cowlitz deposit are known, and possible correlation between the Cowlitz deposit and the carbonaceous shales of King County has not been determined. No ceramic industries are in operation in the county at present.

Douglas County

Clay

J. J. Keegan deposit. - Refractory shales formerly were mined by Gladding, McBean & Co. about 4 miles north of the bridge across the Columbia River at Wenatchee. A 50-acre tract owned by J. J. Keegan, Wenatchee, adjoining the site mined by Gladding, McBean & Co., is said to contain shales with a p.c.e. of 31. An analysis is as follows: Al₂O₃, 30.96 percent; SiO₂, 51.97 percent; Fe₂O₃, 4.44 percent; and ignition loss 11.74 percent.

Other deposits. - No other occurrences of raw materials included in this survey are known in Douglas County.

Ferry County

Feldspar

A 20- to 60-foot wide dike of feldspar is reported in the Belcher mine in sec. 6, T. 37 N., R. 34 E., W. M., 12 miles east of Republic.
Talc and Soapstone

A road cut in sec. 20, T. 36 N., R. 34 E., W. M., exposes a talcose schist and a talc band 3 to 4 feet thick (8) along a felsite-serpentine contact.

King County

Clay

The glacial clay that is widely distributed along the coast has been used for many years in making structural-clay products in the county. The better grades of clay and carbonaceous shales occur in southern King County, and there is an alunite deposit near Enumclaw. This latter deposit and the Durham, Blum, Kanasket, and Green River deposits were drilled during World War II. The mining of the Harris and the Kummer clays by Gladding, McBean & Co. is the most extensive local development of ceramic raw materials of refractory grade. Six manufacturing plants in the Seattle area produce structural-clay products, refractories, glass containers, and flowerpots. There is also a small specialty glass plant in Seattle. Certain nonmetallic deposits and ceramic plants in King County are shown in figure 6.

Low-heat-duty fire clay, high in silica, feldspar, and mica, is produced from the Auburn mine, sec. 28, T. 21 N., R. 6 E., W. M., by Gladding, McBean & Co. by open-pit methods. Reserves are 150,000 tons of clay proved and 150,000 tons inferred.

Palmer mine. - This property is in sec. 14, T. 21, N., R. 7 E., W. M. The material is a siliceous, buff-burning, sedimentary clay. Reserves of 125,000 tons are proved, but the deposit is not fully explored. The ore is mined by open pit, using a power shovel, and hauled to the railroad by truck.

New Castle mine. - This mine is in sec. 27, T. 24 N., R. 5 E., W. M., and produces a red-firing plastic shale. Proved reserves are 50,000 tons; inferred reserves are 100,000 tons. Power-shovel mining and truck haulage are used.

Kummer mine. - This property is operated by Gladding, McBean & Co. The mine, in sec. 26, T. 21, N., R. 6 E., W. M., produces a high-quality carbonaceous clay of exceptional homogeneity. The deposit dips at an angle of 52° and overlies a coal series. Underground mining of this superduty refractory clay is by the room-and-pillar method. Proved and inferred reserves are adequate for 25 to 30 years at the present rate of consumption. The clay is burned in piles on the surface to oxidize carbonaceous material, hauled to Renton, and calcined in a rotary kiln. The deposit is of exceptionally consistent quality.

Renton mine. - A thick bed of red-firing shale, in sec. 17, T. 23 N., R. 5 E., W. M., is mined by Gladding, McBean & Co. The shale is blasted from the 150-foot quarry face and loaded in trucks for hauling to storage. The shale ranges from dark gray to brown and from plastic to sandy in consistency. Reserves are very large.

Harris mine. - A dark-gray carbonaceous shale is mined from a deposit in sec. 32, T. 29 N., R. 6 E., W. M., by Gladding, McBean & Co. The dip of the beds is 35° to 40° NE. Overburden is stripped, and the clay face is blasted and loaded by drum hoist and scraper. Underground mining is planned for the future. Reserves are estimated to be adequate for 50 years at the present rate of consumption.
Figure 6. - Map showing certain nonmetallic deposits and ceramic plants in King County, Wash.
Taylor mine. - The Taylor clay mine and plant, formerly operated by Gladding, McBean & Co. in this area, were purchased by the city of Seattle, and the plant was dismantled to protect the city watershed. Operations ceased in 1950.

Durham deposit. - This deposit of hard, dark-blue-gray shale is in SE1/4SE1/4 sec. 35, T. 22 N., R. 7 E., W. M., 2-1/2 miles northeast of Durham on the saddle of a ridge. An area 500 feet square contains a body of clay 15 to 40 feet thick having the following analysis: Available Al2O3, 46.1 percent; Fe2O3, 2.7 percent; and SiO2, 61.2 percent. The analyses of samples from 8 drill holes and 4 trenches were high in iron, and none contained less than 10 percent available iron. The best grade of clay would have to be mined underground (2). Additional prospecting in this area and south between this deposit and the Cowlitz deposit is warranted.

Blum deposit. - The deposit is in SW1/4NW1/4 and NL/2 of NW1/4 sec. 31, T. 21, N., R. 7 E. and in SE1/4NE1/4 sec. 36, T. 21 N., R 6 E., W. M. Reserves of 1,715 million tons are outlined in this deposit, but the iron oxide content is high, averaging 8.9 percent (2). Kaolinite is the principal clay mineral. Boehmite and gibbsite also are present in the shale.

Kangley deposit. - Two clay beds, exposed 30 feet apart, occur in the SW1/4SE1/4 sec. 26, T. 22 N., R. 7 E., W. M. The beds strike N. 10° to 15° W. and dip 35-40°E. The lower bed is 5.5 feet thick and the upper bed 8.8 feet thick. Kaolinite, associated with boehmite, is the major clay mineral, and quartz, mica, and carbonaceous material are the impurities. These shales are high in ferric oxide, with the upper bed averaging 4.9 percent and the lower bed 7.2 percent available Fe2O3. Alumina content is 27.1 percent for the upper bed and 32.1 percent for the lower bed (2).

Kanaskat deposit. - This deposit is similar to those described above and is in NL/2SE1/4, NL/2NW1/4, SL/2NE1/4, SL/2NW1/4 sec. 12, T. 21 N., R. 7 E., W. M. The bed has been traced for more than 1,000 feet. The average thickness is 18.4 feet. The indicated tonnage is 300,000 tons, averaging 32 percent Al2O3 and 12.7 percent Fe2O3. The clay is predominantly kaolinite, with a minor quantity of boehmite, and contains siderite, quartz, feldspar, mica, and carbonaceous material as impurities (2).

Alumite deposits. - Deposits of alumite-bearing volcanics are in T. 19 N., R. 8 E., W. M., on the slopes of the White River Valley 10 miles east of Enumclaw. In the SE1/4 sec. 4, some 600,000 tons of 30-percent alumite is found, 1-1/4 miles southeast an estimated 240,000 tons of 21.4 percent alumite is found, and in the NE1/4 sec. 7 and in secs. 5 and 6 there is some 300,000 tons, making a total of 1,140,000 tons of alumite-bearing rock (2).

Other deposits. - The semirefractory clays of the Hammer Bluff formation have been mined for various purposes in the past. The exposures and mine workings are in T. 21 N., R. 6 E., W. M.

Expanded clay aggregates

Work done by the authors in 1950, in which 127 samples from the Seattle area were tested for bloating characteristics, showed the following:

1. Glacial clays, which are plentiful in the district, are unsuitable for use as expanding clays. Short firing range, irregular pore structure, and poor strength are characteristic.
2. Samples of carbonaceous shale from the Black Diamond, Wash., area were fair bloaters.

3. A light-gray shale from the Springdale mine 2 miles northwest of Renton, Wash., was the best sample tested. Insufficient quantity of raw material is available.

4. Shales associated with coal measures of King County need to be investigated further.

Recent work by a Seattle concrete-block manufacturer showed that some shales in the Maple Valley area near Renton are excellent bloaters.

Ceramic industry

The highest concentration of ceramic plants of the region is in the vicinity of Seattle, King County. There are 1 large refractory-structural clay-products plant, 3 plants manufacturing only structural products, 1 flowerpot plant, 1 specialty-glass plant, and 1 glass-container factory.

Seattle Brick & Tile Co., Fourth and Andover Streets, Seattle, manufacture face and common brick and load-bearing partition and drain tile. The average monthly production of all types of ware is 2,200 tons. Glacial clay is used for raw material, and reserves in the area are very large. The clay is dried in a rotary drier using hogged-wood waste and is ground in a dry pan with a rubber-tired muller. The ware is formed by extrusion and is dried in a 24-tunnel, double-deck, continuous drier. Waste and auxiliary heat is used. The ware is fired in a coal-fired semicontinuous, Hoffman-type kiln or in either a rectangular or round periodic kiln. Power consumption is 30,000 kw.-hr. a month. Fuel is slab wood, hogged-wood waste, oil and coal. The ware is marketed in the Puget Sound area and Alaska. The plant is operated by John Sterrett, Seattle.

Clay is mined for Seattle Brick & Tile Co. and for Builders Brick Co., by J. B. Stillwell, 3270 Airport Way, Seattle. Clay reserves from this pit are very large. This firm also mines clay for the two brick manufacturers from company-owned pits.

The Renton, Wash., plant of Gladding, McBean & Co. manufactures a completed line of clay-refractory shapes, refractory plastics and mortar, vitrified clay pipe, flue lining, and face brick. The total production of all items is about 4,000 tons per month. Fire clay and miscellaneous clays and shales are mined in King and Spokane Counties.

Refractory Kummer shales are calcined in a rotary kiln, crushed, and sized. The other components of the refractory mix are batched mechanically. The refractory shapes are formed by four mechanical presses and by hand molding for difficult shapes, dried in a humidity drier, and fired in a tunnel kiln, using heavy fuel oil.

The clays for brick and sewer pipe are formed by extrusion and dried in waste-heat and steam-coil driers. They are fired in periodic, round, downdraft kilns using heavy fuel oil. Consumption of electricity is 228,000 kw.-hr. a month.

Builders Brick Co., Seattle, produces all types of structural clay products, with daily production of 50,000 equivalents. Blue glacial clay is mined at the plant site, and some light-firing clay is brought to the plant from the company Clay City plant in Pierce County. Reserves of clay are estimated to be enough.
for 13 years at the present rate of consumption. Clay is dried in a rotary drier, crushed, and screened. The products are formed by extrusion, dried in a continuous-tunnel drier using waste heat, and fired in a 20-chamber Hoffman semicontinuous kiln and 5 round, downdraft kilns. Coal is used as fuel in the Hoffman kiln and oil in the periodic kilns. The products are marketed in the Puget Sound area. R. C. Houlahan is the plant operator.

Abrahamson Brick Co., 5000 West Marginal Way, Seattle, produces 5,200,000 face and common brick a year. Roll crushing is used to prepare the clay, and ware is formed by extrusion. The brick are dried in a tunnel drier, using a separate source of heat, with hogged-wood waste as the fuel and fired in a coal-fired, 16-chamber, Hoffman kiln. Power consumption is 4,550 kw.-hr. a month, and coal consumption is 90 tons a month. The products are marketed in western Washington. Gus Anderson is the plant operator.

Northwestern Glass Co., Seattle, the only glass-container plant in the region has pioneered the electrical melting of glass. The company manufactures a complete line of glass containers from five high-speed automatic-forming lines. Average production from the 2 electrically heated tanks and the 1 oil-electric tank is 22,000 tons of containers a year. Over half the raw material needs are now imported from outside the region. California supplies a portion of the silica and most of the fluxes used. About 50 percent of the remaining silica is obtained locally and the other 50 percent imported from Belgium and Nevada. It is expected that the Gem Silica Co., Emmett, Idaho, will enter this market with completion of a magnetic beneficiation system. The most critical need in local manufacture of glass is a nearby supply of soda ash and high-grade silica. Consumption of electricity is 96,000 kw.-hr. a day. The principal market area for the products is in Washington, with secondary markets in Oregon, Idaho, and British Columbia. Installation of an automatic batching system is planned for 1955. Eleven glass-container plants in California also compete in the same market area. The plant manager is E. S. Campbell.

The Washington Pottery Co., 809 Snoqualamie Street, Seattle, annually produces 2,500,000 flowerpots. Clay is obtained from various sources in and near Seattle. It is ground in dry pans and sized on vibrating screens. Pugmills are used to form slugs for the flowerpot presses. Circulating hot air is used for drying and 2 oil-fired, updraft kilns of 500 cubic feet capacity each are used to fire the ware. The products are sold in Seattle, Yakima, and Wenatchee trade areas.

A flowerpot plant at Auburn, Wash., resumed production in July 1953.

The Pemberthy Instrument Co., 666 Adams Street, Seattle, makes special glasses, the principal product being extremely high lead glass used for absorption of radioactive radiation. The volume of glass made is small, and high-purity raw materials are used.

Other industries are 2 porcelain-enamel plants, 1 plant specializing in enamel signs and the other in stove enamelling. Neither plant manufactures its own frits, hence all ceramic-coating materials are imported from outside the region.

**Summary**

The large and constantly increasing market area of King County makes it a natural center of ceramic industry. Additional sources of ceramic raw materials within the county will depend upon further prospecting in the coal-mine areas for shales suitable for making expanded aggregates and in the areas near the Blum, Kenaskat, Kangley, and Kummer deposits for high-alumina shales for refractory raw materials.
Kitsap County

Clay

Shales of Kitsap County, in the Waterman Peninsula area were tested for bloating properties, and some exhibited good expansion. The location, on waterways to Seattle, Tacoma, Olympia, Bremerton, Everett, and Bellingham, makes this area an ideal location for an expanded-aggregate plant. More extensive prospecting of these shales is needed. No other raw-material resources of concern to this survey are known. There are no ceramic industries in the county.

Klickitat County

Clay

A high-alumina clay deposit is reported by Valentine (22) to be in sec. 5, T. 4 N., R. 12 E., W. M., owned by F. B. Roberts. No additional information is given, and no other deposits of ceramic raw materials are known.

Lewis County

Clay

Toledo deposit. - The Toledo deposit, T. 11 N., R. 1 E., W. M., 10 miles northeast of the Cowlitz deposit, Cowlitz County was investigated by the Bureau of Mines as a source of alumina for the production of aluminum. The proved reserves of this deposit are 2 million tons of clay containing 29.6 percent available Al₂O₃, and 8.8 percent available Fe₂O₃. An additional 6 to 8 million tons is inferred (14). Although the iron oxide content is too high, samples with as little as 1.7 percent Fe₂O₃ have been collected. The area between the Cowlitz and the Toledo deposits warrants further prospecting. The Toledo clay is similar to the Cowlitz but contains about 3 to 4 percent more Fe₂O₃. Like the Cowlitz deposit the Toledo deposit contains siderite (2).

Ladd mine. - The Ladd mine is reported to contain a bed of refractory shale underlying the coal seam. Nothing is known of its quality. The mine is in sec. 12, T. 14 N., R. 4 E., W. M.

Bushwell farm. - In NW1/4 sec. 25, T. 11 N., R. 2 W., W. M., there is an exposure of soft, plastic clay suitable for buff ware (2). On the west bank of the Cowlitz River in NW1/4SW1/4 sec. 24, T. 11 N., R. 2 W., W. M., a siliceous refractory clay is found (7).

Other deposits. - The bloating properties of carbonaceous shales associated with the coal measures of Lewis County have not been evaluated. One sample, taken by the senior author from the Stoker coal mine, Centralia, was tested at the University of Washington and showed excellent possibilities. No other deposits of ceramic material are known.

Ceramic industry. - The Chehalis Brick & Tile Co., plant, Chehalis, is the only ceramic plant in the county. The plant has been in operation for 50 years. Willapa surface clays and associated sandstone constitute the brick mix. Reserves are sufficient for at least 200 years of operation at the present rate. Clay is mined from an open pit by power shovel. Production is 28 thousand equivalents per day of face and common brick, drain, and building tile. The ware is formed by extrusion, dried by waste heat and steam in two tunnel driers, and fired in a round, downdraft kiln.
or in a 14-compartment semicontinuous kiln. Oil is used as fuel in the periodic kiln and coal in the semicontinuous kiln. Over 302,000 kw-hr. is consumed annually. The products are marketed in the area west of the Cascade Mountains from Portland to Seattle. Operators are Fremont Burrows, manager, and Marion Saindon, sales manager, Chehalis.

Summary. - The carbonaceous shales in the Toledo deposit are possibly outcrops of continuous beds between the Cowlitz deposits on the south and the Enumclaw deposits on the north. This possibility can be verified only by investigating the geologic relationship, clay mineralogy, and geographic location. Further examination of the bloating qualities of shales associated with the coal measures is needed.

Lincoln County

Talc

Two deposits of talcose schist are reported in the county. One in W1/2NW1/4 sec. 34, T. 27 N., R. 38 E., W. M., is known as the C. W. Capps deposit. The product formerly mined was shipped to paper mills. The deposit is described as a fair grade of talc 5 feet wide and known to occur over several hundred feet. The other deposit in NE1/4 sec. 6, T. 24 N., R. 39 E., W. M., is a talcose schist of unknown quality.

Okanogan County

Clay

No deposits of good-quality clay are known. A brickyard formerly operated at Oroville, but it has not produced since 1948.

Talc

A small occurrence of talc or soapstone is reported in the south center of sec. 32, T. 35 N., R. 26 E., W. M., on Johnson Creek.

The Kaaba-Texas mine in sec. 14 and 23, T. 40 N., R. 25 E., W. M., is reported to have an 18-inch seam of crystalline talc on the hanging wall of the vein.

Nepheline Syenite and Syenite

Two deposits, Ellencam Mountain in SW1/4 sec. 9 and NW1/4 sec. 16, T. 40 N., R. 26 E., and Kruger Mountain in sec. 3, T. 40 N., R. 26 E., W. M., are possible sources of nepheline syenite and syenite, respectively. Neither deposit could be used without beneficiation (22).

Feldspar

The Tunk Creek deposit in SW1/4SE1/4 sec. 8, T. 35 N., R. 27 E., W. M., is described as small clots of orthoclase in quartz pegmatite, perhaps too small for possible commercial use.
Summary

The possibility of finding clay deposits of good quality in this county is poor. The rugged terrain leaves little opportunity of retaining enough clays for deposition without transportation for long distances.

Additional occurrences of nepheline syenite, syenite, and feldspar might be found. The area, however, is quite remote for low-cost industrial development and transportation to market.

Pend Oreille County

Feldspar

One small deposit of feldspar is reported from the Cusick deposit in sec. 35, T. 35 N., R. 45 E., W. M. The deposit, a lens in granite, is too small for commercial use (22).

Pierce County

Clay

The LaGrande deposit of refractory clay in cuts and pits along the Chicago, Milwaukee & St. Paul Railroad 1/2 mile north of LaGrande, in sec. 28, T. 26 N., R. 4 E., W. M., was mined many years ago by Denny-Renton Clay & Coal Co. The clay is exposed for 150 by 100 feet to a depth of 12 feet (7).

No other deposits of refractory clay or ceramic raw materials are known in the county, despite widespread occurrences of clays suitable for manufacturing structural-clay products.

Ceramic industry. - The Clay City mine and plant of Builders Brick Co., is in sec. 36, T. 17 N., R. 4 E., W. M. The clay used is an altered white to light-gray andesite rock. The fired color ranges from gray to dark red. This plant makes 50 thousand equivalents per day of structural-clay products. The ware is made by extrusion, dried in periodic humidity dryers, and fired in round, downdraft kilns. There are six 30-foot kilns and one 40-foot kiln. Heavy fuel oil is used for firing. Electrical consumption is 1,250,000 kw.-hr. a year. The products are marketed in Washington and Oregon. R. C. Houlahan is the operator.

Summary. - Although Pierce County has in the past had several brick plants, ceramic resources other than structural clays are not numerous or well-known.

San Juan County

Feldspar

The Dear Harbor deposits, which consist of 4 pegmatite dikes 25 to 60 feet thick, are composed of quartz and soda feldspar. Beneficiation tests indicate that a pure feldspar product can be made (14). The dikes, on the water level of Puget Sound, have been mined intermittently by Manufacturers Mineral Co., Seattle.

Nepheline Syenite

A deposit described as nepheline syenite in a conglomerate occurs on Waldron Island.
Andalusite

Andalusite occurs on Blakely Island in diorite that has been extruded and altered by lamprophyre dikes. Similar occurrences on other islands of the San Juan group are postulated.

Summary

Little is known of the occurrences of andalusite, but the deposits are probably too low grade to have commercial value. The feldspar and nepheline syenite may be utilized if demand for this type of flux should be developed.

Skagit County

Talc and Soapstone

There are at least 10 deposits of soapstone in Skagit County, and many were mined in the past for use as furnace blocks in soda furnaces in kraft-paper mills. Present production is used as a carrier for insecticides or as a soil conditioner. None is mined for ceramic purposes.

Skagit Talc Co. deposit. - This deposit is in secs. 11 and 14, T. 36 N., R. 11 E., W. M. Large tonnages of soapstone were mined in the past for furnace blocks, but its high iron content makes most of the deposit unfit for ceramic use (8, 26).

McVrill-Wilson deposit. - This deposit in NE1/4 sec. 21, T. 36 N., R. 11 E., W. M., is similar to the Skagit Talc Co. deposit and formerly was mined for refractory use (8, 26).

Londondarry Mines, Inc. - The mine, in secs. 15 and 17, T. 36 N., R. 11 E., W. M., has a large soapstone body along a 400-foot contact zone between granite and schist.

Dad's Girl claims. - This deposit, in NL/2 sec. 21, T. 36 N., R. 11 E., W. M., has a 20-foot-wide body of soapstone exposed for 75 feet. The talc is high in iron because of the presence of ankerite (26).

Clear Lake talc. - Talc from this deposit, in secs. 16 and 17, T. 34 N., R. 5 E., W. M., is ground for diluent in insecticides and for a soil conditioner. Some good-quality talc is found in lenses in serpentine and schist (2, 26).

Alvard deposit. - This deposit near the southwest corner of sec. 15, T. 36 N., R. 11 E., W. M., is a large body of soapstone with some better grade talc and ankerite (8, 26).

Lyman deposit. - The Lyman deposit of talcose clay is in a valley near the town of Lyman (8, 26).

Sadie Cudworth deposit. - This deposit is in the southeast corner of sec. 21, T. 35 N., R. 12 E., W. M. Soapstone outcrops for 1,000 feet along the road.

Other deposits. - Other small outcroppings of soapstone are known in the SW1/4-NE1/4 sec. 27, T. 36 N., R. 5 E., and SE1/4NE1/4 sec. 15, T. 36 N., R. 4 E., W. M.
**Feldspar**

Small dikes of plagioclase feldspar occur in NW1/4 sec. 10, T. 36 N., R. 7 E., W. M., in the bed of a tributary to the Nooksack River. The dike is too small to have commercial value.

**Kyanite**

Kyanite crystals occur in quartz veinlets on the Johnsburg claim in NW1/4 sec. 34, T. 35 N., R. 13 E., W. M.

**Olivine**

Large olivine deposits are found in the county, and a small grinding mill at Hamilton is producing the olivine for use as a foundry sand.

**Ceramic Industry**

A new plant of 30,000-brick-per-day capacity was built north of Burlington in 1954.

**Summary**

No deposits of ceramic-grade talc are found in the county, and most of the soapstone mining is intermittent.

**Skamania County**

**Clay**

A deposit of light-color clay containing 5 to 10 percent Fe₂O₃ occurs on the C. G. Kocher property, NE1/4SE1/4 sec. 24, T. 3 N., R. 7 E., W. M., about 3-1/2 miles northeast of Stevenson on a county road. The deposit is 1,300 feet long and is exposed only along the road (22).

**Kyanite-type minerals**

Near the headwaters of the North Fork of the Washougal River, rock composed of 2 percent dumortierite, 35 percent andalusite, 32 percent quartz, 27 percent muscovite, and 4 percent accessory minerals is reported (18).

**Snohomish County**

No deposits of minerals of concern in this survey are known in the county.

**Ceramic Industry**

The Pacific Grinding Wheel Co., Everett, annually manufactures 300 tons of grinding wheels of all types. The aluminum oxide and silicon carbide grain are shipped from the east; clay and feldspar for the vitrified bond are imported from the southeast. Most critical needs of the industry are to develop a source of high-quality, uniform-grade clay and to overcome abrasive grain shortages. The abrasive grain is mixed with bond and formed by pressing in hydraulic presses. The wheels are dried in a dry room using hot air and fired in four oil-fired rectangular kilns. Electric ovens are used for resin-bonded wheels. Products are sold in Washington, Oregon, California, Idaho, British Columbia, Montana, and Texas. Power requirements are 7,500 kw.-hr. a month.
Lowell Brick & Tile Co. manufactures common and face brick. The average production is 4,800,000 thousand brick per year. Clay is mined locally from a glacial deposit. Reserves are extensive, but no prospecting has been done. The brick is formed by extrusion and dried in a tunnel drier in front of an oil-fired, 225-foot-long tunnel kiln. The products are sold in the Puget Sound area and in central Washington. Power consumption is 26,000 kw.-hr. a month. John Gorin is the plant operator.

Spokane County

Clay

Certain nonmetallic deposits and ceramic plants in Spokane County are shown on figure 7. The white to buff clays widely distributed in the Spokane area are formed by the alteration of a granitic batholith of the Mesozoic period. The batholith is over 1,000 miles long and 100 miles wide in places. Alteration of the granitic mass formed a kaolinite-quartz-mica residue in which enrichment of the kaolinite resulted from alteration of aplite dikes formed during the cooling of the batholith. Later, erosional forces exposed and cut deeply into the granitic rocks. During this cycle some clays were transported; other deposits were left in place. Subsequent basaltic flows capped many areas, and alteration of the basalt formed red clay. In many places the residual clays are intermixed with colluvial and transported and basaltic clays. Thus, the manufacture of various colors and shades of face brick ranging from deep red to white is possible from one deposit. Irregularity of deposition, effect of erosional forces, and capping by basalt, followed by other erosional cycles, makes prospecting for high-grade clay difficult. The clay deposits of the Spokane area are irregular in shape and quality. This requires drilling on very close intervals to delineate the clay areas. There is, however, excellent possibility of discovering new deposits in many districts.

Pits Owned or Operated by the Washington Brick & Lime Co.

Freeman pit. - The pit is in sec. 1, T. 23 N., R. 44 E., W. M., southwest of Mica Peak. The clay is stratified into red-firing plastic and buff-firing refractory grade. The deposit is large enough for many years production. Reserves of 1 million tons partly developed and 5 million tons probable are estimated by Glover (2). The p.c.e. ranges from 27-30. This is a residual clay with quartz and mica as the principal impurities.

Mica pit. - This pit is in sec. 23, T. 24 N., R. 44 E., W. M., across the track from the Mica plant of Gladding, McBean & Co. The clay is red and buff firing. The pit is not being mined at present owing to the preponderance of red clay.

Other pits. - Other pits in the Mica-Freeman area formerly mined by the Washington Brick & Lime Co., are the Noyd and Mason.

Outcrops of Buff-Firing Clays

Conlon pit. - The pit is in the N1/4 sec. 15, T. 24 N., R. 44 E., W. M., near the Mica pit. The clay is colluvial and probably limited in extent (26).

At Redlin Siding on the south side of the canyon in NW1/4SW1/4 sec. 15, T. 24 N., R. 44 E., W. M., near Redlin Switch on Oregon-Washington Railroad & Navigation Co. there is a 15-foot bed of intermixed yellow, gray, and white clay.
Figure 7. Map showing certain nonmetallic resources and ceramic industry in Spokane County, Wash.
Five-Mile Prairie deposit. - This deposit is about 5 miles northwest of Spokane in secs. 22, 25, and 26, T. 26 N., R. 42 E., W. M. The presence of montmorillonite with kaolinite reduces the refractoriness and increases the shrinkage of this clay. Eleven holes were drilled by the Bureau of Mines in 1942. From 5 of the holes 28 samples were tested. Only 1 sample had a p.c.e. above 31; 1 sample was low-heat-duty, and 26 were nonrefractory (20).

Excelsior-Valley Ford deposit. - The deposit is in the Mica district 15 miles southeast of Spokane in secs. 14, 15, 21, 23, T. 22 N., R. 44 E., W. M. More than 100 holes were drilled by the Bureau of Mines, and samples from 11 were taken for ceramic testing. White sedimentary clay is interbedded with quartz sand and altered basalt. The best refractory clay is a 5-foot bed 30 feet below the surface. Intermediate-heat-duty refractory clay is interbedded with nonrefractory clays. Fired colors are gray, buff, and tan at pyrometric cone 04 and tan and brown at pyrometric cone 4. Average available alumina is 30.6 percent and available Fe₂O₃ is 3.4 percent. Over 3 million tons was outlined (20).

Pits Owned or Operated by Gladding, McBean & Co.

Sommers mine. - The mine is in sec. 35, T. 25 N., R. 44 E., W. M. The clay is plastic, nonuniform, buff-firing, and requires blending before use. The p.c.e. is 18. Reserves of nearly 200 thousand tons are known. The clay is loaded on trucks with a bulldozer and hauled to the Mica plant.

Mica Clay mines. - The mines constitute several pits at the Mica plant in sec. 14 and 23, T. 24 N., R. 44 E., W. M. The clays range from red-firing on the surface to yellow and white. The white clay is badly iron stained in part.

Wellsandt property. - Good-grade refractory clay was encountered in a well in El/2NW1/4 sec. 23, T. 24 N., R. 41 E., W. M. (7).

Skaturn place. - This deposit in Sl/2 sec. 11, T. 26 N., R. 44 E., W. M., has clay suitable for intermediate-heat-duty refractory use.

Moran Prairie. - This deposit in SW1/4 sec. 10, T. 24 N., R. 43 E., W. M., has semirefractory clay and was mined formerly.

Latah. - This pit in Wli/2 sec. 33, T. 21 N., R. 45 E., W. M., has a large body of semirefractory clay (7).

Fitzgerald Place. - A well in NE1/4SW1/4 sec. 23, T. 26 N., R. 44 E., W. M., showed refractory clay (7).

Fairfield. - This occurrence in NW1/4SE1/4 sec. 29 T. 24 N., R. 45 E., W. M., is semirefractory clay exposed in a road cut.

Connor pit. - This pit in N1/4 sec. 4, T. 24 N., R. 42 E., W. M., was mined formerly for refractory clay.

Clay for Structural Ware

Many occurrences of clay suitable for structural ware are found in the county.
Kyanite-Type Minerals

The Silver Hill tin prospect in secs. 23 and 24, T. 24 N., R. 43 E., W. M., has andalusite and sillimanite in mica schist and in pegmatite dikes. The grade of material is below economic limits (2).

Ceramic industry. - The Mica plant of Gladding, McBean & Co. makes refractories, face brick, and sewer pipe (figs. 8 and 9). The ware is formed by extrusion and handmolding, dried in waste-heat steam driers, and fired in round, down-draft kilns. Monthly production of face brick sewer pipe, and refractories totals about 600 tons each. Coal is used as fuel in firing; electrical consumption is 62,000 kw.-hr. per month. All products are marketed in the Pacific Northwest.

The Dishman plant of Washington Brick & Lime Co., makes building brick and hollowware. Production of brick amounts to 9 million equivalents a year. Annual production of hollowware is 9 thousand tons. The brick are extruded, and the sewer pipe is pressed. Ware is dried in waste-heat driers and fired in periodic kilns and a tunnel kiln. Butane is used for fuel. Power consumption is 700,000 kw.-hr. a year. All products are marketed in the Pacific Northwest.

A flowerpot plant is operated by J. F. Mills at Chester. Clays of the Mica-Freeman district are pressed, dried by a hot-water drier, and fired in a small, round, downdraft kiln. The body is mixed in a wet pan, and a pugmill is used to extrude slugs for the flower-pot press. Annual production is about 600 thousand pots.

Summary

The geologic history of the clays in the Spokane area makes prospecting for white-burning clay difficult. The basalt capping in many instances has altered to a red-firing clay and contaminates the white clay that lies below. The area offers good possibilities for further discoveries, but drilling would have to be done at close hole-intervals, owing to the irregular deposition and retention of the better clay deposits.

Stevens County

Clay

Certain nonmetallic mineral deposits and ceramic plants in Stevens County are shown in figure 10. Refractory and structural-grade clay has been mined in the county in the past, with the largest production from Clayton. The Washington Brick & Lime Co., Spokane, has operated the Clayton plant for many years and owns or operates the following clay deposits:

A. B. Pit. - This pit, about 8 miles from Clayton in NW1/4 sec. 32, T. 30 N., R. 42 E., W. M., contains a buff-firing plastic. Reserves of the lesser grades are adequate for many years of operation.

Olson pit. - The deposit, 6 miles from Clayton, is being developed, and it appears to contain large reserves of buff-firing, plastic, refractory clays.

Clayton deposit. - The Clayton clays range from plastic to nonplastic, red-firing clays in large quantities. The reserves have not been estimated because the readily available supply is adequate for many years of operation. The pit is in sec. 19, T. 29 N., R. 42 E., W. M.
Figure 8. - A pit of the Mica, Wash., plant, Gladding McBean & Co., showing white clay underlying red basaltic clay.
Figure 9. - An adjoining pit at Mica, Wash., showing white clay from which overburden of basaltic clay has been removed by erosion.
Figure 10. - Map of Stevens County, Wash., showing certain nonmetallic mineral deposits and ceramic plant.
Neafus pit. - The Neafus pit is in SW1/4 sec. 34, T. 30 N., R. 42 E., W. M. Refractory clays have been mined in the past (7).

Valley deposit. - The Valley, Wash., occurrence is in T. 31 N., R. 41 E., W. M., in a valley east of the town. Farmers report that the valley floor is underlain with a gray to white clay. A reported occurrence in NW1/4 sec. 20 is said to be high grade (2). A sample recently taken from the surface on the farm of J. W. Caskanett in sec. 29 had a p.c.e. of 19. Diaspore was identified tentatively as a constituent of the clay. Deposition of this type of clay is not extensive.

Jumpoff creek. - In T. 31, R. 41 E., W. M., high-alumina clay is reported to occur at Jumpoff Creek in N1/2NE1/4 sec. 31 and semirefractory clay at the Kulzer deposit in NE1/4 sec. 30 (2). Numerous clay deposits suitable for the manufacture of structural-clay products also occur in the county.

Feldspar

The Waits Lake granites are reported to contain high percentages of feldspar, but for ceramic use the ore would require beneficiation.

Talc and Soapstone

Two talcose deposits occur in T. 30 N., R. 38 E., W. M. The Firminhac deposit (W1/2SE1/4 sec. 15) is reported to contain good-quality talc (9), and the C. F. Allen deposit (NW1/4 sec. 21) is a serpentinized schist.

Andalusite

Andalusite occurs with biotite in phyllite or schist near the head of Onion Creek on Galena farm, SE1/2SW1/4 sec. 5, T. 37 N., R. 40 E. W. M. (22).

Ceramic Industry

The Washington Brick & Lime Co. produces 6 million common and face brick annually at the Clayton plant. Ware is formed by extrusion and dried in waste heat and air dryers. Oil-fired scove kilns and coal-fired, round, downdraft kilns are used. Clay is mined near the plant for most of the ware.

Summary

The extensive clay deposits, from refractory to building brick grades, suggest the possibility of finding more and better grade clays in the area. The extent of the gray to white plastic clays of the county and possible uses have not been determined. The one andalusite deposit reported is said to warrant investigation. Dolo-

Clay

ite is quite generally found, and the important Chewelah magnesite deposits are in Stevens County.

Whatcom County

The carbonaceous shale deposits of the Sumas area constitute the only known deposits of clay better than structural grade. The shales are all in T. 40 N., R. 5 E., W. M.
The Denny-Renton clay mine is in SE1/4 sec. 12. It has been worked extensively in the past, but it is now idle.

The Nicolay Spur deposit in NW1/4NW1/4 and SW1/4 sec. 18 is a refractory shale of the Sumas series.

The Post deposit in NW1/4 and SW1/4 NE1/4 sec. 7 and the Smith deposit in the center of sec. 7 also are refractory shales of the Sumas series.

The Sumas clay mine, operated until recently by Gladding, McBean & Co., produced a carbonaceous shale with a p.c.e. of 31. On an ignited basis the Fe2O3 content was 2.45 percent; Al2O3, 47.33 percent; and SiO2, 49.82 percent.

Olivine

The large olivine deposits of the Twin Sisters Mountains are in Whatcom and Skagit Counties.

Ceramic Industry

There are no operating ceramic plants in the county. All demands are satisfied by Canadian plants or by plants in the Everett-Seattle area.

Whitman County

Clay

Structural clays have been used extensively in the county to produce ware in the past, but no clay plants are operating at present.

The Ringo deposit in secs. 17 and 18, T. 16 N., R. 46 E., W. M., is reported to be refractory grade. The clay is exposed in a pit 100 by 200 feet. The quality is unknown.

The Cox pit in NW1/4NW1/4 sec. 7, T. 16 N. R. 46 E., W. M., was formerly mined for refractory clay.

Feldspar

The Bald Butte pegmatite is in secs. 1, 2, 11, and 12 T. 13 N., R. 45 E., W. M., where a feldspathic pegmatite dike cuts the quartz-diorite. Its value has not been determined.

Summary

Very fragmentary information is available on either the clay deposits or the feldspathic dike.

Yakima County

Clay

Structural-grade clays from NW1/4 sec. 35, T. 12 N., R. 23 E., W. M., and near the center of SE1/4 sec. 34, T. 11 N., R. 21 E. W. M., have been used for filler in asphalt flooring. The material is more accurately described as a silt because the clay mineral content is low.
Talc

George Miller of Granger submitted a sample of good talc to the Washington State Department of Mines and Geology.

Ceramic Industry

The plant of the Granger Clay Products Co., is in Granger and the sales office is in Yakima. The plant produces structural-clay products and daily production is 35 thousand equivalents. The clay is mined from 2 pits, 1 at the plant and the other at Sniper Mountain near the plant. The products are dried in a waste-heat tunnel drier and fired in periodic down-draft kilns. Slack coal is used for fuel, and 2,500 tons is consumed annually. The products are sold in southeastern Washington and northeastern Oregon.

Summary

There is little opportunity to develop raw-material sources for an enlarged ceramic industry in this county. Extensive basalt flows and widespread deposition of aeolian and loessal silts are unfavorable to clay deposition.

IDAHO - CERAMIC RAW-MATERIAL RESOURCES AND INDUSTRIES

Industrial Review

Idaho's ceramic industry is confined largely to the southern portion of the State, where 4 of the State's 5 plants are located. Troy, in the northern part, is the site of the other plant. This plant manufactures only refractories. The 4 structural-clay plants produce 8,500 thousand brick a year and make no other products. Certain nonmetallic mineral deposits and ceramic plants in Idaho as shown in figure 11.

Forming, drying, and firing practices are the same in the structural plants. All make an extruded product, use air drying, and fire with coal in scove kilns. Fuel costs in all 4 plants are about $7.00 per 1,000, and electrical consumption averages 16.9 kw.-hr. per thousand brick. All products are marketed in the area centering around Boise in southwestern Idaho, Twin Falls and Burley in south-central Idaho, and Idaho Falls in southeastern Idaho. Some clay products, principally refractories and deep-red structural brick, are shipped into the area from Salt Lake City, Utah.

The Troy Firebrick Co., the State's only refractory plant, has for many years specialized in locomotive-boiler refractories but now is making a broader line of products. The refractories are formed by extrusion, except for more complicated shapes, which are hand molded, and re-pressed in round downdraft kilns. The market area for their products is the entire Pacific Northwest.

The ceramic industry of Idaho has a potential for further development primarily because of its raw-material resources. Normal growth and expansion will, of course, provide opportunity for industrial expansion. No flue lining, sewer pipe, drain tile, or other hollowware is produced in Idaho. Two plants have been added in the past few years.
Figure 11. - Map of Idaho, showing certain nonmetallic deposits and ceramic plants.
Raw-Material Resources - Summary

An accurate appraisal of the State's potentialities is difficult with little knowledge available of the raw-material resources, except in the Troy, Moscow, Bovill district. There, additional investigation would better delineate the clay resources. These deposits contain the best grade and largest quantity of clay now known in the region.

Large areas of Idaho have never been prospected for ceramic raw materials, and lack of demand has retarded exploration. The State has potential resources of clay, kyanite-type minerals, feldspar, and other alumina minerals, but northern Idaho is the only part having good-quality clays.

Review by Counties

Ada County

Clay

No deposits of clay of unusual value are known to exist in the county, although red clays and light-colored silts are widespread.

Ceramic industry. - The Boise Brick Co. at Barber southeast of Boise, produces 1,500 thousand to 2,000 thousand brick a year. Clay is mined at a local pit and hauled by truck to the plant. The clay is screened and formed by extrusion. A small, 50-thousand-brick capacity drier is used, and the brick is fired in scove kilns. Coal is used for fuel. Power consumption is 21,760 kw.-hr. a year. The plant operates 6 to 7 months a year, and the product is marketed in the Boise area. George and Ray Pullman are the plant operators.

Adams County

Clay

No deposits of good-quality clay are known in the county. Prospectors told the senior author that white clay occurs in the county, but the deposits were inaccessible at the time of the inspection trip. E. A. Watkins of New Meadows said that he knew of two exposures of white clay.

Feldspar

Orthoclase is reported to constitute a large portion of a pegmatite dike at the Lucky Strike mine in the Seven Devils mining district.

Summary

Clay, feldspar, and kyanite-type minerals should exist in this county. There has been no demand for them and hence little prospecting.

Benewah County

Clay

White to gray clay crops out in many places in the county, but none of the deposits has been developed. The following occurrences were reported in 1920 (19), but no extensive deposits are known.
St. Maries. - In a cut on the Chicago, Milwaukee & St. Paul railway, 8 miles west of St. Maries, gray clay overlain by pink clay is exposed. The gray clay is buff-firing and has a p.c.e. of 30. The exposure is in sec. 10, T. 46 N., R. 3 W., Boise Meridian (B. M.).

Other deposits. - Six miles west of St. Maries in sec. 12, T. 46 N., R. 3 W., B. M., a railway cut shows 8 feet of white and 8 feet of yellow clay. The p.c.e. of a sample of the yellow clay was 30. Analysis of the white clay was 71.3 percent SiO₂, 11.4 percent Al₂O₃, and 1.7 percent Fe₂O₃.

At the east end of a railway cut 2 miles west of St. Maries, in sec. 21, T. 46 N., R. 2 W. B. M., red and yellow clay is exposed over a width of 19 feet and a length of 100 feet. Analysis of the clay is 59.9 percent SiO₂, 24.6 percent Al₂O₃, and 6.6 percent Fe₂O₃.

One-fourth mile east from the St. Maries station on the railway a yellow and white clay of low alumina content occurs.

In sec. 16 or 17, T. 45 N., R. 3 W., B. M., a white clay is reported on the Joe Sweighart place.

Other exposures occur on the road between Bovill and St. Maries. One surface sample taken 6 miles south of St. Maries had a p.c.e. of 19-26, and the melted cone was dark gray. Kaolinite is the clay mineral.

Thorn Creek Hill deposit. - A 20 to 30-foot bed of white clay occurs in sec. 17 and 18, T. 45 N., R. 1 W., B. M.

Feldspar

Near the mouth of Cornwall and Homestead Creeks in T. 43 and 44 N., R. 3 E., B. M., pegmatite dikes containing large quartz and feldspar crystals are found. The dikes segregate into nearly pure quartz and high feldspar phases.

Summary

Clay prospecting in Benewah County has not been extensive, and most exposures are small. The occurrences of both clay and feldspar warrant further prospecting.

Boise County

Clay

One deposit of "china clay" was reported in the Grimes Pass area, but local prospectors knew nothing of its location.

Feldspar

Pegmatite dikes with a high feldspar content are found in the Grimes Pass area on the Thornton Mining Co. property near Garden Valley and elsewhere. Ceramic grade feldspar probably could be produced by hand-sorting or beneficiation.

Kingsley deposit. - Three miles east of Grimes Pass there is a 50-foot pegmatite dike with feldspar borders. White quartz and feldspar are the principal minerals. An outcrop on the road did not appear to be ceramic grade.
Summary

The extensive igneous activity in the Grimes Pass area makes it a favorable location to prospect for feldspar. Large clay deposits are unlikely, as the granitic rocks have not been kaolinized extensively and the rough terrain is not favorable for clay deposition.

Bonneville County

Feldspar

A high-feldspar dike occurs 48 miles southeast of Idaho Falls in T. 43, R. 4 E., B. M., at Mount Caribou. It is said to contain 88 percent orthoclase, 8 percent quartz, and some ferromagnesian minerals and zircon (18).

Ceramic industry. - The Idaho Falls Brick & Tile Co. annually produces 3,200 thousand equivalents common, face, and roman brick and building tile. The clay is mined locally, crushed and screened, and formed by extrusion. The ware is air-dried and fired in scove kilns. About 0.7 tons of coal is used to fire each thousand brick. Power consumption is about 9,000 to 10,000 kw.-hr. a month, and the operating season is about 9 months a year.

Cassia County

Clay

No clays of unusual value are known to occur in this county. Great deposits of loessal or aeolian silt are found along the Snake River, but they are not good-grade clay.

Feldspar

At the south end of South Mountain 18 miles from Oakley pegmatite dikes containing 75 percent feldspar and 25 percent quartz were reported (1, 10). No estimate of quality was given. The location is too remote for economical operation.

Ceramic Industry

The Burley Brick & Tile Co. is the only ceramic plant in the county. Ware produced includes common, face, and roman brick and building tile. Clay is mined at the plant and is ground and screened. The ware is formed by extrusion and air dried. Annual production of building brick and building tile is 3,500 thousand equivalents. Firing is in scove kilns using coal for fuel. Fuel costs are $4.00 per thousand brick, and power consumption is 10,220 kw.-hr. a month on a 6-month a-year operating basis. The products are marketed locally. Joe Pullman is the plant owner.

Clearwater County

Clay

Several clay deposits are known in the county, one of which was discovered by the Bureau of Mines. No production of clay from the county has been reported.

Elk River deposit. - The deposit is near Elk River, in SE1/4 sec. 3, T. 39 N., R. 2 E., B. M. Inferred reserves are 5 to 10 million tons of clay (10). The clay
is sedimentary and is derived from the decomposition of feldspathic rocks. Available \( \text{Al}_2\text{O}_3 \) is 25 to 26 percent and available \( \text{Fe}_2\text{O}_3 \), 2 to 3 percent. No ceramic tests were made, and exploration has been limited.

R. W. Beck deposit. - The clay deposit is 15 miles from Pierce about 1 mile southeast of the Musselshell Ranger Station. It is reported to be 300 feet long and 10 feet thick. Halloysite is the principal clay mineral, and one sample had a p.c.e. of 34+ (2). Many other outcrops of white to gray clay are found in the vicinity, and two recently sampled had p.c.e. of 33 to 34. None have been prospected sufficiently to permit determining their extent.

Feldspar

The Wild Rose pegmatite at Pierce City is reported to contain pink orthoclase, white quartz, and muscovite.

Summary

No ceramic industry or production has been reported from the county. Investigation of the clay deposits is warranted. Although the area of known occurrences is remote, ceramic resources are promising.

Gem County

Clay

The silts of the Snake River are distributed widely in this county, and the silica-sand deposits contain a variable proportion of white clay.

Feldspar

The Gem Silica Co. mines a large deposit of silica and feldspar near Emmett, (fig. 12). The deposit contains about 30 percent feldspar. The sand is washed to remove the clay, which is not recovered. The feldspar could be removed by flotation to make a cleaner silica product and probably ceramic-grade feldspar. Reserves are extensive, as the sand constitutes a chain of hills 3-1/2 miles long. Chemical analysis of the sand being mined follows:

<table>
<thead>
<tr>
<th></th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{SiO}_2 )</td>
<td>85.21</td>
</tr>
<tr>
<td>( \text{Al}_2\text{O}_3 )</td>
<td>6.75</td>
</tr>
<tr>
<td>( \text{Fe}_2\text{O}_3 )</td>
<td>0.38</td>
</tr>
<tr>
<td>( \text{TiO}_2 )</td>
<td>0.15</td>
</tr>
<tr>
<td>( \text{Na}_2\text{O} )</td>
<td>2.00</td>
</tr>
<tr>
<td>( \text{CaO} )</td>
<td>0.69</td>
</tr>
<tr>
<td>( \text{K}_2\text{O} )</td>
<td>3.14</td>
</tr>
<tr>
<td>( \text{MgO} )</td>
<td>0</td>
</tr>
</tbody>
</table>

Summary

No ceramic industry of interest to this report is located in the county, but the size of the silica deposit mined by the Gem Silica Co. indicates huge reserves of readily available feldspar. No ceramic tests have been made on the feldspar fraction.

Idaho County

Clay

Two deposits of clay were investigated by the Bureau of Mines near Grangeville.
Figure 12. - Hills of silica sand, feldspar, and clay from which Gem Silica Co., Emmett, Idaho, mines silica.
Sherwin deposit. - The deposit, in Sec 31, T. 30 N., R. 2 E., B. M., includes 5 million tons of clay containing 2 to 3 percent available Fe2O3 and 29 to 31 percent available Al2O3. This deposit underlies 40 feet of soil and gravel.

The other deposit is in the NE1/4NW1/4 sec. 29, T. 30 N., R. 3 E., B. M. (2, 10). This deposit covers 60 acres and consists of eroded remnants.

Glenwood deposit. - This deposit is in a valley of a branch of the North Fork of the Lochsa River. Gray to white clay is exposed along the road, and the clay underlies the meadow at Glenwood. The clay is light to dark gray and very plastic. Other occurrences, inaccessible at the time of the inspection, were reported.

Taylor Burton deposit. - The deposit is in the SE1/4SE1/4 sec. 4, T. 29 N., R. 2 E., B. M., where a 20-foot thickness of clay is exposed for 350 feet. The white clay is associated with a micaceous clay. The exposure is 1/2 mile from U. S. Highway 95 (10).

Other deposit. - About 3 airline miles from Stites, just south of the northwest corner of sec. 35, T. 32 N., R. 3 E., B. M., 16 miles from Grangeville, a deposit of intermixed granitic sedimentary and basaltic clay occurs. The deposit would have to be mined by underground methods. Alumina content is 34.3 percent and ferric oxide 1.9 percent (10).

Feldspar

Pegmatite dikes containing feldspar are reported on the divide between the first and second creek east of Jersey Creek in T. 24 N., R. 8 E., B. M. (2).

Kyanite

Kyanite has been reported in the placer gravels of the Selway River near Lowell. Source of the kyanite was probably from an occurrence recently discovered between Lowell and Kooskia. A belt of kyanite-bearing rock has been traced for about 5 miles. No commercial concentrations were observed by the senior author on a visit to the deposit, but the locator, H. J. Clements, Stites, Idaho, submitted a sample containing 38 percent kyanite.

Talc

A talc occurrence is reported in the southeast portion of Idaho County and the northeast part of Lemhi County.

Summary

The undeveloped ceramic raw materials of the county offer good possibilities for prospecting. Little is known of the resources, but indications are that kyanite deposits similar to those north in Shoshone County may be found. Further investigation of the kyanite deposits in both counties is warranted.

Kootenai County

Clay

Stockton deposit. - The deposit is in parts of secs. 9, 10, and 15, T. 50 N., R. 4 W., B. M., 3 miles by paved highway and gravelled road from Couer d'Alene.
An estimated 600 to 700 thousand tons of clay is available, with an average of 23 percent $\text{Al}_2\text{O}_3$ and 3 percent $\text{Fe}_2\text{O}_3$ (10).

**Fernan Hill deposit.** - The clay is in secs. 8, 9, 16, and 17. T. 50 N., R. 3 W. B. M. 3 miles northeast of the center of Coeur d'Alene. An area 500 by 1,000 feet contains clay up to 30 feet thick. Inferred reserves are over 600 thousand tons of clay. An analysis gives SiO$_2$, 64.5 percent; $\text{Al}_2\text{O}_3$, 21.2 percent; $\text{Fe}_2\text{O}_3$, 2.86 percent; and ignition loss, 6.7 percent (10).

**Other deposits.** - Other exposures of clay occur at Blue Creek and Kid Island. Thick overburden and limited mining area owing to lake flooding make exploitation of these deposits unlikely. Clay of unknown extent occurs in the Medicine Lake area.

**Summary**

Kootenai County lies in the belt of altered granitic rocks that extends from north of Spokane, Wash., south through Idaho. Alteration of the granite has formed pockets and large deposits of residual and sedimentary clays. Prospecting may disclose additional clay resources.

**Latah County**

Clay deposits in this county offer an excellent opportunity to develop raw-material resources for a whiteware or electrical porcelain industry. Wilson and Goodspeed (23) did extensive work in washing the clays to remove quartz and mica and in testing the washed kaolins for many purposes. Major prospecting was done by the Bureau in drilling and investigating the Olson, Deary, Bovill, Benson, Stanford, Canfield, and Rogers deposits. These deposits represent the major clay occurrences in the county; many others are known but are undeveloped. (See fig. 13.)

**Olson clay deposit.** - The clay is about 8 miles northeast of Troy and 22 miles northeast of Moscow. The deposit underlies 928 acres in sec. 30, T. 24 N., R. 2 W. and sec. 24, T. 40 N., R. 2 W., B. M. The clay is derived from weathered Thatuna Mountain granites and occurs in beds from a few inches to 126 feet thick. Average thickness is 26.4 feet (20). The average available $\text{Al}_2\text{O}_3$ is 24.3 percent and the average available $\text{Fe}_2\text{O}_3$ is 4.7 percent. Large bodies of high-heat-duty clay are interbedded with thin beds of low-, intermediate-, and super-duty clays. Most samples are buff to tan when fired to pyrometric cone 4.

**Deary deposit.** - The deposit is 2-1/2 miles south of Deary in sec. 34, T. 40 N., R. 2 W., B. M. Proved reserves are estimated at 2,700 thousand tons of clay, with at least 10 million tons inferred (10). The clay is plastic, occurs in a bed nearly 50 feet thick, and is covered with less than 15 feet of overburden. The available $\text{Al}_2\text{O}_3$ content is 25.6 percent and available $\text{Fe}_2\text{O}_3$ 5.0 percent. One surface sample taken at the highway junction with the Washington, Idaho & Montana Railway showed a p.c.e. of over 31 despite intermixture of red and gray clay.

**Bovill deposit.** - The clay is near Bovill and is cut by the Bovill-Troy highway. The areal extent of the deposit is 2,000 acres. The upper 30 feet constitute 30 million tons, and 20 million additional tons is inferred. The gray sedimentary clay has an average of 24 percent available $\text{Al}_2\text{O}_3$ and 2 percent available $\text{Fe}_2\text{O}_3$ in the upper 30 feet. Residual clay resulting from alteration of basalt has a similar $\text{Al}_2\text{O}_3$ content but is higher in $\text{Fe}_2\text{O}_3$ (2, 10).
Figure 13. - Map showing certain nonmetallic deposits in Latah County, Idaho.
Canfield deposit. - The deposit is in sec. 16, T. 39 N., R. 5 W., B. M., about 1 mile southeast of the center of Moscow. The material is a gray plastic sedimentary clay overlain by loess and interbedded with coarse sand and gravel. Available Al₂O₃ is about 21 percent and Fe₂O₃ is 2.6 percent. Some 52 million tons of proved reserves is estimated, with 50 to 100 million additional tons inferred. Mining would be expensive due to excessive overburden and lack of adequate drainage. Clay from the Canfield pit, in sec. 14, T. 39 N., R. 5 W., B. M., formerly was used in manufacturing firebrick by the Moscow Firebrick & Clay Products Co. The clay is reported to have a p.c.e. of 32. Average analysis from 3 seams is SiO₂, 56.6 percent; Al₂O₃, 30.4 percent; and Fe₂O₃, 2.7 percent.

Joel pit. - The pit is 5 miles east of Moscow in NW₁/₄ sec. 18, T. 39 N., R. 4 W., B. M., and about 3/4 mile northwest of Joel. The pit was worked last in 1928. The clay results from decomposition of schist intruded by granitic, pegmatitic, and aplitic dikes. Estimated reserves are 500 thousand to 3 million tons. An analysis from 3 seams is as follows: SiO₂, 56.6 percent; Al₂O₃, 30.4 percent; and Fe₂O₃, 2.7 percent.

Calen pit. - This clay is about 5 miles from Troy near the junction of secs. 27, 28, 33, and 34, T. 40 N., R. 3 W., B. M. There has been little production from this pit. Reserves of clay are estimated to range from 500 thousand to 8 million tons.

Johansen pit. - The pit is in NW₁/₄ sec. 34, T. 40 N., R. 3 W., B. M. north of the main highway from Troy to Deary, 5 miles from Troy. The pit has produced 50,000 tons of clay and contains possible 250,000 more tons. The source is similar to that of the Joel clay. This deposit and land nearby are held under lease by the Pacific Northwest Kaolin Co., of which Bernard Potter, Jr., Los Angeles, Calif., is president. Some 900 acres near the junction of sections 27, 28, 33, and 34 is leased by his company. Mr. Potter estimates that the deposit contains over 30 million tons of clay. Although the deposit has not been developed, the company has investigated beneficiation of the clay-quartz-mica material.

McKeehan pit. - The pit is in the east center of SW₁/₄ sec. 6, T. 39 N., R. 3 W., B. M., about 1 mile north of Troy. High-grade kaolin blocks are found in the stream bed.

Benson deposit. - The Troy Firebrick Co. has mined clay from this deposit for many years (fig. 14). The pit is 1 mile north of State Highway 8 in the northwest corner sec. 33, T. 40 N., R. 3 W., B. M. The clay is residual from the alteration of granitic rock and retains the quartz and mica of the parent rock. Removal of these two impurities increases the p.c.e. of the clay from 31 to 33+. The deposit is estimated to contain 6 million tons, although basaltic clay is probably included in this estimate. Thickness and quality of the clay are variable, and careful mining is necessary to maintain quality.

Stanford deposit. - This deposit is in secs. 1, 2, 6, and 7, T. 40 N., R. 3 W., B. M. The residual basaltic and residual and sedimentary granitic clays are 15 to 50 feet thick over a square mile. An analysis shows SiO₂, 51.7 percent; Al₂O₃, 34.7 percent; Fe₂O₃, 3.48 percent; CaO, 1.2 percent; and MgO, 0.5 percent.

Vassar Station deposit. - The deposit is in NW₁/₄NW₁/₄ sec. 5, T. 40 N., R. 2 W., B. M., about 1-1/2 miles north of Vassar Station. White clay 40 feet thick is reported there on the farm of J. H. Nesbit.

Other deposits. - Outcrops of white residual and sedimentary granitic clays occur over several square miles in the vicinity of Park. Analysis of a sample from a railroad cut near Park is as follows: SiO₂, 70.6 percent; Al₂O₃, 11.8 percent;
CaO, 1.74 percent; Fe₂O₃, 2.58 percent. The clay lies in sec. 6, T. 39 N., R. 1 E., B. M., and in sec. 8, T. 39 N., R. 1 W., B. M. (10).

Other occurrences of clay are in the vicinity of Onaway. One is 2 miles north in sec. 25, T. 42 N., R. 5 W., B. M. Another is in sec. 6, T. 41 N., R. 4 W., B. M. Inferred reserves are 3 million tons underlying an area of 2 to 3 square miles. The average analysis is SiO₂, 55.96 percent; Al₂O₃, 31.56 percent; Fe₂O₃, 1.57 percent; CaO, 1.46 percent; and MgO, 1.36 percent. The p.c.e. is 32. Up to 60 feet of Palouse soil covers the clay. These deposits are north of the Thatuna Mountains, whereas the Troy-Moscow area is south of the mountains.

**Feldspar**

The pegmatites of the Avon district provide a possible source of feldspar. Three to six miles north of Avon northward-trending pegmatites occur in T. 41 N., R. 2 W., B. M. Tests by Wilson showed some feldspar to be ceramic grade (26); p.c.e. was 6-7.

**Sillimanite**

The Olson Sillimanite deposit is 9 miles northeast of Troy in SW₁/₄SW₁/₄, sec. 6, T. 39 N., R. 2 W., B. M. The deposit occurs in a schist, and samples ranged from 0.62 to 14.3 percent sillimanite. The crystals are extremely small, and the average grade is not high enough for economic recovery (21).

**Ceramic Industry**

The Troy Firebrick Co., now operated by the Washington Brick & Lime Co., is the only ceramic plant in the county. Clay is mined from the Benson pit and hauled to Troy by truck, crushed in a hammer mill, and screened on a vibrating screen. The plant manufactures high-heat-duty firebrick by extrusion, repressing, and handmolding. The bricks are dried in a four-tunnel drier and firing in four periodic kilns. Coal is used as fuel.

**Summary**

The clays of this county are among the most promising of the region. Proving deposits by systematic investigation and drilling on a close grid system should lead to development of these resources.

Much of the clay has been formed in place or has been transported very short distances and when newly exposed retains the granitic texture of the parent rock. The feldspar has been kaolinized completely, however, leaving the quartz unaltered and the muscovite relatively unaltered. The ferromagnesian minerals usually have undergone almost complete alteration. These residual clays contain about 50 percent clay and about 50 percent nonclay minerals, mostly quartz and mica. The clay can be separated from the quartz and mica by pneumatic or hydraulic classification or by froth flotation. Using classification methods, a clay concentrate is made, leaving a quartz-mica tailing product. Further separation of these two minerals by gravity methods is not feasible. By flotation a mica concentrate, a clay concentrate, and a quartz tailing can be made. All are salable products. The clay could be used in the ceramic industry, the mica as roofing granules or as additives to paint, and the quartz in the glass industry or in manufacturing sodium silicate, ferrosilicon, or silicon carbide. Testing and evaluation of the feldspar and further prospecting for sillimanite are warranted.
Lewis County

Clay

A brickyard formerly operated in Nez Perce, making white structural brick. The deposit from which the clay came is now owned by George Barney, Nez Perce. The clay appears to be similar to that found near Glenwood, Idaho County.

Payette County

Clay

The Payette Valley is covered with silts and clays of high iron content suitable for making structural-clay products. The silica, feldspar, and clay deposits on the Snake River banks are not as evident in this county as at Weiser or Emmett. No deposits of clay of unusual value are known.

Ceramic industry. - The Payette Brick Co., Payette, makes about 500 thousand building brick per year. Brick are formed by extrusion, air-dried, and fired in scoop kilns. Coal is used as fuel. All products are marketed in the Weiser-Payette area.

Shoshone County

Feldspar

A large area in the southern part of T. 43 N., R. 4 E., B. M., contains rocks high in soda-lime feldspar and labradorite. Hornblende and other mafic minerals are accessories.

Kyanite Group Minerals

A biotite schist high in kyanite and andalusite is found in an area 1,500 by 7,500 feet in T. 24 N., R. 5 W., B. M. A sample of the kyanite sent to the Federal Bureau of Mines Electrotechnical Station at Norris, Tenn., was reported to meet National Stockpile specifications. Beneficiation would be required to make a refractory product because the schist had a p.c.e. of only 8. A handpicked crystal of kyanite and a heavy-medium concentrate each had a p.c.e. of 37+. The deposit is relatively inaccessible, as it is 34 miles from a rail point and roads are impassable until midsummer.

Summary

Little development work has been done on the reported kyanite deposit, since markets for the material are distant from the deposit. This, coupled with necessity to beneficiate and the remote alpine location of the deposit, has retarded development. Rugged terrain makes prospecting for other ceramic raw materials difficult.
Valley County

Feldspar

South of Gold Fork, a tributary of the North Fork of the Payette River, in T. 16 N., R. 3 or 4 E., B. M., a pegmatite containing high-quality feldspar is reported (2).

Washington County

Feldspar

An organization was formed to treat a thick unconsolidated deposit of arkose sandstone in sec. 32, T. 11 N., R. 4 W., B. M., near Weiser. The deposit, in a hill 700 feet high, contained 79.6 percent SiO₂, 9.86 percent Al₂O₃, and 0.87 percent Fe₂O₃. Attrition scrubbing and froth flotation produced silica with 0.03 percent Fe₂O₃ and potash-soda feldspar with 0.08 percent Fe₂O₃. White clay was a secondary product. No production was recorded (2).

MONTANA - CERAMIC RAW-MATERIAL RESOURCES AND INDUSTRIES

Industrial Review

In the past 2 years 2 ceramic plants in Montana have ceased operations, leaving only 4 structural clay plants and 1 refractory plant (fig. 15). The refractory plant produces clay and silica refractories for use in the Anaconda Copper Mining Co. smelter at Anaconda. The clay refractories are extruded, and the silica refractories are dry-pressed. Production of the former is 315 thousand and of the latter 735 thousand 9-inch equivalents a year. The production varies from year to year, however, because only enough ware is produced to replace stocks. The other clay plants have been in operation for many years and are all that remain of the 30 plants that were in business in 1907. The Western Clay Products Co. at Helena makes the most complete line of structural clay products and in addition operates a small pottery and terra cotta plant. Red-firing structural-clay products are made in Lewistown, Helena, and Billings and buff-firing ware in Great Falls. Natural gas is the fuel used in the Helena, Billings, and Great Falls plants, resulting in considerably lower fuel costs than are achieved in the Lewistown plant, which burns coal from the nearby Roundup coal field. Extrusion forming and waste-heat driers are employed by all structural-ware manufacturers. No sewer pipe and only a small quantity of drain tile are made in the State. Sewer pipe is imported from Washington and Wyoming.

Raw-Material Resources - Summary

Montana offers excellent possibilities for developing resources of talc, feldspar, kyanite-type minerals, and clay. However, no ceramic raw materials have been developed except talc. Talc deposits near Dillon and Ennis have been mined for several years, and promising deposits of kyanite-group minerals are found in the same area.

Numerous pegmatite dikes in the Sheridan to Virginia City and Rochester districts are potential sources of ceramic fluxes. None has been tested.

Clays for structural products are widely distributed, but the sparse population supports only four structural-clay-products plants. Carbonaceous shales are mined at Arlington for refractory use; otherwise, little is known of the clay resources. The high-grade clay deposit near Lewistown was investigated by the Bureau of Mines during World War II.
Review by Counties

So little is known of the ceramic materials that only 10 of the 56 counties are listed in the following review by counties.

Beaverhead County

Talc

A belt of dolomitic marble of early pre-Cambrian age extends from the Madison River valley near Ennis, Mont., to Black Tail Deer Creek near Dillon. Talc is found in 2 areas in commercial quantity and quality within this 40-mile belt. The area east of Dillon includes portions of Beaverhead and Madison Counties (fig. 16). The area south of Ennis is wholly within Madison County.

The Cherry Creek series of metamorphic rocks includes schists, phyllites, gneisses, amphibolites, quartzites, and coarsely crystalline marble. Talc is found only in the latter rock. The talc is believed to have been formed by hydrothermal solutions acting upon magnesium-bearing rocks (17).

Talc has been mined in Beaverhead County for about 11 years, with most of the production coming from the Smith-Dillon mine.

Smith-Dillon mine. - The property is in Axes Canyon about 11 miles by road from Dillon in secs. 22 and 23, T. 8 S., R. 8 W., Principal Meridian (P. M.). Extensive development work has exposed a large body of talc that is being mined by the Tri-State Minerals Co., Ogden, Utah. Talc is mined by both open-pit and underground methods, trucked to Barratts, and washed. The washed product is shipped from Barratts to Ogden, Utah, for grinding. The property was producing four 50-ton cars a week in 1952. Reserves were estimated at 225 thousand tons.

Crescent or Timber Gulch deposit. - This deposit of talc is 3 miles south of the Smith-Dillon mine. Intermittent exposures of talc have been traced for over 1,000 feet, and talc 10 to 20 feet thick is exposed in pits. The presence of graphite flakes throughout the talc has resulted in this talc being classed as lower grade than that mined elsewhere in the area.

Many other occurrences of talc are known in the area but present showings do not indicate the high-quality talc mined at the Smith-Dillon mine and some of the properties in Madison County.

Sillimanite

The Dillon sillimanite area is in the central portion of Madison and Beaverhead Counties (fig. 16). The area includes parts of T. 7 S., R. 6 W.; T. 7 S., R. 7 W.; T. 8 S., R. 8 W.; and T. 9 S., R. 7 W., P. M. The deposits are scattered throughout an area 14 miles long and 4 miles wide. Some 40 occurrences are known in the area; 8 appear to be promising. The sillimanite is found in schists, gneisses, pegmatite dikes, and massive forms. Pegmatitic injections into the schists and gneisses appear to result in higher concentrations of sillimanite. Since no investigations of grade have been made, the reserves or individual occurrences cannot be evaluated. The distribution of sillimanite is highly irregular, but an average tenor of 5 percent is estimated. The general area is the same as that in which the Dillon talc is found (11).
Figure 16. - Map of Beaverhead and Madison Counties, Mont., showing talc, feldspar, and sillimanite deposits.
Summary

The extensive areas containing talc also contain sillimanite and pegmatites that probably contain concentrations of ceramic-grade feldspar. The talc is of excellent quality but sillimanite and feldspar deposits have not been investigated for quantity or quality.

There is no ceramic industry in Beaverhead County except talc mining.

Cascade County

Clay

A dark-gray, dense, carbonaceous, refractory shale of the Kootenai formation has been mined at Armington for many years for use in the Anaconda Copper Mining Co. refractory plant in Anaconda. Other exposures of the shale are known in the area, but quality tests have not been made.

Armington mine. - The mine is in SW1/4 sec. 31, T. 19 N., R. 7 E., P. M. Mining is intermittent, with production only sufficient to supply the needs of the refractory plant in Anaconda. Underground mining is employed.

Other deposits. - Other refractory clay is found in SW1/2 sec. 32, T. 20 N., R. 5 E., P. M., north of Great Falls. A p.c.e. of 31 was reported (2). Bentonitic shales of the Great Falls area have shown bloating characteristics in tests at the Montana School of Mines, Butte.

Ceramic industry

The Great Falls Brick Co., Great Falls, mines a buff-firing clay at Tracy, 13 miles south of Great Falls. The clay lies below a coal measure. It is mined with a tractor in an open pit and shipped to the plant by rail. Annual production is 1,000 brick and 500 tons of building tile and flue liners. The clay is formed by extrusion. Hot air drying is used and firing is in round, downdraft kilns using natural gas as fuel. The firing costs are about $1.50 and power costs $1.00 per thousand brick. The total power consumption in 1952 was 9,960 kw.-hr. The products are marketed in the Great Falls area. W. H. Gunnis owns the plant.

Fergus County

Clay

Whiteware deposit. - The deposit, 8 miles northwest of Lewistown in the SW1/2 sec. 12, T. 16 N., R. 17 E., P. M., is a deposit of excellent-grade kaolin. Drilling and trenching by the Bureau of Mines during World War II showed irregular, isolated bodies of creamy white, brittle kaolinite. The deposit contains an estimated 144 thousand tons of clay. Available Al2O3 of 38.73 percent and total alumina of 39.91 percent, with 0.43 percent Fe2O3 and 45.96 percent SiO2, were determined from a 4,800-pound sample. Ten channel samples all had a p.c.e. of 33 (1,745° C.) or over, a superduty refractory classification (20). Holes aggregating 1,241 feet were drilled, and 20 surface trenches were dug.

The deposit is leased to a group headed by Lester S. Harrison, Kellogg, Idaho, which plans development. This organization holds other clay deposits in the area near the old Kendal mine. Recent tests have shown that these clays are high in iron oxide and probably bentonitic.
Other deposits. - There are other deposits of white clay in the county, but none appears to be large enough for consideration.

Feldspar

A deposit of loessal sand, which contains about 20 percent altered feldspar, 10 percent kaolin, and 70 percent quartz, occurs in the county. The deposit has considerable areal extent and might be suitable for use as a ceramic flux and as a potential source of clay and silica. A p.c.e. test of the material resulted in a light-gray fusion at cone 13 (1,350° C.). The deposit is near Hilger.

Ceramic Industry

The Lewistown Brick & Tile Co. has operated in Lewistown for many years, mining a red-firing clay from a local pit. Production is by extrusion. A humidity drier is used, and firing is in round, downdraft kilns using coal as fuel. Production in 1952 amounted to 4,500 thousand face and common brick and 750 tons of hollow building tile. Fuel costs are about $5.00 per thousand brick, and consumption of electricity was 225,132 kw.-hr. in 1952. The plant is operated by Steve, Carl, and John Grettencourt.

Summary

Fergus County contains one of the best deposits of high-quality kaolin known in the Pacific Northwest. The limited size would necessitate use of the clay in the manufacture of small, high-value products unless the resources could be extended by development. Other clay deposits probably will be discovered by further prospecting, but the distance from population centers makes utilization economically hazardous.

Lewis and Clark County

Clay

No clay of unusual value is known in the county. Several occurrences have been tested but not enough to permit proper evaluation.

A shaft on the Boeing Clipper property near Austin, west of Helena, exposed white kaolin. No data are available on the quality of the clay. East of Helena in Broadwater County small pockets of white clay are reported in the Townsend area. So little is known of clay resources that no estimate of potentialities can be made.

Ceramic industry. - Western Clay Manufacturing Co., Helena, manufactures the most complete line of clay products made in Montana. The clay is mined at Bossburg 16 miles west of Helena and shipped to the plant by rail. Annual production is 3,750 tons of brick, which includes face, common, roman, and normen shapes. Also, 3,000 tons of building and drain tile and radial chimney block is made each year, of which the greatest tonnage is in building tile. The clay is ground in dry pans, screened, and extruded. The product is dried in steam, tunnel, and hotfloor driers and fired in round, downdraft kilns. Natural gas is used as fuel. Costs are about $3.00 per thousand for firing and are $0.57 per thousand for power. The total power consumption was 49,880 kw.-hr. in 1952. Products are marketed in western Montana.

The company also runs a small pottery and terra cotta operation at the plant. The pottery produces standard items - fancy flowerpots, ash trays, and architectural
and decorative tile. The annual consumption of pottery clay is 100 thousand pounds. A. C. Bray operates the brick plant and pottery.

Lincoln County

Feldspar

At the Universal Zonolite Insulation Co. in T. 31 N., R. 30 W., P. M., large masses of syenite are exposed in mining (16). The syenite contains a soda-potash feldspar with small quantities of ferromagnesian minerals. A sample taken by H. J. Kelly had a p.c.e. of 5 and the test cone was mottled gray. The syenite would have to be beneficiated for use in good-grade whiteware.

Madison County

Talc

Talc deposits similar to those in the limestones of Beaverhead County occur to the east in the Madison County limestones (fig. 16). Mining and development of these deposits, like those in Beaverhead County, have been conducted since World War II, and talc from the Montana deposits is forming an increasing portion of the Nation's output.

Yellowstone mine. - This property has been the county's largest producer, and during World War II a small quantity of block steatite talc was mined. Reserves of 200 thousand tons of steatite-grade talc suitable for grinding have been blocked out. Inferred reserves are large. The property is operated by the Sierra Talc & Clay Co., South Pasadena, Calif. (17).

Keystone mine. - The Keystone property is on Carter Creek 8 miles northeast of the Smith-Dillon deposit. The talc at the Keystone mine contains limonite, which gives the ground product a darker color than is desirable for the best grade. The property is not now being worked (17).

Stone Creek mine. - This property is being developed by the Tri-State Minerals Co., Ogden, Utah, as an open-pit operation. The ore is steatite grade, and inferred reserves are about 500 thousand tons to a depth of 100 feet. Greater vertical extent would greatly increase reserves.

White Talc mine. - This deposit is in secs. 3 and 4, T. 6 S., R. 3 W., P. M. Large tonnages of steatite-grade talc are reported (17).

Kyanite-Type Minerals

Sillimanite occurs in 10 pegmatite dikes 2 to 14 inches wide in an area 17 miles west of Norris in sec. 6, T. 4 S., R. 2 E., P. M. Sillimanite ranges from a trace to 67 percent of the rock, but iron impurities make the sillimanite of doubtful value. The pegmatites are composed of a quartz-plagioclase matrix with varying proportions of sillimanite, biotite, chlorite, and garnet (17). Kyanite-sillimanite pegmatites also occur 13 miles southwest of Ennis in T. 6 S., R. 1 W., P. M.

Proffitt Gulch. - This sillimanite occurrence is in T. 8 S., R. 7 and 8 W. Sillimanite is found in massive form and in biotite-garnet schists that grade into sillimanite schists. Accessory minerals are graphite, zircon, and magnetite. Where pegmatitic veinlets become more abundant, the schists grade into massive sillimanite (12). Where sillimanite weathers away from the rock mass, occurrences of massive pods of sillimanite are found.
Feldspar

Fifteen pegmatite occurrences are recorded in Madison County in the area between Sheridan and Varney (Fig. 16). Of these, the White Swan pegmatite appears to be the most likely source of ceramic-grade feldspar.

White Swan deposit. - These pegmatites are on the east side of the East Fork of Granite Creek in sec. 19, T. 5 S., R. 2 W., P. M. Fourteen pegmatites that strike N. 25° to 60° W. in a belt 1,000 feet long and 700 feet wide were exposed by 6 bulldozer cuts made by the Bureau of Mines in 1944. The pegmatites range in width from a few feet to 40 feet and in length from 5 feet to 200. A 10-foot-wide core of cream-colored microcline-perthite occurs in a cut and adit. The pegmatite is 25 feet thick, and the hanging-wall zone 5 to 10 feet thick. Other pegmatites in the deposit show segregations of quartz and feldspar. Accessory minerals are plagioclase, garnet, biotite, black tourmaline, and books of muscovite (11). The country rock is mica gneiss and mica-garnet-gneiss. Samples of feldspar from this deposit seen by H. J. Kelly appeared to be of ceramic quality, but the deposit was not accessible at the time of the investigation in March.

Rochester pegmatites. - A series of pegmatites occurs in the north central portion of sec. 6, T. 3 S., R. 8 W., P. M. northwest of the Sheridan-Varney area and southwest of Rochester. The deposits are accessible by secondary road from Twin Bridges. Areas underlain by the dikes are indicated by quartz chunks that have weathered from the mass. One surface sample of feldspar had a p.c.e. of 6+ and was gray-white.

Summary

Madison County has promising deposits of talc, kyanite-type minerals, and pegmatic feldspar. The quality of the minerals other than talc is unknown. The use of the feldspar and sillimanite in ceramics has not been evaluated. Distance from market and lack of demand has retarded investigation.

Powell County

Clay is associated with phosphate rock at the Anderson mine in sec. 10, T. 10 N., R. 10 W. P. M. The mine is 4 miles west of Garrison (2).

White clay resulting from the alteration of quartz monzonite occurs on the south slope of Miller Mountain.

Silver Bow County

Clay of refractory quality is reported from the Ogle mine 11 miles south of Butte.

Sheridan County

A large bed of white clay, p.c.e. 20, occurs in sec. 2, T. 35 N., R. 52 E., P. M., 1 mile southwest of Redstone, Mont. The bed is reported to be 8 feet thick (2).
Clay

No clay of unusual value is known in the county. Bentonitic shales found near Billings have good bloating characteristics, but little is known of their extent or other characteristics. Basalt flows and resulting bentonitic clays are widely distributed.

Ceramic industry. - The Lovell Clay Products Co. plant at Billings manufactures face and common brick and hollow building tile. The clay is mined near the plant, formed by extrusion, and dried by waste-heat in a tunnel drier. Firing, in round, downdraft kilns, is with natural gas. Fuel costs in 1952 were about $1.85 per thousand, and power consumption was 143,000 kw.-hr. Production in 1952 was 1,375 thousand face brick, 2,042 thousand common brick, and 1,873 tons of hollow building tile. R. E. Steward is the plant manager.
## APPENDIX

### TABLE 6. - Summary, ceramic plants - Oregon and Idaho

<table>
<thead>
<tr>
<th>Plant name or location</th>
<th>County</th>
<th>Bricks tile, thousand feet</th>
<th>Other hollow ware, tons</th>
<th>Structural brick, tons</th>
<th>Refractories, tons</th>
<th>Kiln type</th>
<th>Fuel used</th>
<th>Fuel and power cost of consumption</th>
<th>Raw material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>per year</td>
<td>Source</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corvallis Brick &amp; Tile Co.</td>
<td>Benton</td>
<td>200</td>
<td>50</td>
<td>465</td>
<td>Periodic</td>
<td>Wood</td>
<td>$15 cords/kiln</td>
<td>14,000</td>
<td>Local, $5.50</td>
</tr>
<tr>
<td>House Brick &amp; Tile Co.</td>
<td>do.</td>
<td>1/2,700</td>
<td></td>
<td>12,000</td>
<td>Periodic</td>
<td>Wood</td>
<td>$4.50/1000 brick</td>
<td>273,000</td>
<td>do, 3.50-50</td>
</tr>
<tr>
<td>Mollala Brick &amp; Tile Co.</td>
<td>Clackamas</td>
<td>150</td>
<td>80</td>
<td>68</td>
<td>Round</td>
<td>Wood</td>
<td>(8 months)</td>
<td>8,000</td>
<td>do, 1.67</td>
</tr>
<tr>
<td>Neady Brick &amp; Tile Co.</td>
<td>do.</td>
<td>1/3,000</td>
<td>210</td>
<td></td>
<td>Periodic</td>
<td>Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Klamath Falls Brick &amp; Tile Co.</td>
<td>Klamath</td>
<td>180</td>
<td>430</td>
<td>5,560</td>
<td>do.</td>
<td>do.</td>
<td>$10.00/1000 brick</td>
<td>160,000</td>
<td>Calif, 10.00</td>
</tr>
<tr>
<td>Albany Brick &amp; Tile Co.</td>
<td>Lyon</td>
<td>70</td>
<td>250</td>
<td>2,200</td>
<td>Periodic</td>
<td>Wood</td>
<td>20 cords/kiln</td>
<td>61,000</td>
<td>Local, 7.50</td>
</tr>
<tr>
<td>Oregon Clay Products Co.</td>
<td>Malheur</td>
<td>-</td>
<td>-</td>
<td>4,125</td>
<td>Scove</td>
<td>Coal</td>
<td>$4.55/1000 brick</td>
<td>34,000</td>
<td>do, 1.17</td>
</tr>
<tr>
<td>Donalo Brick &amp; Tile Co.</td>
<td>Marion</td>
<td>1,500</td>
<td>430</td>
<td>125</td>
<td>Round</td>
<td>Wood</td>
<td>1 cord/kiln</td>
<td>do.</td>
<td></td>
</tr>
<tr>
<td>Hubbard Clay Works</td>
<td>do.</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Periodic</td>
<td>Oil</td>
<td>40-50 kilns</td>
<td>276,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>Columbia Brick Works</td>
<td>Multnomah</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Scove</td>
<td>Coal</td>
<td>$10.00/1000 brick</td>
<td>220,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>Pacific Stone Ware/</td>
<td>do.</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Periodic</td>
<td>Oil</td>
<td>$1.85/1000 pots</td>
<td>71,000</td>
<td>do, 1.50</td>
</tr>
<tr>
<td>Sylvan Brick Co.</td>
<td>do.</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Scove</td>
<td>Coal</td>
<td>$6.00/1000 brick</td>
<td>36,000</td>
<td>do, 1.44</td>
</tr>
<tr>
<td>Homestead Brick &amp; Tile Co.</td>
<td>Polk</td>
<td>350</td>
<td>200</td>
<td>200</td>
<td>Round</td>
<td>Wood</td>
<td>40-50 bbls.</td>
<td>15 cords/kiln</td>
<td>2,000</td>
</tr>
<tr>
<td>Tillamook Clay Works</td>
<td>do.</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Periodic</td>
<td>Oil</td>
<td>$9.00/1000 brick</td>
<td>24,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>La Grande Brick Co.</td>
<td>Union</td>
<td>-</td>
<td>-</td>
<td>1,575</td>
<td>Scove</td>
<td>Coal</td>
<td>$7.00/1000 brick</td>
<td>24,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>O. E. Brickyard</td>
<td>Washington</td>
<td>-</td>
<td>-</td>
<td>550</td>
<td>Scove</td>
<td>Propene</td>
<td>$7.00/1000 brick</td>
<td>5,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>Scholls Tile Co.</td>
<td>do.</td>
<td>250</td>
<td>1/4,200</td>
<td>2,600</td>
<td>Round</td>
<td>Wood</td>
<td>$7.00/1000 brick</td>
<td>129,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>McDaniel Brick &amp; Tile Co.</td>
<td>Yamhill</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Periodic</td>
<td>Oil</td>
<td>$1.82/1000 pots</td>
<td>71,000</td>
<td>do, 1.50</td>
</tr>
<tr>
<td>Williamsburg Clay Products Co.</td>
<td>do.</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Scove</td>
<td>Coal</td>
<td>$6.00/1000 brick</td>
<td>36,000</td>
<td>do, 1.44</td>
</tr>
<tr>
<td>Idaho</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Periodic</td>
<td>Oil</td>
<td>$9.00/1000 brick</td>
<td>24,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>Boise Brick Co.</td>
<td>Ada</td>
<td>-</td>
<td>-</td>
<td>1,125</td>
<td>Scove</td>
<td>Coal</td>
<td>$9.00/1000 brick</td>
<td>24,000</td>
<td>do, 0.33</td>
</tr>
<tr>
<td>Idaho Falls Brick &amp; Tile Co.</td>
<td>Bonneville</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Scove</td>
<td>Coal</td>
<td>$5.50/1000 brick</td>
<td>22,000</td>
<td>do, 0.27</td>
</tr>
<tr>
<td>Burley Brick &amp; Tile Co.</td>
<td>Cassia</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Scove</td>
<td>Coal</td>
<td>$7.00/1000 brick</td>
<td>570,000</td>
<td>do, 0.67</td>
</tr>
<tr>
<td>Troy Fire Brick Co.</td>
<td>Latah</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
<td>Periodic</td>
<td>Oil</td>
<td>$6.00/1000 brick</td>
<td>61,000</td>
<td>do, 0.53</td>
</tr>
<tr>
<td>Fayette Brick Co.</td>
<td>do.</td>
<td>-</td>
<td>-</td>
<td>1,375</td>
<td>Scove</td>
<td>Coal</td>
<td>$9.00/1000 brick</td>
<td>22,000</td>
<td>do, 0.33</td>
</tr>
</tbody>
</table>

1/ Includes drain tile.
2/ Principal product, 6 million flowerpots.
3/ Per 1,000 pots.
4/ 200 cu. ft. equals 1 unit of sawdust or hog fuel.
<table>
<thead>
<tr>
<th>Plant name or location</th>
<th>County</th>
<th>Annual production</th>
<th>Fuel and power cost of consumption</th>
<th>Raw material</th>
<th>Cost per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Montana</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Falls Brick Co. ...</td>
<td>Cascade</td>
<td>500 2,750</td>
<td>Periodic Gas $1.50/M brick 10,000</td>
<td>13-mile RR</td>
<td>$.22/.32</td>
</tr>
<tr>
<td>Anaconda Copper Mining Co.</td>
<td>Deer Lodge</td>
<td>- 1,065</td>
<td>do. 3.99/ton 207,000</td>
<td>Anaconda</td>
<td>.30</td>
</tr>
<tr>
<td>Lewistown Brick &amp; Tile Co.</td>
<td>Fergus</td>
<td>750 12,200</td>
<td>Round down draft Gas $5.00/M brick 325,000</td>
<td>Local</td>
<td>.67/.80</td>
</tr>
<tr>
<td>Western Clay Mfg. Co.</td>
<td>Lewis &amp; Clark</td>
<td>3,000 3,750</td>
<td>Periodic Gas $3.00/M brick 50,000</td>
<td>16-mile RR</td>
<td>1.00</td>
</tr>
<tr>
<td>Lowell Clay Products Co.</td>
<td>Yellowstone</td>
<td>3,873 9,400</td>
<td>Rectangular down draft do. $731/ton 145,000</td>
<td>Local</td>
<td>.45</td>
</tr>
<tr>
<td><strong>Washington</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wenatchee Brick &amp; Tile Co.</td>
<td>Chelan</td>
<td>- 1,325</td>
<td>Scove Oil 50-60 gal./K brick 6,000</td>
<td>Local</td>
<td>.33-.67</td>
</tr>
<tr>
<td>Muffett Brick &amp; Tile Co.</td>
<td>Clark</td>
<td>1,500</td>
<td>Periodic Wood Oil 30,000</td>
<td>Local</td>
<td>.33-.50</td>
</tr>
<tr>
<td>Abrahamsen Brick Co.</td>
<td>King</td>
<td>14,300</td>
<td>Hoffmein Oil 6 units/day 54,000</td>
<td>Local</td>
<td>.50</td>
</tr>
<tr>
<td>Builders Brick Co.</td>
<td>do.</td>
<td>2/32,000</td>
<td>Hoffmein Oil 20,000 bbls./yr. 750,000</td>
<td>Clay City</td>
<td>2.00</td>
</tr>
<tr>
<td>Gladding, McBean &amp; Co.</td>
<td>Benton</td>
<td>8,000 12,000 36,000</td>
<td>Tunnel Periodic Oil 36,000 bbls./yr. 2,640,000</td>
<td>Local</td>
<td>2.00</td>
</tr>
<tr>
<td>Seattle Brick &amp; Tile Co.</td>
<td>do.</td>
<td>2/32,500</td>
<td>Hoffmein Coal 130 tons/month 350,000</td>
<td>Canada &amp; Slop</td>
<td>.45</td>
</tr>
<tr>
<td>Chehalis Brick &amp; Tile Co.</td>
<td>Lewis</td>
<td>4,700 9,625</td>
<td>Hoffmein Oil 40 tons/month 350,000</td>
<td>Local</td>
<td>.45</td>
</tr>
<tr>
<td>Builders Brick Co.</td>
<td>Pierce</td>
<td>- 341,250</td>
<td>Hoffmein Oil 275 bbls./M brick 300,000</td>
<td>do.</td>
<td>.63</td>
</tr>
<tr>
<td>Lowell Brick &amp; Tile Co.</td>
<td>Snohomish</td>
<td>- 9/13,200 6,000</td>
<td>Tunnel Periodic Oil 100 bbls./M brick 1,250,000</td>
<td>do.</td>
<td>2.50</td>
</tr>
<tr>
<td>Gladding, McBean &amp; Co.</td>
<td>Spokane</td>
<td>6,000 6,000 6,000</td>
<td>Periodic Coal 600 bbls./month 312,000</td>
<td>do.</td>
<td>.53</td>
</tr>
<tr>
<td>Washington Brick &amp; Lame Co.</td>
<td>Dishman</td>
<td>- 2/9,000 76,000</td>
<td>Tunnel Periodic Oil 2,900 tons/month 744,000</td>
<td>do.</td>
<td>.70</td>
</tr>
<tr>
<td>Clayton Brick &amp; Lime Co.</td>
<td>Stevens</td>
<td>- 16,500</td>
<td>Scove Oil 120,000 tons/month</td>
<td>Local</td>
<td>.30-.80</td>
</tr>
<tr>
<td>Hidden Brick Co.</td>
<td>Vancouver</td>
<td>- 962</td>
<td>Wood 2,000</td>
<td>Variance</td>
<td>-</td>
</tr>
<tr>
<td>Oregon Clay Products Co.</td>
<td>Vancouver</td>
<td>- 3/27,500</td>
<td>Periodic Coal 2,500 tons/year</td>
<td>Local</td>
<td>-</td>
</tr>
</tbody>
</table>

1/ Also 750 tons of other ware.
2/ 200 cu. ft. equals 1 unit of sawdust or hog fuel.
3/ Includes brick and other hollowware.
4/ Includes hollowware.
5/ Includes drain tile.
GLOSSARY

Alumite. - A hydrous sulfate of aluminum and potassium. Closely resembles kaolinite and occurs in similar locations.

Andesite. - A volcanic rock, generally porphyritic, composed essentially of plagioclase, with one or more mafic minerals, biotite, hornblende, and pyroxenes.

Available analysis. - An assay of the acid-soluble iron and alumina in a clay after calcining to 800° C. and digesting one-half hour in 20 percent H₂SO₄.

Bauxite. - An aluminous lateritic rock in which aluminum hydrates predominate over other lateritic constituents.

Bentonite. - A clay derived from volcanic ash containing minerals of the montmorillonite group. Some, but not all, varieties swell greatly upon wetting.

Boehmite. - A hydrated aluminum oxide mineral, assumed to be Al₂O₃·H₂O.

Brick, common. - A type of building brick intended for use as backup or interior masonry.

Brick, face. - The best type of building brick, used for the exterior of buildings and other structures where the brick must have a pleasing color, good strength, resistance to weathering, and uniformity of size and shape.

Brick, roman. - Brick 1-1/2 by 4 by 12 inches in dimensions.

Down draft kiln. - A kiln in which the hot gases pass from the fireboxes on the periphery up the side walls of the kiln and down the center through the ware and thence out of the kiln through flues beneath the kiln floor.

Dry pressing. - Method of forming ceramic ware by pressing comparatively dry materials in a steel die box under high pressure.

Equivalents. - The term, as used in this publication, means the theoretical number of 2- by 4- by 8-inch building brick that would be obtained from the same weight as that of the structural-clay products actually produced.

Expanded-clay aggregate. - A lightweight product made by rapidly heating clay or shale to cause bloating. The bloated product is sized and sold as a low-density aggregate.

Extrusion. - A method of forming clay products by forcing a plastic clay mass through a die. Water content of the extruded mass is much higher than for dry pressing.

Feldspar. - A general name for a group of abundant rock-forming minerals. They are aluminum silicates with sodium, potassium, calcium and/or barium content determining the exact mineral species. Feldspars are used widely in the ceramic industry as a flux.

Frit. - The product of the fusion of certain components of a glaze. This fused material is finely ground and added to other ingredients to form the complete glaze composition.
Gibbsite. - A natural-occurring hydroxide of aluminum, Al₂O₃·3H₂O (contains 65.4 percent alumina).

High-duty fireclay brick. - A term relating to refractoriness of fireclay brick and defined by ASTM, as one having a p.c.e. not lower than cone 31 or that will not deform more than 1.5 percent at 2,460° F. in the standard load test.

Hoffman kiln. - A semicontinuous kiln built with many separate chambers and usually fired from the top. The chambers are heated progressively with waste heat from those already fired.

Hollowware. - Ware that is not solid, such as drain, building, and sewer tile, conduit, etc.

Intermediate-duty fire-clay brick. - A term relating to the refractoriness of fire-clay brick and defined by ASTM, as one having a p.c.e. not lower than cone 29 or that will not deform more than 3 percent at 2,460° F. in the standard load test.

Kaolinite. - A clay mineral having the theoretical composition of Al₂O₃·2SiO₂·2H₂O. This composition corresponds to 39.5 percent alumina, 46.5 percent silica, and 14.0 percent water. This mineral is the principal constituent of most fire clays.

Laterite. - A geological term applied to partly consolidated materials, such as siliceous and ferruginous bauxites, siliceous and aluminous iron deposits, and manganese deposits formed by surface weathering and leaching, primarily of basic igneous rocks. They are characteristic especially of tropical-type weathering.

Low-duty fireclay brick. - A term relating to refractoriness of fire-clay brick and defined by ASTM, as one that has a p.c.e. not lower than cone 19.

Montmorillonite. - A clay mineral with the theoretical composition, Al₂O₃·4SiO₂·2H₂O, with Fe₂O₃ and MgO replacing part of the alumina.

Pegmatite. - Dike or vein acid igneous rock, generally coarse-grained but usually irregular in texture and composition, composed mainly of silicate minerals of large size, including quartz, feldspar, muscovite, biotite, tourmaline, beryl, zircon, etc.

Periodic kiln. - A batch kiln in which ware is loaded, heated, cooled, and unloaded before the next batch is introduced.

Pyrometric cone equivalent (p.c.e.). - A measure of the refractoriness of a material made by comparing the softening of the unknown with cones of known thermal behavior.

Refractory. - Materials suitable for use at high temperature. According to ASTM definition they must not fuse at temperatures below 2,759° F.

Rhyolite. - An extrusive volcanic rock composed of quartz and alkalic feldspar and accessory minerals in a fine-grained to glassy groundmass of chemical composition similar to granite.
Scove kiln. - A simple, temporary, updraft periodic kiln constructed of the ware to be fired. It is used only for firing common brick, which is placed in such a manner that the combustion gases will percolate upward through the brick.

Semicontinuous kiln. - In a multichambered kiln settings are made in one chamber while others are being fired. The hot gases from the fired chamber are used to heat those to be fired. The firing process is semicontinuous.

Superduty fire-clay brick. - A fire-clay brick having a p.c.e. not lower than cone 33 on the fired product, not more than 1 percent linear shrinkage in the reheat test, schedule C (2,910° F., 1,600° C.), and not more than 4 percent loss in the panel spalling test (preheated at 3,000° F., 1,650° C.).

Water-smoking period. - The first period of firing clay products, during which the hygroscopic water and the water of composition are removed.

BIBLIOGRAPHY

2. BUREAU OF MINES. Files, Mining Division, Region I, Spokane, Wash.
10. GEOLOGICAL SURVEY. Open files, Spokane, Wash., office.


