State of Washington
ARTHUR B. LANGLIE, Governor
Department of Conservation and Development
ED DAVIS, Director

DIVISION OF GEOLOGY
HAROLD E. CULVER, Supervisor

Report of Investigations
No. 8

The Buckhorn Iron Deposits
OF
Okanogan County, Washington

RESULTS OF A MAGNETIC SURVEY

By
W. A. BROUGHTON

OLYMPIA
STATE PRINTING PLANT
1948

For sale by Department of Conservation and Development,
CONTENTS

Foreword ................................................................. 3
Introduction .......................................................... 5
   Mining operations ............................................... 5
   Earlier investigations .......................................... 7
Field work ............................................................ 7
Acknowledgments .................................................... 7
Regional geology .................................................... 8
Local geology ......................................................... 8
   Quartzites and limestone ....................................... 8
   Basic dikes ....................................................... 9
Quartz-bearing hornblende syenite ................................ 9
Contact metamorphic rock ........................................ 10
Quartz veins ........................................................... 10
Structure ............................................................... 10
Iron ore deposits .................................................... 11
   Character of the iron ore ...................................... 11
Origin of the iron ore ............................................. 12
Sampling and analyses ............................................ 12
Estimation of iron ore reserves ................................. 14
Exposures of magnetite ........................................... 14
Diamond drilling .................................................... 15
Areas of local magnetic attraction ............................... 15
Estimation of tonnages ............................................... 17

ILLUSTRATIONS

Plate 1. Detailed map of the north and east slopes of Buckhorn Mountain, showing the geology, topography, culture, locations of the iron ore bodies, and the results of the magnetic studies .............. In pocket

Correction: Because of an error in drafting, section numbers 13 and 14 are reversed. The section above section 24 should be number 13.

Figure 1. Index map showing the locations of Buckhorn Mountain 5
2. Map of the area southeast of the Magnetic mine pits showing dial compass and dip needle readings .............. 18
3. Block diagram showing possible fault structure. Southeast end of ore body. Magnetic mine .................. 19
4. Block diagram showing possible lenticular structure. Southeast end of ore body. Magnetic mine .......... 20
FOREWORD

The occurrence of iron ore in Washington has been known for nearly ninety years, and deposits of some size have been reported from a score of counties.

Half a century ago certain deposits were officially described as "inexhaustible", and a vast iron and steel industry was envisioned. Even a decade earlier the first furnace to operate in Washington had been blown in. This and subsequent developments have been fully and competently described by Daniels.⁹

Increased interest in iron resulted in a more careful study of the known occurrences, and as the necessity for large volumes of ore became better understood it was realized that few of the many deposits held possibilities of commercial development. For some time, indeed, it seemed that none of the known deposits were large enough to sustain continuous operations.

More recently, particularly since the building of the dams at Bonneville and Grand Coulee, interest in the possibility of an iron industry has been greatly stimulated. Certain new factors related to both power and market have appeared, and it has been necessary to reconsider all features of the proposed program.

An important part of the review of the situation is the reexamination of the deposits of iron ore, and the Division of Geology began this task in 1941. The accompanying presentation is the first of a series of reports on specific districts.

In the Buckhorn Mountain area previous field work had provided most of the information which could be gained by examination of the exposures alone. Quite clearly the need was for subsurface data which would indicate the area probably underlain by ore and suggest the depth to which ore might extend. As the ore itself is magnetic it seemed probable that significant results might be gained from a magnetic survey.

It must be borne in mind the results of such a survey are indirect and hence inconclusive. They can only be used intelligently in conjunction with data from other sources. There has not been time since the conclusion of the field work to assemble all data which are now available, and the study of all information will take considerably longer. Because of the present interest in the Buckhorn ores and the current studies by other agencies, both public and private, it has seemed best to make the results of this season’s magnetic work available immediately.

INTRODUCTION

Buckhorn Mountain, sometimes referred to as Copper Mountain, is in the Myers Creek mining district in the northeast corner of Okanogan County, and just south of the International Boundary (fig. 1). It rises to an elevation of 5,584 feet above sea level. The mountain slopes are steep, heavily covered with coniferous timber, and drained by several streams capable of furnishing water for mining operations. The iron deposits discussed in this report are on the north and east slopes of the mountain in secs. 13 and 24, T. 40 N., R. 30 E. Willamette meridian.

Accompanying this report is a topographic map of the north and east slopes of Buckhorn Mountain (pl. 1) showing the rock formations, iron deposits, and some of the results of the magnetic studies. The topographic contouring was based on the summit elevation of Buckhorn Mountain, 5,584 feet, as shown on the Republic quadrangle sheet (U. S. Geol. Survey Topographic Atlas, 1904). The mining claims are not shown, since no recent claim map is available to the Division of Geology and it did not seem that the present report required preparation of one.

![Figure 1—Index map showing the location of Buckhorn Mountain.](image)

MINING OPERATIONS

During the later part of the 19th century and the early part of the present century much prospecting and small scale mining was done on Buckhorn Mountain. Hundreds of short adits, open cuts, shallow shafts, and several long adits were driven in the search for gold, silver, and copper ores, and a small amount of these ores was produced. Some diamond drilling was

---

Correction: Because of an error in drafting, section numbers 13 and 14 are reversed. The section above section 24 should be number 13.
done for The Granby Consolidated Mining, Smelting & Power Co. Ltd., of Grand Forks, B. C. in 1911. The first reference to iron ore in the district was made in 1908 when magnetite was reported on the Neutral claim, which is now a part of the Magnetic mine property. Most of the recent development work has been done at the Magnetic mine.

The Magnetic Mining Company, owned by Mr. A. E. Wilson and Mr. John Citkovich of Colville, Washington, controls 8 unpatented claims on the north slope of the mountain in secs. 13 and 24. The claims are the Iron Horse, Neutral, Iron King, Iron Mask, No. 9, Copper Queen, Crystal Spring, and Polaris. Improvements on the property consist of two cabins, two bunkhouses, a large cookhouse, blacksmith shop, compressor, and a small crusher. The main development work consists of three open pits and one 100-foot adit, besides numerous short adits, open cuts, and inaccessible shafts. The main pit (No. 1) is about 500 feet below the top of the mountain, is 300 feet long, averages 50 feet in width, and has a maximum vertical face of about 90 feet. A smaller pit (No. 2), about 70 feet long and 45 feet wide, is 110 feet northeast of the main pit. Both of these openings are producing ore at the present time. Another pit (No. 3), about 75 feet long and 45 feet wide, is 300 feet northwest of and 120 feet below the main pit. The 100-foot adit has been driven into the mountain from near the center of the southwest face of the main pit. At different times and under different owners from 1908 to 1942 several thousand tons of magnetite have been shipped to the Northwest Magnesite Company at Chewelah, Washington where the ore was used in making dead-burned magnesite for refractory purposes. At the present time this property is producing several car loads of ore a day. The ore is trucked 24 miles to Curlew, Washington, and from there is shipped by rail to Tacoma.

The Roosevelt property, consisting of 10 unpatented claims and 2 unpatented fractions, is in secs. 24 and 25 about four-fifths of a mile south and one-fifth of a mile east of the Magnetic mine. The claims are the Farmington, Elk, Velvet, Annabell, Grant, Double Standard, Crystal Light, American Girl, Lucky Jim, Snowshoe, Ruby Fraction, and Sir Robert Frac-
tion. The property is controlled by Mrs. Elise MacLean Dewar, Mrs. Joseph McCarthy, and Mr. Roger O. Ocarson of Spokane, Washington. Improve-
ments consist of three cabins, two barns, a blacksmith shop, and a large power-house with two steam boilers. Truck roads connect the property with both Chesaw and Curlew as well as with the Magnetic mine. The main development work consists of an 825-foot lower adit with about 800 feet of drifts and a stope about 35 feet long, 25 feet wide, and 30 feet high which is in magnetite ore. About 200 feet above the lower adit are several caved adits and open cuts. One of these upper adits is 140 feet long with a 25-foot drift and a 25-foot raise to the surface. Most of these upper workings are inaccessible. In 1919 and 1920 about 2,000 tons of magnetite ore was shipped to the Northwest Magnesite Company at Chewelah, Washington.

The East Side claim, controlled by L. R. Phillips of Evans, Washington, and the Aztec claim are located just south of the Magnetic mine's Neutral claim. Both of these claims contain small amounts of magnetite, but to date no attempts have been made to develop and mine the iron ore.
EARLIER INVESTIGATIONS

The number of published detailed reports on the iron deposits of Buckhorn Mountain is limited, and even reports on the general area are not numerous. Several unpublished private reports have been made. Brief mention of the various mining activities on the mountain has been made from time to time in technical journals. The more important reports are listed as follows:

1897. Hodges, L. K., Mining in the Pacific Northwest, p. 110. A brief account of mining activities in the Myers Creek mining district. No mention of the iron ore is made.


FIELD WORK

Field work on the Buckhorn Mountain iron deposits was carried on from June 15, 1942, to August 1, 1942, by the writer with the assistance of Lennart T. Teir and Grant Valentine, field assistants of the Division of Geology. An area about 2 miles long and 1 mile wide on the north and east slopes of Buckhorn Mountain was covered by a network of dip needle and sun compass traverses. Plate 1 shows the area so mapped.

ACKNOWLEDGMENTS

The writer is greatly indebted to Mr. A. E. Wilson and Mr. John Citkovich, owners of the Magnetic Mining Company, who not only generously-contributed information but also made it possible for the field party to live at their camp. Mr. J. T. Mullen, Jr., Assistant Geologist of the
Northern Pacific Railroad, and Mr. Clyde L. Holmberg, chief of field party for the Northern Pacific Railroad, contributed helpful information. Mr. Roger Oscarson of Spokane, Washington willingly permitted the writer to study his private report on the area. Mr. Ned E. Nelson of Vancouver, B. C. kindly made available a report by Mr. E. E. Campbell on diamond drilling for Granby Consolidated. The magnetic instruments were kindly loaned by Mr. R. H. B. Jones and Mr. H. N. Westaway of the Oliver Iron Mining Company of Duluth, Minnesota.

REGIONAL GEOLOGY

The regional geology of the area around Buckhorn Mountain was admirably summed up by Umpleby, and the following passage is taken from his report:

"The oldest rocks in the area are probably of Paleozoic age and consist of quartzites, slates, schists and limestones with intimately associated intrusive and extrusive igneous rocks of basic composition, all of which have been subjected to a great period of diastrophic movement which resulted in their regional metamorphism. At least part of the series is thought to be Carboniferous. Intruded into these are two great batholiths of acid granular rock which show no evidence of having passed through a period of intense crustal movement and are for that reason, together with other considerations taken up later, assigned provisionally to the late Mesozoic. Erosion was the dominant feature of the Tertiary with possibly a period of movement resulting in elevation, at about the close of the Eocene. In the Pleistocene a southward extension of the Cordilleran ice sheet covered the entire area leaving a heavy mantle of drift, much of which remains in situ, especially west of Myers Creek."

LOCAL GEOLOGY

In essential features the geology of Buckhorn Mountain is the same as that of the entire district. The oldest lithologic unit is a series of Paleozoic (?) quartzites and limestones that are cut by younger basic dikes. The sedimentary series and the basic dikes have been intruded by a large mass of quartz-bearing hornblende syenite which, according to Umpleby, is probably of late Mesozoic age. The intrusion of the syenite greatly altered the older sedimentary rocks to form the contact metamorphic rock that occupies a wide zone between the igneous and sedimentary rocks. It is this contact zone that carries the iron ore as well as most of the gold, silver, and copper ores on the mountain.

QUARTZITE AND LIMESTONE

Quartzite and limestone occur mainly along the west and south slopes of the mountain, and areas of partially replaced quartzite occur within the contact zone on the north and east slopes. Quartzite is the predominant rock of the sedimentary series and it is mainly very fine grained, but pebbles up to one-fourth of an inch in diameter can be found. Much of the quartzite is

@ Umpleby, J. B., Geology and ore deposits of the Myers Creek mining district: Washington Geol. Survey Bull. 5, pt. 1, p. 17, 1911.
finely laminated. The limestone appears to be in the form of large lenses within the quartzite, and there are two such bodies in the area studied. The larger extends from about 350 feet west of the high lookout tower on the top of the mountain northward for about 3,000 feet and eastward for about 700 feet forming the low saddle between the high lookout tower and the emergency lookout. The smaller area of limestone is about 300 feet long and 200 feet wide and occurs along the southern boundary of the area studied about 1,700 feet S. 40° E. of the high lookout tower. The limestone is exposed in low, light-gray to white outcrops. On fresh exposures the rock is gray to bluish. Bedding is indistinct. Small nodules of chert occasionally occur within the rock. The only fossils found in the limestone were poorly preserved crinoid plates and stems. The limestone has largely been altered to marble, some of which is extremely coarse grained with calcite crystals up to 3 inches in diameter.

BASIC DIKES

A small number of basic dikes cut the quartzite-limestone series. One of these dikes is exposed in No. 1 pit and in the 100-foot adit on the Magnetic Mining Company's property, and another one is exposed in the road between No. 1 pit and No. 2 pit. Both dikes are narrow, averaging 2 to 3 feet in thickness. They strike about N. 20° E. and dip from 60° NW. to vertical.

QUARTZ-BEARING HORNBLENDE SYENITE

The quartz-bearing hornblende syenite covers an area of about 4 square miles extending north and east of Buckhorn Mountain and is in contact with the older sedimentary series mainly at elevations of 600 feet to 700 feet below the top of the mountain. This contact is irregular with occasional tongues of the older rocks jutting out into the syenite, but, in general, it continues northward from the Roosevelt mine for about 4,700 feet, then westward for about 1,000 feet to the Magnetic mine and then continues at least 4,100 feet in a northwesterly direction. South and west of the main contact quartzite surrounds several small bodies of syenite which probably are small stocks of the main mass.

The quartz-bearing hornblende syenite was described by Umpleby (1) as follows:

"The average specimen from the quartz-bearing hornblende syenite mass is a dark bluish gray rock of inequigranular to equigranular texture and megascopically consisting of hornblende and feldspar with local development of biotite and an occasional grain of quartz. The texture varies considerably, in places being uniformly about equigranular while in others hornblende crystals are far larger than the feldspars and yet again feldspars of two distinct sizes appear. Quartz and hornblende both have a considerable range of variation, the former running from one-half of one per cent to about seven per cent of an entire thin section, although in one instance twenty-five per cent of quartz was noted, while the hornblende varies between eight or ten per cent and twenty per cent. In thin sections the feldspar is shown to be about one-fifth albite and four-fifths ortho-

clase with occasional microcline crystals. Within the igneous rock itself the hornblende is commonly altered to epidote and chlorite, and the feldspars to epidote, zoisite and sericite. In both hornblende and feldspar green epidote is the chief alteration product. Pyrite is usually developed as cubes irregularly distributed. Magnetite is present but not conspicuous."

**CONTACT METAMORPHIC ROCK**

Contact metamorphic rock occupies a zone 1,500 to 2,500 feet wide between the unaltered sedimentary beds and the syenite. Metamorphism was most intense close to the syenite contact. What appears to have been limestone has been almost entirely replaced at the contact by large irregular masses of magnetite, pyrite, pyrrhotite, chalcopyrite, epidote, and garnet. A few small bodies of unaltered limestone several feet in diameter have been found within this highly mineralized zone. Beyond this largely replaced zone the contact rock is mainly quartzite that has been only slightly replaced. South and west of the main syenite contact the metamorphism lessens in intensity, the contact zone showing no sharp boundary. Finely disseminated grains of pyrite, pyrrhotite, and chalcopyrite are abundant, and along shear zones that acted as channel-ways for mineral-bearing solutions there is frequently much development of these sulphides together with small amounts of galena and sphalerite. Some of the original quartzite beds were probably more calcareous than others, and these have been largely replaced by garnet and epidote with a small amount of the sulphides. The sulphides in this contact zone carry small amounts of gold, silver, and nickel. Extensive prospecting of the mineralized shear zones and the narrow garnet-epidote areas has been carried on with a small production of ore. Finely disseminated grains and occasional small masses of magnetite up to several inches in diameter may be found in this zone, but all of the large, workable bodies of magnetite are in the replacement zone close to the contact. The most pronounced metamorphism has taken place along the contact between the syenite and limestone (?), while quartzite, even in direct contact with the syenite, has been only slightly altered.

**QUARTZ VEINS**

A few quartz veins ranging from several inches to several feet in thickness cut the syenite and the older sedimentary series. As far as could be determined, these veins are barren of ore minerals.

**STRUCTURE**

The sedimentary rocks on Buckhorn Mountain appear to form the east limb of a northeastward-trending anticline. Easily discernible bedding in the quartzite-limestone series is not common. In general, the sedimentary rocks strike northeast and dip to the southeast. In the vicinity of the Roosevelt mine the beds strike from N. 10° E. to N. 60° E. and dip from 25° SE. to 65° SW. East of the emergency lookout the beds strike N. 47° E. and dip 65° SE. In the lower Buckhorn adit west of the emergency lookout the quartzite beds strike N. 65° E. and dip 88° NW. Departures from the general northeast strike and southeast dip probably indicate local folding and faulting on the limb of the major anticline.

The contact metamorphic zone is cut by numerous shear zones that strike from N. 67° W. to N. 75° E. Most of the shear zones striking north-
west dip from $35^\circ$ to $55^\circ$ SW., but some dip as much as $60^\circ$ NE. and
some are vertical. Most of those shear zones striking northeast are nearly
vertical, but some dip to the northwest at angles as low as $30^\circ$. There may
have been considerable movement along some of the shear zones, and
there is a suggestion that faulting has taken place between No. 1 pit on
the Magnetic Mining Company’s property and No. 2 pit to the northeast,
with No. 2 pit block having possibly moved about 300 feet northeast rela-
tive to No. 1 pit block. This faulting is suggested by both a zone of
shearing between the two pits and the magnetic studies. However, the
suggestion of faulting may be due to irregular replacement along the
contact.

The several small areas of syenite south and west of the main contact
between the quartzite-limestone series and the syenite suggest that the
igneous rock underlies the whole area beneath a relatively thin cover of
the older sedimentary rocks and that the subsurface contact is very irregu-
lar. This irregularity of the contact would greatly affect the thickness
of the roof of older rocks.

**IRON ORE DEPOSITS**

The iron on Buckhorn Mountain occurs in the sulphide form as pyrite
and pyrrhotite, and in the oxide form as magnetite. Only the magnetite
can be regarded as iron ore. The entire possible iron-bearing area in
the vicinity of Buckhorn Mountain was not studied, but within the lim-
ited area of study, nearly all of the indicated magnetite bodies large
enough for commercial operations are in the narrow zone of extreme
metamorphism along the contact between the syenite and the older sed-
imentary rocks.

**CHARACTER OF THE IRON ORE**

The iron ore is best exposed in the pits on the Magnetic Mining
Company’s property. Here the magnetite is intimately associated with
pyrite, pyrrhotite, chalcopyrite, garnet, and epidote. In some places
there are solid masses of magnetite weighing hundreds of tons and com-
prising easily mined bodies of ore. In other places the magnetite occurs
as fine disseminations or as small bodies several feet in diameter in a com-
plex mixture of the sulphides, garnet, and epidote. In such cases either
the sulphides or the silicates make up the bulk of the material so that the
magnetite must be sorted out during mining operations. In still other
places along the replaced zone the predominant material is an intimate
mixture of grossularite garnet and epidote, with minor amounts of zo-
isite, calcite, actinolite, diopside, and quartz. The magnetite may grade
into sulphide or garnet-epidote rock, or the change may take place at a
sharp contact between the solid magnetite and the surrounding material.
There appears to be no system to the mineralization that can be followed
in mining operations, for the replacement has been extremely irregular
with bodies of magnetite scattered through the sulphides and silicates
rather than confined to definite zones that can be followed for distances
of hundreds of feet. The magnetite is apparently confined to a narrow zone
along the syenite contact, and farther out from the contact it gives way
to the sulphides and the silicates.
The magnetite is both fine- and coarse-grained, with crystals up to an inch in diameter. Some of it is of the lodestone variety. The magnetite is reported to carry a small amount of gold, varying from $0.75 up to $7.00 per ton. The pyrrhotite and pyrite are usually more or less mixed in massive form, but there are some bodies of nearly solid pyrrhotite several feet in diameter. The pyrrhotite carries a small percentage of nickel. The chalcopyrite occurs in lesser amounts than either the magnetite or the other sulphides and is found as disseminated grains or in narrow veinlets cutting the sulphides and the magnetite. The chalcopyrite carries a small amount of gold and silver. The garnet is of the grossularite variety and usually occurs as large masses more or less intergrown with massive epidote, but euhedral crystals of both garnet and epidote are common. Zoisite, actinolite, and diopside are common, but make up only a small part of the replaced mass and are more or less closely associated with the garnet-epidote rock. Calcite is common and occurs as interstitial fillings between crystals of the other minerals. Euhedral crystals of calcite and quartz are not uncommon, especially lining the walls of small cavities. Small crystals of scheelite ranging from minute specks to crystals one-sixteenth of an inch in diameter occur infrequently throughout the garnet-epidote rock.

The iron ore on the Roosevelt property is in general similar to that on the Magnetic Mining Company's property and shows the same mineral associations and relationships.

ORIGIN OF THE IRON ORE

The commercial iron ore bodies were possibly formed only at those places where the syenite intruded beds of limestone. That the replaced beds were originally limestone is supported by the presence of unreplaced bodies of the limestone within the zone of intense metamorphism, by the abundance of calcite and high calcium silicates in the replaced zone, and by the fact that where the syenite is in contact with quartzites there has been practically no replacement.

At the time of intrusion and during the early stages of cooling of the syenite, heat and mineralizing solutions were given off by the igneous mass, and these together with the latent water in the sedimentary rocks were apparently capable of reacting chemically with the limestone and to a much lesser degree with the quartzite. A part of the limestone was probably dissolved and carried away, being replaced by the sulphides and the magnetite. Other parts of the limestone were undoubtedly altered by heat and chemical action to form the silicates. Probably due to a relative lack of porosity the remaining part of the limestone was not replaced and remains as the blocks of unaltered limestone surrounded by the contact minerals.

SAMPLING AND ANALYSES

There is very little published information concerning the composition of the Buckhorn Mountain iron ores. A specimen of magnetite from the Neutral claim was collected by H. H. Cooper and analyzed by R. P. Cope. ①

The results of the analysis are as follows:

Iron (Fe) .................................. 70.17%
Silica (SiO₂) .................................. 1.90
Phosphorus pentoxide (P₂O₅) ................. 0.02
Sulphur (S) .................................. 0.21

The analyses of three samples of the Magnetic mine ore were given by Sheldon L. Glover. Mr. Glover’s descriptions of the three samples were: Sample 1. "Indicative"; Sample 2. "Picked sample"; Sample 3. "One-ton mine-run sample; analyses by a Portland, Oregon, chemist and supplied by Mr. Archie Wilson, owner of the property". It is not known where and how these samples were taken, and it is unsafe to rely on them without that knowledge. However they do give helpful information as to the composition of the ore. The analyses of these three samples are as follows:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td>70.15%</td>
<td>73.20%</td>
<td>62.28%</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>4.35</td>
<td>4.15</td>
<td>6.75</td>
</tr>
<tr>
<td>Lime (CaO)</td>
<td>0.50</td>
<td>0.50</td>
<td>1.10</td>
</tr>
<tr>
<td>Magnesia (MgO)</td>
<td>1.25</td>
<td>...</td>
<td>Tr.</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>1.70</td>
<td>1.85</td>
<td>...</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>0.09</td>
<td>...</td>
<td>7.60</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.11</td>
<td>0.15</td>
<td>0.028</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>1.50</td>
<td>1.40</td>
<td>0.012</td>
</tr>
<tr>
<td>Titanic acid (H₂TiO₅)</td>
<td>Nil</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Combined water, etc.</td>
<td>1.50</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>...</td>
<td>Tr.</td>
<td>...</td>
</tr>
<tr>
<td>Nickel oxide (NiO)</td>
<td>1.00</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Chromic oxide (Cr₂O₇)</td>
<td>2.00</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Alkalies, oxygen, etc.</td>
<td>15.85</td>
<td>18.75</td>
<td>22.23</td>
</tr>
</tbody>
</table>

Average samples of ore shipped during ten successive weeks in 1920 from the property now owned by the Magnetic Mining Company to the Northwest Magnesite Company at Chewelah, Washington showed from 90.36 percent to 83.80 percent Fe₂O₃ plus Al₂O₃, 9.8 percent to 7.46 percent SiO₂, and 6.4 percent to 3.82 percent CaO. It must be remembered that these shipments of magnetite ore were hand sorted and thus contained a higher iron content than that of the average pit-run ore.

No extensive sampling of the Buckhorn Mountain iron deposits has been made by the Division of Geology. However, in order to secure some definite facts as to the composition of the iron ore bodies, three channel samples were cut. Each sample constituted average ore as far as could be told from visual inspection. One sample was taken at the south face of No. 2 pit 4 feet above the floor from a horizontal channel 15 feet long, about 4 inches wide, and about 2 inches deep. Another sample was taken from a 15-foot horizontal channel about 3 inches wide and about 2 inches deep cut approximately 30 feet below the top of the southwest face of No. 1.
pit. The third sample was cut in the east wall of the 100-foot adit about 65 feet from the portal. This channel was 17 feet long, about 4 inches wide, and about 1 inch deep. The three samples were combined and showed the following composition on analysis:

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td>47.30%</td>
</tr>
<tr>
<td>Titanium (Ti)</td>
<td>0.03</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.03</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>1.57</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>Trace</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>Trace</td>
</tr>
</tbody>
</table>

Analyst: Laucks

A complete magnetic separation was made on a 1-pound portion of the composite sample. The magnetic fraction was found to constitute 79.4 percent of the sample, and the sulphur content of the magnetic fraction was 1.68 percent (Analyst: Laucks). If all of this sulphur were combined with iron in the mineral pyrrhotite 76.0 percent of the composite sample would be magnetite.

The specific gravity of the composite sample was determined, by the Division of Geology, to be 4.15, and this figure was used in the estimation of ore tonnages.

During the summer of 1942 the Northern Pacific field party carried out an extensive sampling program of the Magnetic mine iron deposit. The U. S. Bureau of Mines, in 1942, and the U. S. Geological Survey, in 1941, did some sampling of the iron deposit.

The iron ore is complex, both mineralogically and chemically, and it is doubtful that it can be successfully treated by the common blast furnace methods. The ore could probably be treated in electric furnaces, but much experimental work will have to be done before the metallurgical problems can be solved.

ESTIMATION OF IRON ORE RESERVES

The total reserves of iron ore on the north and east slopes of Buckhorn Mountain can only be roughly estimated. Despite the fact that a great deal of development work has been done, none of the large bodies of ore have been outlined. The extreme irregularity of magnetite development within the replaced zones adds to the difficulty of making any exact statement as to the total tonnage of magnetite that may be present.

EXPOSURES OF MAGNETITE

The largest exposures of magnetite are in the open pits at the Magnetic mine. Much magnetite is visible in the walls of the 100-foot adit at No. 1 pit. Good magnetite is showing in the road cut and the short adits 300 feet southeast of No. 1 pit, in open cuts and short adits 100 feet west of No. 1 pit, and 150 feet south of the east end of No. 1 pit. Thus the area that has showings of magnetite is about 1,000 feet long and 300 feet wide (average) with a vertical distance of about 200 feet between the highest and the lowest exposure. About 1,700 feet northwest of No. 1 pit a few small fragments of magnetite can be found on the dumps of the
open cuts, caved adits, and shafts, but the presence of a minable body of magnetite is not suggested.

There are no surface exposures of magnetite at the Roosevelt mine. In the lower adit about 550 feet from the portal a body of magnetite was encountered, and it was from this ore body that the production of the Roosevelt magnetite was made. Practically all of the known magnetite above the adit level has been stope d out, the stope being approximately 35 feet long, 25 feet wide, and 30 feet high.

Several pieces of magnetite up to 5 inches in diameter and a small amount of disseminated magnetite were found on the dumps of the open cuts and adit in the southwest corner of the area studied and in the dumps of the open cuts 1,100 feet south and 1,000 feet east of the Buckhorn lookout tower. There is nothing to suggest minable bodies of magnetite in either of these two places.

**DIAMOND DRILLING**

In 1911 The Granby Consolidated Mining, Smelting & Power Co. Ltd., of Grand Forks, B. C. had five holes drilled on Buckhorn Mountain approximately where shown on plate 1. The drilling was done in the search for copper, gold, and silver ores, and apparently no record of the magnetite content of the cores was kept. However, the available records of the drilling do cast some light on the problem of ore reserves.

Hole No. 1 was drilled vertically on the Aztec claim on top of the ridge south of the Magnetic mine, about 700 feet south and 250 feet west of No. 1 pit. It showed "ore" down to a depth of 112 feet, but no mention is made as to the kind of ore. No magnetite crops out in the vicinity of this hole, and the magnetic traverses do not show the presence of magnetite, so the ore referred to is probably a mixture of chalcopyrite, pyrrhotite, and pyrite which are abundant in that area.

Hole No. 2 was drilled vertically on the upper side of a "magnetite ledge" about 100 feet west and 50 feet south of No. 1 pit. It encountered no ore.

Hole No. 3 was drilled vertically into a "magnetite outcrop" about 300 feet east and 70 feet south of No. 1 pit. It showed "iron" (probably magnetite) down to 180 feet.

Hole No. 4 was drilled vertically about 1,400 feet west and 1,150 feet north of No. 1 pit. It showed several small bodies of "ore" (probably not magnetite).

Hole No. 5 was started about 400 feet down the slope from the location of No. 4. It was inclined at 20° from the horizontal and directed toward No. 4 hole. "Ore" was cut in two places, from 201 to 204 feet and from 476 to 478 feet along the hole. The ore cut was probably not magnetite and, if it were, would not constitute minable bodies of ore at that depth.

**AREAS OF LOCAL MAGNETIC ATTRACTION**

A detailed magnetic survey was made of the north and east slopes of Buckhorn Mountain for the purpose of outlining the magnetic areas around known bodies of iron ore and locating other magnetic areas that would
suggest unexposed ore bodies. The instruments used were the Gurley
dial compass and dip needle.

The area of study was covered by a series of east-west control traverses
spaced 600 feet apart, and then areas of local magnetic attraction were
covered by a network of traverses spaced 100 feet apart. Instrument read-
ings were recorded every 25 feet, horizontally, along the traverses. The
distances between stations were chained, and the slope angles were recorded.

Areas of magnetic attraction were outlined by connecting points of
maximum dial compass declination on successive traverses. These areas
are shown on plate 1 and are listed as follows:

The largest area of local magnetic attraction extends for 3,100 feet
southward from the vicinity of the Magnetic mine pits with an average
width of about 1,200 feet.

A double-pronged area 800 feet long and 100 feet wide trending
northwestward is about 1,000 feet N. 45° W. of the west end of No. 1 pit.

At the Roosevelt mine there is a magnetic area trending northeastward
with an average width of 150 feet and a length of 600 feet. The eastern
half of this area is on the syenite side of the contact between the syenite
and the sedimentary rocks.

An "S" shaped magnetic area with a total length of 600 feet and an
average width of 30 feet is 1,400 feet south of the Roosevelt mine camp.

An "L" shaped magnetic area is 1,300 feet S. 45° E. of the lookout
tower. It has a total length of 850 feet and an average width of 60 feet.

Three magnetic areas are 1,200 feet east of the lookout tower. Two
of them are roughly parallel and elongated in a north-south direction.
They are about 100 feet apart, 100 feet wide, and 700 feet long. The
third area is 200 feet long and 50 feet wide.

A magnetic area 150 feet long and 35 feet wide is 650 feet N. 20° E.
of the lookout tower.

A magnetic area 550 feet long and 100 feet wide is 1,250 feet N. 25° E.
of the lookout tower.

Two magnetic areas about 300 feet long and averaging 40 feet in
width trending in a north-south direction are 500 feet N. 30° W. of the
lookout tower.

The magnetic intensities within the areas of local magnetic attraction
were contoured on the basis of the dip needle readings. Areas of moder-
ately high dip needle readings, more than 10° below normal, and areas of
extremely high readings, more than 25° below normal, are shown on
plate 1.

The largest area of the moderately high dip needle readings is around
the open pits and extends southward for about 600 feet. In general, the
dip needle readings indicate that the ore body pitches into the mountain
toward the south. A small area about 30 feet in diameter was located 600
feet northwest of No. 1 pit. On the Roosevelt property there is a small
area about 50 feet in diameter.

There are eight areas of the extremely high dip needle readings within
the area of moderately high dip needle readings near the open pits. The
locations of these areas are as follows:
South side of No. 3 pit.
West end of No. 1 pit.
Southwest side of No. 1 pit.
Southeast side of No. 2 pit.
200 feet east of the east end of No. 1 pit.
50 feet southwest of the adits 350 feet southeast of the east end of No. 1 pit.
50 feet northwest of the adits 350 feet northeast of the east end of No. 1 pit.

These extremely high magnetic areas may indicate faulted segments of the ore body, individual bodies of magnetite due to irregular replacement of the limestone, or merely sizable bodies of magnetite close to the surface.

Those areas of magnetic attraction that do not give even moderately high dip needle readings are linear in shape, being very narrow as compared to their length. Exposures within several of these areas exhibit sheared zones slightly mineralized with pyrite, chalcopyrite, and magnetic pyrrhotite. It is probably the pyrrhotite that is producing the magnetic disturbance rather than magnetite.

ESTIMATION OF TONNAGES

Due to the lack of development work and surface exposures outlining proven ore, and due to the extreme irregularity of mineralization within the replaced zone, any figures of tonnages are purely estimations and must be regarded as such. Diamond drilling or other development work must be done to prove up the ore definitely.

The largest body of easily mined magnetite ore on the north and east slopes of Buckhorn Mountain is in the vicinity of the Magnetic mine pits. Some of the magnetite probably overlaps onto the Aztec and East Side claims, but since there is no accurate claim map available, no attempt will be made to estimate the tonnages of ore on individual properties or claims. The exposures of magnetite in this vicinity cover an area roughly 1,000 feet long and 300 feet wide (average) with a vertical distance of about 250 feet between the highest and lowest exposures. Assuming that a block of ore, with the above dimensions, underlies this area down to the elevation of the lowest exposure there would be 4,826,000 tons of iron ore within the block.

All of the magnetite exposures that indicate large bodies of ore lie either within or close to the margin of the area of moderately high dip needle readings, and it is reasonably safe to assume that this area is underlain by ore. This would be easily mined ore close to the surface, and there is no reason to assume that the ore is limited to this area or that the ore does not continue to greater depths. In fact, the magnetic readings indicate that the ore body pitches southward down into the mountain.

The area of moderately high dip needle readings is roughly "U" shaped with the "U" opening to the northwest and its base about 700 feet southeast of No. 1 pit. Figure 2 is a map of the southeast portion of this area showing the dip compass and the dip needle readings. The southwest arm of the "U", about 1,300 feet long and averaging 200 feet in width, extends through No. 1 and No. 3 pits. The northeast arm of the "U", about 800 feet long and 200 feet wide, extends through No. 2 pit. The
two arms of the "U" suggest a duplication of the ore body. There are at least two possible explanations for this apparent duplication.

The apparent duplication of the ore body could be explained by a fault striking northwest and dipping northeast so as to cut the ore just east of No. 1 pit. The hanging wall side of the fault would have moved downward and northward with relation to the foot wall side (fig. 3). The northwest side of the proposed hanging wall block has been eroded more deeply than the southeast side. Due to this erosion the northwest portion of the faulted ore body would contain a smaller mass of magnetite than the southeast portion and the width of the area of moderately high dip needle readings would increase to the southeast. This increase in width does take place. If the fault is present, the ore in the northeast side of the "U" would not be expected to continue to as great a depth as the ore in the southwest side of the "U". The two ore bodies, 1,300 feet and 800 feet long and each 200 feet wide with a difference of 400 feet in surface elevation between their southeast and northwest ends, would contain about 16,210,000 tons of ore provided that the ore continues to a depth of 100 feet below the surface elevations of their northwest ends. From the size and shape of the ore bodies, it seems reasonably safe to assume that the ore will continue to at least this depth.
The apparent duplication of the ore body could also be explained by the mineralization of a nearly vertical lens of limestone striking northwest and having two projections along its upper edge interfingering with the surrounding quartzite (fig. 4). If this were the case the ore would be continuous across the base of the "U". This would provide another ore body 500 feet long and 100 feet wide with a difference of 150 feet in surface elevation between its southeast and northwest ends. If this block of ore continued to the same depth as the two larger blocks there would be an additional 2,411,000 tons of ore available, or a total of about 18,621,000 tons.
The tonnage of magnetite at the Roosevelt mine is much lower than that in the vicinity of the Magnetic mine. The ore bodies are small and as much as 200 feet below the surface. Due to the small size of the ore bodies the expense of underground mining of the magnetite on the Roosevelt property would be considerably greater than the open pit mining in the area to the northwest.

The only exposure of magnetite ore seen at the Roosevelt mine is in the floor of the large stope about 550 feet from the portal of the lower adit. There is nothing to indicate that the ore has been entirely mined out nor that it extends for any great depth below the stope floor. It is probably safe to assume that there is at least as much ore remaining as has been
removed. This would amount to about 2,000 tons. A small area of moderately high dip needle readings lies 250 feet S. 60° E. of the stoped area. This magnetic area is roughly 80 feet long and 60 feet wide. If the ore body represented by this magnetic area were 100 feet thick it would contain not more than 62,000 tons of iron ore.

The 18,621,000 tons of iron ore at the north end of the limited area of study and the 64,000 tons on the east side of the area of study are reasonable estimations of possible ore. Diamond drilling or other development work must be done to prove these tonnages.