A SILLIMANITE DEPOSIT NEAR TROY, LATAH COUNTY, IDAHO

By

J. DONALD FORRESTER

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INTRODUCTION

An extensive occurrence of sillimanite-bearing rock was reported to occur a
few miles southeast of Troy, Latah County, Idaho, and the study of this
potentially valuable mineral resource was deemed advisable by the Idaho Bureau
of Mines and Geology. Upon invitation of the owners, a preliminary examination
was, therefore, undertaken in reconnaissance by the writer in the latter part of
August, 1941.

The primary effort was to determine, if possible, the mode of occurrence, distribution, and general geologic setting of the sillimanite-rich rocks. The
field data upon which this report is based were accumulated at that time.

Sillimanite, which has the composition Al2SiO5, is similar chemically to
kyanite and andalusite, other minerals of the so-called sillimanite group, and
all three, together with dumortierite (Al8 BSiO3 O19-OH) are useful in the
refractories industry. They have the property of forming a product known as
mullite (3Al2O3. 2SiO2) and a siliceous glass when they are heated to
approximately 1300 degrees Centigrade. This converted substance, mullite, is a
very desirable refractory ingredient inasmuch as it tends to increase the fired
strength, the resistance to deformation, the thermal resistivity and the
dielectric properties at high temperatures of the refractory product. In
addition, the coefficient of expansion and the tendency to "spall" of the
fabricated material seems to be considerably lessened.

Because of these desirable attributes, the sillimanite group of minerals
are used in the manufacture of high-grade porcelain wares and, particularly, are
sought for spark plug manufacture, high-temperature cements, and such similar
uses and product as demand exceedingly high heat resistivity, low coefficients
of expansion, good insulating capacities, etc.

There has been no commercial production of sillimanite from this occurrence
under consideration; in fact, sillimanite as such, apparently has not heretofore
been used extensively for refractory purposes in the United States. The major
commercial demand and production has been chiefly for kyanite, dumortierite, and
andalusite (as previously noted). Indeed, no sillimanite shipments or imports
are reported from the United States in 1940, whereas the use of kyanite for
refractories during this same year increased 1291 short tons in quantity and
$25,000 in value over what it had been in 1939. The domestic production of
andalusite and dumortierite has ranged from 400 to 2000 tons per year and
essentially all of these materials have been used in spark plug manufacture.
The leading producing states of kyanite, andalusite, and dumortierite are
California and Virginia, with some minor amounts also obtained from Nevada,
Georgia, and North Carolina. Considerable imports of kyanite have been realized
from British India.

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INDEX MAP
SILLIMANITE DEPOSIT
NEAR
TROY, LATAH COUNTY, IDAHO
As a measure of what prices may be gained for such materials, the following figures are given: The average price of all domestic kyanite sales reported to the United States Bureau of mines for 1940 was $22.10 a short ton, f.o.b. mines. The degree of fineness (down to a certain minimum dimension) to which flotation concentrates are ground and also the calcining of the product adds a premium to the price. Extra-low iron grades also are premium or special products and some shipment of this class from North Carolina have been offered for sale at $78.00 per ton f.o.b. Freight rates from producing areas to northern and midwestern consuming centers average from $5.00 to $6.00 a ton on carload lots.

In addition to the suitability of sillimanite for the manufacture of spark plugs and other high-refractory purposes, the use of the mineral, which has an Al₂O₃ content of 63.2%, as a source of metallic aluminum is possible, and certainly is worthy of pertinent mention. This is particularly apt when the aluminum industry is experiencing a vital activity as at the present time.

It appears, therefore, that the development of this mineral resource, if commercially feasible, will contribute to the industrial expansion of Idaho and the Pacific Northwest.

The area over which this study was made is controlled by the Troy Sillimanite Company, Troy, Idaho, and is denoted as area "A" on Map 1 accompanying this report. Mr. Robert Olson and Mr. Herman Krier, both of Troy, are Manager and Secretary-Treasurer, respectively, of the above company. Mr. Arthur Anderson, a rancher of the vicinity to the east of "A" also proposed that there was an appreciable deposit of sillimanite on his land. A few samples were gathered from this area "B" (Map 1) as a check and guide for possible future work.

The writer was ably assisted during the field examination by Dr. John A. Wilson, Assistant Geologist, Idaho Bureau of Mines and Geology. Appreciation is also herewith expressed to Mr. Joseph Newton, Metallurgist, of the Idaho Bureau of Mines and Geology, for the flotation tests and concentration data which are embodied in this report.

**Location and Accessibility**

**PHYSICAL FEATURES**

Area "A" encompasses approximately one-half square mile over a portion of Section 7, T. 39N, R.2W, Boise Principal Meridian. Test pits and trenches dug subsequent to this study have reputedly revealed the extent of the sillimanite occurrence for several hundred feet easterly, in fact, beyond the limits of area "B", previously mentioned.

The general region is served by improved and semi-improved county and state roads and is, therefore, reasonably accessible. Travel to the site of the actual occurrence controlled by the Troy Sillimanite Company, however, can be gained at this time, only by use of trails or abandoned roads for a distance of roughly one mile. New road construction or repairs of the old road could be made without great difficulty and at a very nominal cost.
Topography, Drainage, and Vegetation

The master stream of the region is Big Bear Creek, which is a tributary of the major Clearwater River System. Big Bear Creek is now only of an intermittent character although it is reported to have flowed the year around prior to the establishment of extensive logging and farming operations throughout the region as a whole. Since the flow of this creek is from east to west along the southern limits of the area under consideration, the smaller drainage channels which are aligned transversely across the region and which are tributary to Big Bear Creek, trend generally from north to south (Maps 1 and 2). They are, for the most part, simply dry channels or gulches and carry runoff only during rainy seasons or at times of snow melt, etc. Thus, it may be seen that this particular sillimanite-bearing area is largely localized to the north side slope of Big Bear Creek Canyon but that this slope is, in turn, incised and dissected by relatively shallow, steep gulches. The land relief is quite abrupt and is in the youthful stage of erosion.

The net result is, therefore, a generally southward sloping surface of the inter-gulch divide areas, as well as in and along the gulches themselves. It follows, of course, that where the small north-south tributaries are most numerous and pronounced, the general land surface is lower and more dissected.

The area has been uniformly timbered in the past, and today, where fire or logging, etc., have not removed trees, the forest cover is still pervasive.

Western white pine, tamarack, and fir are the chief tree species, although dense "second-growth" underbrush is sporadically present and in some local areas is the dominant vegetation. There are ample timber resources for mining requirements, but the development of a sufficient and sustained water supply would entail considerable cost and difficulty.

GEOLOGY

Two distinct rock types constitute the majority of the materials in the region. They are, respectively, the relatively flat-lying flows of Columbia River Basalt (Miocene) and the contorted, gneissic and schistose Belt Series (Algonkian) metamorphics. Map 2 shows the general distribution and field relation of the two rock classes.

Belt Series

The Belt Series rocks, whose exact age is undetermined, but which probably are Prichard or the stratigraphic equivalent, have suffered dynamic metamorphism and also give pronounced evidence of having undergone "soaking" and injection effects as the result of the intrusion of batholithic magmas. They lie within the border zone of rocks which bound the great granitic and dioritic massif of the Idaho Batholith, as it is situated to the east. Their mineralogic character ranges from black, biotite schists to heavily-banded quartzose gneisses. Quartz, biotite, and potash feldspars are the chief component minerals. Pegmatite pods and tabular dikes are common as later structural features, and are oriented in occurrence more or less parallel, "lit par lit," to the schistosity of the metamorphics. Rather localized zones of granular textured rocks also are present and appear to be typical contact variants of the rocks that have developed
because of the proximity of the formerly molten intrusive batholithic magma. As a result of the injection of magmatic juices, together with the "border zone" contact metamorphism, certain tracts within the Belt Series rocks have been enriched in their aluminum silicate content and, as a consequence, sillimanite localizations have been developed. The sillimanite characteristically is white or blue-white and occurs as rather long, bladed, acicular masses oriented generally parallel to the grain of the metamorphic schists and gneisses. Because of the zone-like character of the sillimanite-rich tract (Map 2), it would seem that this mineral may, in large part, have resulted from the contact metamorphism of an original rock belt relatively high in alumina content, but field relations also give evidence of a close association with pegmatite occurrences which would indicate a possible alumina silicate enrichment by the soaking of magmatic juices. The pegmatites are composed dominantly of heavy, massive quartz; some occurrences, however, approach the structure and composition of graphic granite. Regardless of the exact mode of origin, the major concentrations of sillimanite undoubtedly occur in somewhat localized zones within the Belt Series sequence, although a uniform distribution does not exist. Some sillimanite is present in sporadic amounts and lens-like bodies outside the "high-grade" tract but is in such small quantities and is so distributed as to be essentially inconsequential.

Although the structural relations are quite obscure because of a lack of continuity of outcrops and, therefore, direct surface interpretations are difficult, the author is of the opinion that a series of transverse (N-S) faults have offset the Belt rocks, the pegmatites, the sillimanite tract, and, in fact, all pre-existing structures, to the right. This condition has tended to disrupt the continuity of the "high-grade" zone. (Map 2)

Following the batholithic intrusion and the attendant formation of the schistose border zone in the Belt Series, erosion was active and developed what was probably a mature surface over which the Columbia River basalts were later extruded. The basalts were evidently hot enough to induce a contact metamorphic effect upon the immediately underlying contiguous rocks. The result was primarily an increase in iron content of the Belt Series materials and a slight coarsening of texture. That this metamorphic effect was relatively very shallow is demonstrated by the fact that it is now observable only in rocks which have not been reduced markedly by post Miocene erosion. The rocks on the higher inter-gulch divide areas and those in close proximity to the present basalt occurrence show this condition, but those materials in the gulches themselves, where erosion has been most pronounced, are quite unchanged. Weathering has tended to alter the iron-enriched rocks more rapidly, and thus a softened and limonite-stained character has usually resulted in those outcrops of the Belt Series on the divide localities. The basalt metamorphism does not appear to have appreciably changed the original sillimanite content which the rocks had.

**Columbia River Basalt**

As before noted, the basaltic flows are practically horizontal in attitude and at the time of their extrusion were considerably more extensive than at present, since erosion is active and is attending their removal. The distribution and relation of the basalt is shown on Map 2. They are typically the densely grained basic extrusives of the Columbia River class and are often marked by a scoriaceous character. A localized opal occurrence, somewhat shattered and broken, was noted in the basalt near the central portion of Area.
MINES AND PROSPECTS

One accessible tunnel exists near the western border of the area studied. It is reported to have been driven primarily as a copper development project in the early days. A few veinlets of malachite occur in the schist as exposed by this underground development and minor concentrations of chalcopyrite may be observed. As a copper prospect it is not of economic importance, but the work has served to reveal a sub-surface, albeit shallow occurrence of a portion of the sillimanite zone (Map 3).

Numerous shallow trenches and pits have been dug throughout the area on the Belt Series rocks and in many cases are clean enough to permit sampling of the rock exposures. Their locations have been shown on Map 2.

SAMPLES AND TESTS

Because the abundance and relative quantity of sillimanite cannot be reasonably determined and comparatively "weighed" by visual inspection in the field, it was decided that a number of samples should be taken and that they be analyzed for their sillimanite content by a suitable laboratory technique. Inasmuch as chemical analyses would not measure the sillimanite mineral directly but would instead reveal only the quantities of aluminum and silica present in the whole sample, a selective separation of the mineral was undertaken by a flotation process.

In addition to thus serving as a means of ascertaining relative quantities of sillimanite present in a given sample, the process also indicates that the material is amenable to this manner of concentration.

The Flotation Process

A batch flotation test, using potassium palmitate and oleic acid as collectors was made on each of the samples. The same reagents were used in all cases, except that in some tests, additional amounts of oleic acid and pine oil were added until it appeared that all the flotable mineral had been removed. The concentrates and tailings were weighed, and the amount of sillimanite in each concentrate was ascertained by microscopic examination. From these figures, the estimated amount of sillimanite in the head sample was determined.

All the tailing samples were examined microscopically, and this showed that only small amounts of sillimanite remained in the tailings, except in the case of Sample Nos. 18, 20, 28, 29, 31, and 33. Where there was considerable sillimanite in the tailings, the amount was determined by microscopic examination and the total content of the heads calculated from the estimates on both tailings and concentrates. In all other cases it was assumed that 90 per cent of the sillimanite was recovered in the concentrate.

With the exception of Samples 18, 20, 28, 29, 30, 31, and 33, the sillimanite was readily floated, and the sillimanite would probably float in all the samples if the proper reagents were used. Since, however, it was possible to make
ACCESSIBLE TUNNEL
A SILLIMANITE DEPOSIT (AREA 'A')
NEAR TROY, LATAH COUNTY, IDAHO

SCALE IN FEET

Symbols are same as used on Map 2.
only one test on each sample, it was necessary to adopt a certain set of reagents and use them in all cases. These gave poor results for only a limited number of samples, and in these cases the sillimanite content of both tailings and concentrate was estimated by microscopic examination.

Sillimanite is easily recognized under the microscope because of its perfect cleavage and its occurrence in the form of prismatic and acicular crystals—it can be distinguished readily from mica, quartz, feldspars, and other minerals found in these samples.

The method of determining the amount of sillimanite in samples by microscopic examination of flotation products is satisfactory enough for a rough examination of the amount present, and it was employed because it was the best technique available for reasonably reliable and rapid determination. The method could be made more accurate, but this would require several tests on each sample to discover the best reagent combination. Also, the concentrates would have to be cleaned and re-cleaned until they contained practically nothing but sillimanite.

In most of the samples there was a considerable amount of mica in the concentrates, although, as a rule, the sillimanite appeared to float more readily than the mica.

As a result of the flotation analyses, the following chart of the sillimanite content of the various samples collected has been prepared. When applied to the locations from which the respective materials were gathered and when correlated with other field data, they indicate the presence of the zone-like character of the main sillimanite concentration. It will be noted that a uniform distribution does not exist throughout the Belt Series rocks and the proportional abundance is not pervasive.

The nature of the occurrence on Arthur Anderson's land (Area "B", Map 1) is geologically similar to that of the less concentrated sillimanite-bearing rocks in Area "A", that is, similar to those materials which are outside the limits of the "high-grade" zone.

See Maps 2 and 3 for sample localities.
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location of Sample</th>
<th>Sample Width, In feet</th>
<th>Composition of Concentrate</th>
<th>Estimated % Sillimanite in Concentrates</th>
<th>% of Sillimanite in Sample, Assuming 90% Recovery</th>
<th>Remarks and Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Area A Map 2</td>
<td>60</td>
<td>Chiefly sillimanite some mica</td>
<td>80.0</td>
<td>8.6</td>
<td>From outcrop in stream channel</td>
</tr>
<tr>
<td>2</td>
<td>Area A Map 2</td>
<td>30</td>
<td>Mica</td>
<td>2.0</td>
<td>Trace</td>
<td>Outcrop (at surface)</td>
</tr>
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<td>Area A Map 2</td>
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<td>Mica and some slime</td>
<td>10.0</td>
<td>0.7</td>
<td>Outcrop</td>
</tr>
<tr>
<td>4</td>
<td>Area A Map 2</td>
<td>60</td>
<td>Predominantly Sillimanite</td>
<td>95.0</td>
<td>15.1</td>
<td>Chip sample from pits</td>
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<td>5</td>
<td>Area A Map 2</td>
<td>55</td>
<td>Chiefly sillimanite</td>
<td>90.0</td>
<td>10.9</td>
<td>Chip sample from pits</td>
</tr>
<tr>
<td>6</td>
<td>Area A Map 2</td>
<td>10</td>
<td>Mica</td>
<td>10.0</td>
<td>0.1</td>
<td>Chip sample from pit and outcrop</td>
</tr>
<tr>
<td>7</td>
<td>Area A Map 2</td>
<td>3</td>
<td>Predominantly Sillimanite</td>
<td>95.0</td>
<td>3.7</td>
<td>Grab sample from pit outcrop not well exposed</td>
</tr>
<tr>
<td>8</td>
<td>Area A Map 2</td>
<td>15 overall</td>
<td>Mica</td>
<td>0.0</td>
<td>0.0</td>
<td>Outcrop (at surface)</td>
</tr>
<tr>
<td>9</td>
<td>Area A Map 2</td>
<td>30 overall</td>
<td>Mica</td>
<td>0.0</td>
<td>0.0</td>
<td>Outcrop (at surface)</td>
</tr>
<tr>
<td>10</td>
<td>Area A Map 2</td>
<td>15</td>
<td>Mica</td>
<td>0.0</td>
<td>0.0</td>
<td>Outcrop (at surface)</td>
</tr>
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<td>Mica</td>
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<td>0.0</td>
<td>Outcrop (at surface)</td>
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<td>Mica</td>
<td>0.0</td>
<td>0.0</td>
<td>Outcrop (at surface)</td>
</tr>
<tr>
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<td>Area A Map 2</td>
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<td>Mica</td>
<td>0.5</td>
<td>0.7</td>
<td>Grab sample from pit dump</td>
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<td>Chiefly sillimanite</td>
<td>90.0</td>
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<td>Mica</td>
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<td>0.0</td>
<td>Along creek course</td>
</tr>
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<td>Chiefly sillimanite</td>
<td>90.0</td>
<td>4.9</td>
<td>In stream channel</td>
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<tr>
<td>Sample No.</td>
<td>Location of Sample</td>
<td>Sample Width, In feet</td>
<td>Composition of concentrate</td>
<td>Estimated % Sillimanite in Concentrate</td>
<td>% of Sillimanite in Sample, Assuming 90% Recovery</td>
<td>Remarks and Descriptions</td>
</tr>
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<tr>
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<td>Area A Map 2</td>
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<td>90.0</td>
<td>12.2</td>
<td>Chip sample from pits</td>
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<td>Mica and sillimanite</td>
<td>25.0</td>
<td>10.7</td>
<td>Chip sample from pits and outcrops</td>
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<td>Chiefly mica</td>
<td>10.0</td>
<td>0.3</td>
<td>Outcrop (at surface)</td>
</tr>
<tr>
<td>20</td>
<td>Area A Map 2</td>
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<td>Mica and sillimanite</td>
<td>30.0</td>
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<td>Outcrop in stream channel</td>
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<td>Chiefly mica Some sillimanite</td>
<td>15.0</td>
<td>0.7</td>
<td>Outcrop in stream channel</td>
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<td>Area A Map 2</td>
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<td>Predominantly mica</td>
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<td>In stream channel</td>
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<td>Mica and sillimanite</td>
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<td>In stream channel</td>
</tr>
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<td>Area A Map 2</td>
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<td>Mica and sillimanite</td>
<td>20.0</td>
<td>1.3</td>
<td>In stream channel</td>
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<td>Area A Map 3</td>
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<td>Slime and some mica</td>
<td>10.0</td>
<td>1.4</td>
<td>Channel sample</td>
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<td>Mica and slime</td>
<td>0.0</td>
<td>0.0</td>
<td>Channel sample</td>
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<td>27</td>
<td>Area A Map 3</td>
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<td>Mica and some slime</td>
<td>50.0</td>
<td>1.8</td>
<td>Channel sample</td>
</tr>
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<td>Area A Map 3</td>
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<td>Mica and slime</td>
<td>10.0</td>
<td>7.3</td>
<td>Channel sample</td>
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<tr>
<td>29</td>
<td>Area A Map 3</td>
<td>25</td>
<td>Mica and some slime</td>
<td>70.0</td>
<td>11.8</td>
<td>Channel sample</td>
</tr>
<tr>
<td>30</td>
<td>Area A Map 3</td>
<td>25</td>
<td>Slime and some mica</td>
<td>5.0</td>
<td>0.2</td>
<td>Channel sample</td>
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<td>31</td>
<td>Area A Map 3</td>
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<td>Mica and sillimanite</td>
<td>60.0</td>
<td>15.6</td>
<td>Channel sample</td>
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<tr>
<td>32</td>
<td>Area A Map 3</td>
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<td>Mica and sillimanite</td>
<td>35.0</td>
<td>1.6</td>
<td>Channel sample</td>
</tr>
<tr>
<td>Sample No.</td>
<td>Location of Sample</td>
<td>Width, In feet</td>
<td>Composition of Concentrate</td>
<td>Estimated % Sillimanite in Concentrates</td>
<td>% of Sillimanite in Sample, Assuming 90% Recovery</td>
<td>Remarks and Descriptions</td>
</tr>
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</tr>
<tr>
<td>33</td>
<td>Area A Map 3</td>
<td>6</td>
<td>Mica and sillimanite</td>
<td>60.0</td>
<td>18.4</td>
<td>Sample from face of drift</td>
</tr>
<tr>
<td>34</td>
<td>Area A Map 3</td>
<td>24</td>
<td>Mica and sillimanite</td>
<td>50.0</td>
<td>8.5</td>
<td>Channel sample</td>
</tr>
<tr>
<td>35</td>
<td>Area B</td>
<td>12±</td>
<td>Preponderantly mica</td>
<td>5.0</td>
<td>Trace</td>
<td>Grab sample several outcrops</td>
</tr>
<tr>
<td>36</td>
<td>Area B</td>
<td>20±</td>
<td>Chiefly mica</td>
<td>15.0</td>
<td>0.3</td>
<td>Grab (chips from several outcrops)</td>
</tr>
<tr>
<td>37</td>
<td>Area B</td>
<td>20±</td>
<td>Chiefly mica</td>
<td>10.0</td>
<td>0.1</td>
<td>Grab (chips from several outcrops)</td>
</tr>
<tr>
<td>38</td>
<td>Area B</td>
<td>25±</td>
<td>Chiefly mica, Minor sillimanite</td>
<td>15.0</td>
<td>0.8</td>
<td>Grab (chips from several outcrops)</td>
</tr>
</tbody>
</table>
In addition to the flotation analyses, a fire test was run on a combined, selected high-grade sample of the crude sillimanite rock by the Washington Brick and Lime Company. This test revealed that fusion of the material developed at approximately 2903 degrees F. (Cone 26). This fusion range of the so selected material would indicate that the crude rock is not likely to prove sufficiently high in sillimanite content to serve as a refractory product without beneficiation by a flotation or similar process of concentration.

SUMMARY

This reconnaissance study reveals that zones and localizations of sillimanite occur within Belt Series schists and gneisses on the drainage slopes of Big Bear Creek southeast of Troy, Latah County, Idaho. The mineral appears to have formed chiefly as the result of contact metamorphism induced by the intrusion of magmas of the Idaho Batholith which is situated in the near region to the east, although small off-shoot apophyses and stocks are in the near vicinity of the area examined. The sillimanite is closely associated with pegmatite injections and may also have become somewhat localized and zoned through the introduction of magmatic juices during the pegmatitic emplacements. Columbia River (Miocene) basaltic flows were extruded over the region as a more or less complete blanket but have now been removed by erosion from certain portions of the Belt Series materials.

The sillimanite, as it occurs in the crude rock, is amenable to concentration by mineral-dressing flotation processes.
GEOLOGIC MAP
A SILLIMANITE DEPOSIT (AREA 'A')
NEAR
TROY, LATAH COUNTY, IDAHO

SCALE IN FEET
0 500 1000