The Blewett Iron-Nickel Deposit Chelan County Washington

GEOLOGICAL SURVEY BULLETIN 969-D

THE BLEWETT IRON-NICKEL DEPOSIT, CHELAN COUNTY, WASHINGTON

By Carl A. Lamey

ABSTRACT

The Blewett iron-nickel deposit is about 80 miles east of Seattle, Wash., in the Wenatchee National Forest, northern Cascade Mountains, adjacent to United States Highway 97.

The deposit consists of an early Tertiary peridotite conglomerate, containing iron-rich lenses and veinlets, that rests upon a pre-Tertiary serpentinized peridotite. In some places the conglomerate is covered by the Swauk formation of Eocene age. Eocene diabase dikes cut the peridotite, conglomerate, and Swauk formation.

The conglomerate is composed almost exclusively of fragments of serpentinized peridotite embedded in a ferruginous and serpentinous matrix. The fragments range in size from grains to boulders. The dominant diameter of the larger fragments is from 2 to 12 inches, but exceptionally it is as much as 5 feet, and drilling indicates the possibility of an extreme size of 25 feet. The fragments of cobble and boulder size are rather widely and uniformly separated in the matrix, and make up about two-fifths of the conglomerate.

The conglomerate was derived probably in part from a lateritic iron deposit and in part from the serpentinized peridotite on which the laterite formed. The mode of accumulation is obscure, but it seems to be best explained by landslide or mudflow activity.

The geologic structure of the area is incompletely known, largely because insufficient time was allowed for field work. The rocks are cut by numerous faults; the outstanding one is a reverse fault along which the conglomerate has been overthrust upon the younger Swauk formation.

The United States Bureau of Mines explored the deposit by 10 diamond-drill holes. Chemical analyses of core and surface samples show that both the fragments and the matrix of the conglomerate contain appreciable amounts of iron, nickel, and chromium, but that these constituents are much more abundant in the matrix. They are most abundant in the principal iron-rich lens.

INTRODUCTION

The Blewett iron-nickel deposit is a few miles south of the old Blewett gold mining district in the Wenatchee National Forest, northern Cascade Mountains, Wash., about 80 miles east of Seattle, and is within the Mount Stuart quadrangle (fig. 5). It lies at the eastern end of a series of similar iron-nickel deposits that occur at intervals westward through the mountains for about 20 miles, from the Blewett deposit to the Cle Elum River.

The conglomerate forms much of the crest and upper slopes of the part of the ridge that was mapped, whereas the Swauk formation is present chiefly along the south side of the ridge, is lower than the conglomerate, and dips northeast beneath the conglomerate. This relation has resulted from faulting, which locally thrust the conglomerate southward over the sandstone.

Many dikes and some larger bodies of diabase cut the conglomerate and the Swauk formation. It is considered by other writers to be of Eocene age and to fill the conduits through which the flows of Teanaway basalt of this general region reached the surface (Smith, 1904, p. 6). In the area mapped, a large mass of the diabase cuts across the northwestern end of the conglomerate, and extends 1,500 feet westward. Several smaller diabase bodies are exposed and other bodies have been encountered in drilling (pl. 18).

DESCRIPTION OF FORMATIONS

IGNEOUS ROCKS

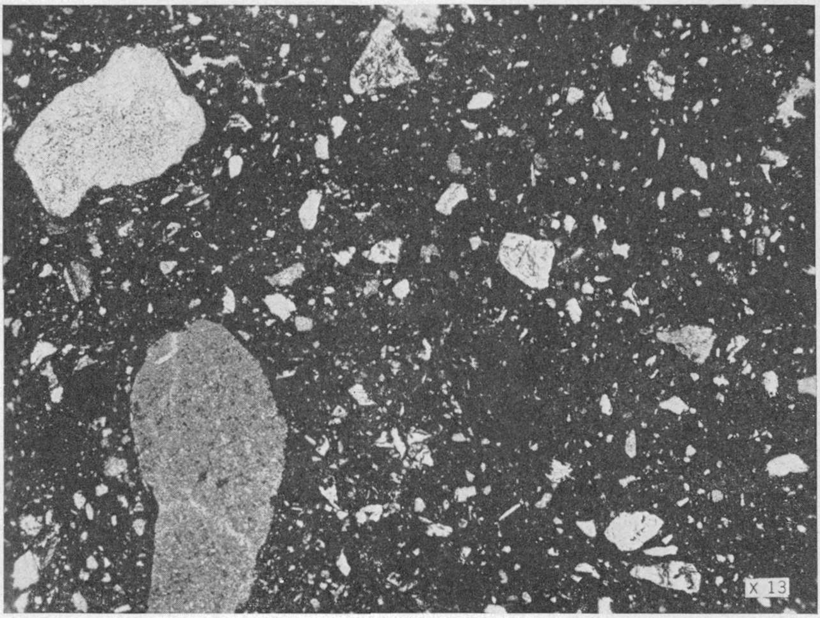
Diabase.—The fresh diabase is dark green to nearly black, but weathers rusty brown. The chief constituent recognizable under a hand lens is greenish lath-shaped plagioclase. Smith (1904, p. 6) reports that the plagioclase is chiefly labradorite; that the principal pyroxene is augite, with which some hypersthene is intergrown; that olivine is a common constituent in much of the diabase; and that quartz also is present.

Serpentinized peridotite.—All peridotite obtained from the drill cores is wholly or partly serpentinized. Much of it is dark green to nearly black, but some of it is mottled. The mottled type is composed of light-green crystals of altered orthopyroxene (now probably bastite) surrounded by massive, dark-green serpentine, and probably is altered saxonite or harzburgite, whereas the homogeneous type may be altered dunite.

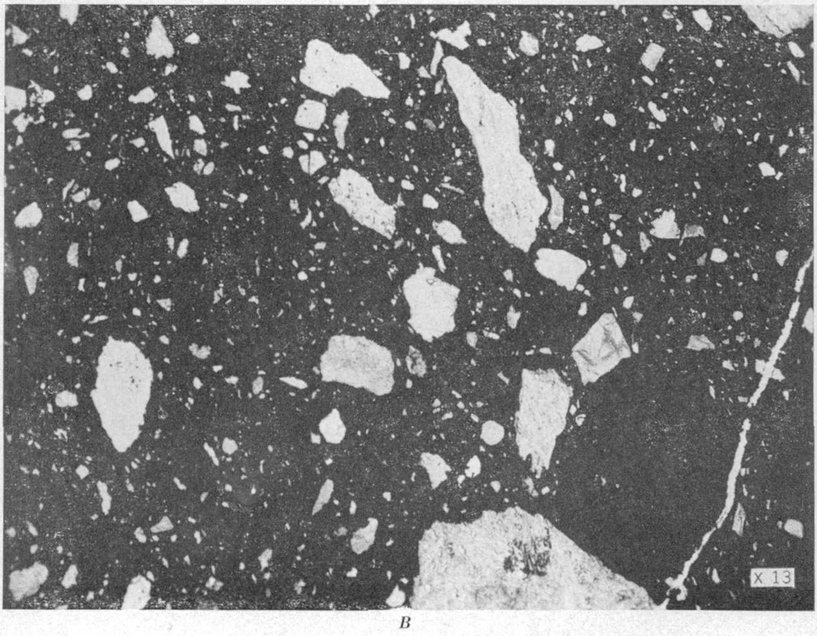
SEDIMENTARY ROCKS

Alluvium and terrace deposits.—The alluvium and terrace deposits consist of pebbles, cobbles, and boulders, intermixed with sand; that is, the common type of material of local origin to be expected along stream courses.

Swauk formation.—The Swauk formation exposed in the vicinity of the iron-nickel deposit is chiefly gray, medium- to coarse-grained feldspathic sandstone and some shale. Some of the Swauk formation exposed along United States Highway 97 is distinctly conglomeratic. The peridotite conglomerate, which constitutes the iron-nickel deposits, may be the basal part of the Swauk formation, but for the purpose of this report it is described and mapped as a separate unit.



A



B

PHOTOMICROGRAPHS SHOWING CHARACTER OF THE FERRUGINOUS MATRIX OF THE PERIDOTITE CONGLOMERATE

Figure *A* shows chiefly serpentine fragments surrounded by only slightly ferruginous matrix, and *B* shows a more ferruginous phase. Plane polarized light.

Peridotite conglomerate.—The peridotite conglomerate is composed of subangular to well-rounded pebbles, cobbles, and boulders embedded in a ferruginous and serpentinous matrix, and also of a few iron-rich lenses that may indicate the bedding of the conglomerate. At some places the cobbles and boulders, rather widely and fairly uniformly distributed, stand out in considerable relief.

Practically all of the larger fragments are composed of serpentine or partly serpentinized peridotite with very few well-rounded cobbles of basaltic rock. Lupher (1944, p. 14) reported a few well-rounded and water-worn cobbles and pebbles of fine- to medium-grained basic rocks, and Broughton (1943, p. 10) reported some pebbles and cobbles of slate and fine-grained diabasic rock. Many of the serpentine fragments are surrounded by a shell of weathered material as much as an inch thick. This shell was also noted and described by Lupher (1944, p. 15).

The dominant size range of the serpentine fragments is 2 to 12 inches. Many boulders a foot or two across, and some 5 feet or more in diameter, are exposed at the surface; boulders as much as 25 feet thick are indicated by drilling. In some places it is difficult to determine the point at which the drill passed from conglomerate into the serpentine basement as, apparently, the boulders are progressively larger and the amount of matrix reduced so that the cores show practically nothing but serpentine in which there are scattered seams of matrix only an inch or two thick. Some of these serpentine masses may be not boulders but blocks of the basement around which thin seams of matrix accumulated through crevices.

Microscopic examination of several thin sections shows that the matrix of the conglomerate is composed dominantly of angular, subangular, irregular, and rudely rounded particles enclosed in fine-grained ferruginous material, apparently chiefly magnetite, hematite, and serpentine (pl. 19). The small particles in the matrix are chiefly serpentine (principally antigorite), magnetite, spinel, and probably chromite. Associated with the serpentine are considerable amounts of carbonate and small quantities of a green mineral that was not positively identified. Probably it is a magnesian silicate closely related to serpentine—perhaps deweylite or garnierite. Minor constituents include bastite, pyrite, mica (probably biotite), chlorite, and perhaps cliachite. Some of the matrix is cut by minute veins of magnetite, hematite, and serpentine. Such veins are more abundant in the iron-rich parts of the matrix and the iron-rich lenses than in the matrix.

The iron-rich lenses of the conglomerate resemble the matrix except that they are finer-grained, contain much less serpentine and much more magnetite and hematite. In the lenses the larger particles appear to be chiefly chromite and spinel. Although the grain size is smaller in the lenses, the same fragmental texture that characterizes the matrix is evident. The principal lens is about 450 feet long, 35 feet wide, and extends downward for about 450 feet, possibly in the direction of the bedding of the conglomerate.

STRUCTURE

The structure of the rocks is not clearly revealed by the map because the area shown is small. Many small faults are present, but the outstanding feature is a reverse fault that strikes about N. 45° W. and dips steeply north; it is shown in part on the southwest area of plate 17. Along this fault the conglomerate has been thrust southward over the younger Swauk formation. This reverse fault appears to have been displaced by a fault along which a prominent dike rose (pl. 17). The reverse fault extends farther west, beyond several hundred feet of conglomerate, where northward-dipping Swauk formation is exposed at a lower altitude than the conglomerate.

The massive character of the conglomerate makes determination of its attitude difficult. Locally it appears to strike N. 57° E. and to dip southeast about 50°; drilling has shown that the iron-rich lenses of the conglomerate dip to the south (pls. 17 and 18).

Undoubtedly, the surface of the serpentine basement is irregular but drilling indicates that here its dominant slope is southeastward (pl. 18).

ORIGIN OF THE CONGLOMERATE

Writers have generally agreed, in their concepts of the origin and accumulation of the conglomerate: the serpentine, the partly serpentinized peridotite, and the ferruginous material, all came from the serpentinized peridotite of the area. However, these writers disagreed regarding the mode of accumulation of the conglomerate. Smith (1904, p. 5) considered it one of several kinds of basal conglomerate of the Swauk formation that are of very local occurrence and that probably were derived chiefly from the underlying rock. He regarded at least one of these conglomerates, composed almost wholly of granodiorite boulders, as residual material that had been subjected to little or no transportation. He suggested that these conglomerates accumulated in a large lake, and that they

> mark the position of shallow bays where the sediments deposited were derived from the region immediately bordering the shore, and thus foreign material among the pebbles is of exceptional occurrence.

Broughton (1944, p. 13) states:

> The fine-grained beds or lenses probably represent material deposited as mud from more or less stagnant water, whereas the conglomerate probably represents deposition by torrential streams

but Lupher (1944, pp. 38–39), who discusses the question in some detail, states:

The unsorted character of the deposits, the extreme range of grain size from clay to large boulders, lack of stratification, and spacing of boulders in clay all suggest some form of soil and rock flow conditions. The deposit is similar in some respects to the mudflow and landslide materials formed on and below serpentine areas of the Mount Stuart region in the Pleistocene and still forming today.

Several fields of inquiry regarding the origin of the conglomerate may be suggested, chief among which are (1) the source and origin of the serpentine and the ferruginous matrix; (2) the mode of accumulation of the material; (3) changes subsequent to accumulation.

SOURCE AND ORIGIN OF THE SERPENTINE FRAGMENTS AND THE MATRIX

The writer believes that the information supplied by diamond drilling and chemical analyses furnishes the best clue to the source and origin of the serpentine fragments and the matrix of the conglomerate. Six of 10 holes drilled passed through conglomerate into underlying serpentine, and the others either remained in conglomerate or ended in the diabase that intrudes both the serpentine and the conglomerate. This fact indicates that the conglomerate normally rests upon the serpentine.

Chemical analyses of serpentine boulders, of some of the underlying serpentine, of the matrix, and of the iron-rich lenses, show clearly the distribution of iron, nickel, and chromium in the conglomerate, and are very instructive when compared with analyses cited by Leith and Mead (1915, p. 76) for residual iron ore and underlying serpentine in the Mayari district, Cuba. Analyses of the Cuban serpentine show the composition of material at 1 foot intervals from the surface to a depth of 29 feet, the depth at which the iron ore lies on serpentine. The analyses of the lowermost 6 feet are most pertinent, and are given in part below.

Partial analyses of Cuban ore grading downward into serpentine

Depth, feet	Composition, percent				
	Fe	Ni and Co	Cr	SiO_2	Al_2O_3
23–24	44.62	1.57	2.19	15.86	4.70
24–25	40.00	1.43	1.85	17.40	4.00
25–26	35.12	1.80	1.89	22.54	4.57
26–27	23.00	1.43	1.12	28.60	4.18
27–28	12.78	1.35	.77	35.64	2.33
28–29	7.10	.97	.20	39.80	1.39

Chemical analyses of the Blewett deposit showing progressive change from conglomerate into serpentine were not made, but analyses of various grades of Blewett material that correspond roughly to the grades of Cuban material cited are available. These roughly comparable analyses follow.

Partial analyses of various grades of Blewett material

Kind of material	Composition, percent				
	Fe	Ni	Cr	SiO_2	Al_2O_3
Matrix and lens, iron content above average	45.0	1.06	2.07	12.9	4.4
	40.8	----	----	17.0	3.4
	38.8	.98	2.04	----	----
Principal lens, average composition	32.6	.90	1.66	21.2	5.2
Matrix, iron content above average	23.0	----	----	29.9	6.7
	22.9	.68	1.14	----	----
Matrix, average composition	18.1	.52	.88	30.5	----
Entire conglomerate, average composition	13.3	.47	.64	34.4	----
Chiefly serpentine	7.1	.29	.36	----	----

The analyses of various grades of Blewett material show a remarkable similarity to roughly corresponding grades of Cuban material, and also show the same kind of variation of nickel, chromium, and silica in proportion to variation in iron content. The Cuban deposits are generally considered to be residual material formed in place from the underlying serpentine. The comparative analyses indicate clearly that the Blewett deposit also originated as residual material from serpentine, although it may not have accumulated in place. They also indicate that, probably, the Blewett peridotite was serpentinized before the formation of the residual material, as that probably was the history of the Cuban peridotite (Leith and Mead, 1911, p. 92).

The writer concludes that the serpentine and the matrix of the conglomerate were derived from the serpentine adjacent to and underlying the conglomerate; that the material of the matrix and lenses originated by weathering of the serpentine and that the shell of material surrounding many of the cobbles and boulders originated in the same manner; and that the serpentine fragments had been converted into serpentine from peridotite before they were incorporated into the conglomerate. It is probable, however, that at least part of the conglomerate in the Blewett area has been transported.

MODE OF ACCUMULATION

Explaining the accumulation of the conglomerate is more difficult than determining its origin because of (1) the nearly homogeneous composition and rather wide and uniform spacing of the cobbles and boulders; (2) the great range in size of the fragments imbedded in a comparatively fine-grained matrix; (3) the shell of weathered material surrounding many of the cobbles and boulders; and (4) the apparent lack of bedding. Furthermore, drilling indicates that the conglomerate rests on serpentine in which there were fissures into which finer material was carried, or upon whose surface there were large blocks of serpentine around which fine material accumulated, or a combination of these two conditions.

No theory requiring much transportation of the material by water is tenable because the large boulders are widely spaced in a fine-grained matrix, and a shell of weathered material surrounds many of them. Either the residual material accumulated almost entirely in place, or it has been moved but a short distance; however, the material might possibly have originated as a fault breccia, as the conglomerate locally is in fault contact with the Swauk formation.

The writer does not favor the fault breccia concept. If the material is fault breccia, either (1) it was converted into fault breccia after it had first been formed as residual material and after the deposition of the Swauk formation, or (2) it was converted into fault breccia before exposure and weathering of the serpentinized peridotite. The first theory does not account for the character and distribution of the boulders in the conglomerate, as residual weathering in situ probably would produce material of nearly uniform size, like that of the Cuban lateritic deposits. The second theory requires that the fault breccia consisted of fine-grained material (such as gouge) throughout which larger serpentine fragments were more or less uniformly distributed, and that this fault breccia was subsequently exposed and weathered. If so, the matrix of the conglomerate would be the finer and more completely weathered material that surrounded the larger fragments, and the cobbles and boulders would be spheroidally weathered larger fragments of the serpentine. This mode of origin implies pre-Swauk faulting of the serpentinized peridotite followed by surface exposure and long weathering of the fault breccia as the Swauk formation rests upon the conglomerate in the surrounding area. It also implies subsequent burial of the weathered breccia beneath the Swauk formation, and later faulting to account for the present field relations.

The evidence indicates the residual formation of material, probably combined with landslide or mudflow activity. This theory would require that the serpentine have a very uneven surface, possibly due to faulting, such as there is in parts of the region today. Chemical weathering in the flatter areas produced material resembling that of the iron deposits of the Mayari district, Cuba. In the more rugged areas chemical weathering probably was effective along the lower slopes and may have been accompanied by gradual movement of material down slope. In the steepest places, serpentine talus collected along the lower slopes and along benches. The larger serpentine fragments were gradually rounded by attrition and their outer portion was weathered, whereas the smaller serpentine fragments were completely decomposed and supplied much of the fine material that filled in around the larger fragments and in cracks in the underlying serpentine. Talus and residual material on slopes and benches moved as landslides or mudflows, and large fragments surrounded by muddy material could thus have been transported to lower areas. The writer believes that this theory of the origin and accumulation of the conglomerate is consistent with most of the features portrayed by the deposit. It is similar to the concept presented by Lupher (1944, pp. 38–39).

The writer's theory of the origin and accumulation of the conglomerate appears to fit well into the regional relations that exist between the serpentinized periodotite and the Swauk formation. Lupher (1944, pp. 42–63) presented a series of representative sections from the Blewett area west to Cle Elum River, showing the character of the material between the serpentinized peridodite and the lower part of the Swauk formation. These sections show that patches of peridodite conglomerate similar to that of the Blewett area are exposed in the vicinity of Nigger Creek, about 5 miles west of the Blewett area; that at many of the exposures in the next 7 or 8 miles west of Nigger Creek the material is finer grained, and peridotite conglomerate is not abundant; and that still farther west, near Cle Elum River, nearly all the ferruginous material is fine-grained and the peridotite conglomerate is practically absent. These facts could mean that west of the Blewett area the relief was generally less, and hence fine-grained residual material accumulated uninterrupted by talus formation, mudflows, and landslides. Lupher (1944, pp. 36–39) presented a somewhat similar regional picture, but believed that most of the fine-grained rock was transported residuum.

CHANGES SUBSEQUENT TO ACCUMULATION

After the conglomerate accumulated it was covered by the Swauk formation, folded, faulted, intruded by diabase, probably faulted again, and then exposed by erosion. Its present mineralogical composition reveals some of this history. Presumably, hydrous iron oxide, limonite, was formed in the early stages of weathering, and was later converted to the anhydrous oxide, hematite. This change may have taken place during a late phase of the residual accumulation. Descriptions of the residual deposits of Cuba (Leith and Mead, 1911, p. 92) show that the material near the bedrock is limonitic but that near the surface is hematitic. Chromite, magnetite, and spinel are comparatively resistant to chemical weathering, and probably accumulated in the conglomerate as unchanged constituents of the weathered peridotite. A considerable amount of magnetite may have accumulated in this manner, as practically all peridotites contain some magnetite. Probably some of the magnetite of the conglomerate was formed from limonite or hematite by thermal metamorphism induced by the higher temperature that must have prevailed during the intrusion of the many diabase dikes. Small veins of hematite and calcite that cut the conglomerate may well have been formed by downward moving ground water. The presence of magnetite veins suggests that there were two periods of iron migration, one before and the other after thermal metamorphism, the magnetite veins being thermally metamorphosed hematite veins of the first period of formation. Also, at least some hydrothermal veins and alterations probably are associated with igneous activity in the area.

ECONOMIC GEOLOGY

EXPLORATION

Many analyses made in connection with the early gold prospecting in the Blewett district showed the presence of some nickel in the serpentine, but there appears to have been very little early exploration of the Blewett iron-nickel deposit.

Claims owned by the Washington Nickel Mining Alloys, Inc., of Seattle, Wash., cover most of the area shown in plate 17. Exploration done some years ago consists of 10 pits and 2 caved adits. All of them are located in iron-rich lenses in the conglomerate.

Diamond drilling by the Bureau of Mines was started about June 1, 1943, and during that summer four holes were drilled. Additional drilling was done during the winter of 1943–44 and in the early part of the summer of 1944. Altogether 10 holes totaling 2,395 feet were drilled. The Bureau of Mines selected the locations of the diamond-drill holes and did the drilling, and members of the Geological Survey logged the cores of most of these holes. In addition, the Bureau of Mines collected a number of surface samples of the principal iron-rich lens and the conglomerate. The purpose of the exploration was to determine the continuity, extent, and composition of the principal iron-rich lens and also of the entire conglomerate.

In July 1943 Geological Survey geologists mapped the most promising part of the area and carefully collected samples of the conglomerate. These samples were sorted into (a) matrix, and (b) pebbles, cobbles, and boulders, in order to determine not only the average composition of the conglomerate, but also variations of composition within it.

PRINCIPAL IRON-RICH LENS

CHEMICAL COMPOSITION

The chemical analyses indicate that the principal iron-rich lens contains the highest percentages of iron, nickel, and chromium. Its probable average composition follows.

Average of partial analyses of the principal iron-rich lens, Blewett iron-nickel deposit

Constituent	Percent		Feet analyzed	Number and kind of samples		
				Bureau of Mines		Geological Survey
	Average	Range		Surface	Drill core	Surface
Fe	32.65	18.65 –45.35	282.7	30	11	10
Ni	.90	.62 – 1.16	236.2	30	11	--------
Cr	1.66	.96 – 2.22	236.2	30	11	--------
SiO_2	21.2	12.9 –29.9	78.5	3	2	10
Al_2O_3	5.2	3.3 – 7.5	46.5	--------	--------	10
Mn	.36	.27 – .45	32.0	3	2	--------
S	.073	.054– .114	32.0	3	2	--------
P	.035?	------------	5.0	--------	1	--------

The analyses of the Bureau of Mines samples were made by the Bureau and furnished to the Geological Survey. The analyses of the Geological Survey samples were made by the Metallurgical Laboratory, 5200 Airport Way, Seattle, Wash.

In general, nickel and chromium vary directly and silica varies inversely as the iron content. The analyses show wide variation, but analyses grouped according to range of iron content show fairly consistent relations. The alumina content appears to decrease with increase in iron content, but this fact is not well established from the few analyses made. Some of these variations are shown by the following tables and by figure 6.

Variation of nickel and chromium with the amount of iron in the iron-rich lens Blewett iron-nickel deposit

Range of iron content, percent	Composition, percent			Feet of core analyzed
	Fe	Ni	Cr	
20–25	22.07	0.76	1.06	38.0
25–30	27.25	.86	1.54	59.5
30–35	32.96	.87	1.63	50.7
35–40	38.84	.98	2.04	29.0
40–45.35	43.17	1.05	2.11	54.0

Variation of silica and alumina with the amount of iron in iron-rich lens Blewett iron-nickel deposit

Composition, percent			Feet of core analyzed
Fe	SiO_2	Al_2O_3	
23.0	29.9	6.7	3.0
26.2	25.2	7.4	6.0
26.5	27.5	4.8	4.5
26.5	27.3	6.3	3.5
29.8	23.5	4.7	4.5
33.2	21.7	4.2	3.0
33.6	21.1	7.5	5.0
40.8	17.9	3.3	6.0
40.8	16.0	3.5	5.0
45.0	12.9	4.4	6.0

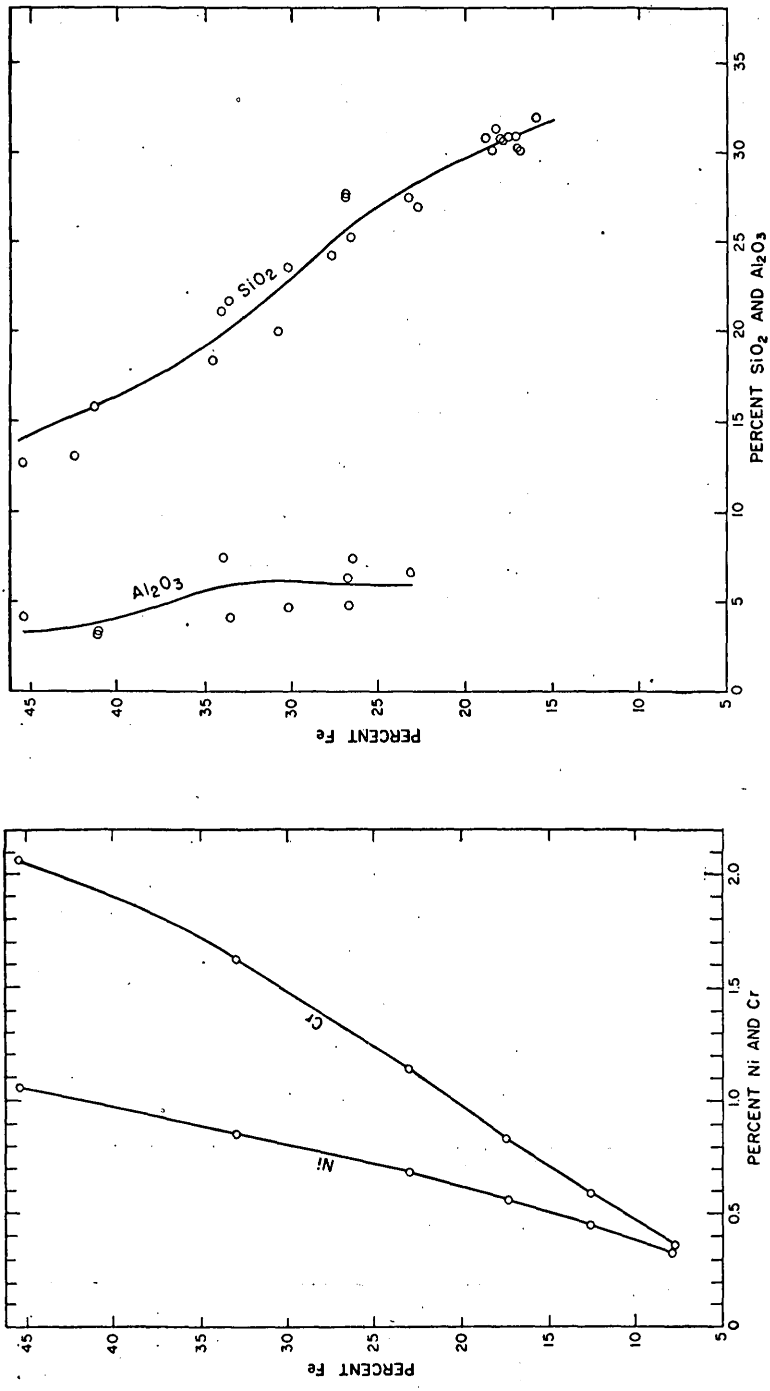


FIGURE 6.—Variation of nickel, chromium, silica, and alumina in relation to the iron content of the iron-rich lens. Points plotted represent average analyses grouped according to range of iron content, except for silica and alumina values which were obtained from analyses of matrix and iron-rich lenses only.

EXTENT

Drilling has indicated that the principal iron-rich lens is small, becomes thinner down the dip toward the southeast, and probably ends at the south against a reverse fault (pls. 17 and 18).

THE PERIDOTITE CONGLOMERATE

CHEMICAL COMPOSITION

Analyses of the conglomerate samples from drill holes and surface exposures have been grouped to show the composition of (a) matrix, (b) cobbles and boulders, (c) conglomerate containing various size fragments and various amounts of serpentine, and (d) the entire conglomerate. A tabulation of the average results follows.

Distribution of iron, nickel, and chromium in the peridotite conglomerate, Blewett iron-nickel deposit

Type of material	Average composition, percent		
	Fe	Ni	Cr
Principal iron-rich lens	32.65	0.90	1.66
Matrix of the conglomerate	18.11	.52	.88
Conglomerate containing serpentine fragments not more than ½ foot across	14.86	.49	.73
Entire conglomerate, including all iron-rich lenses	13.34	.47	.64
Conglomerate containing serpentine fragments larger than ½ foot across	12.11	.43	.60
Material consisting of about 75 percent serpentine	8.54	.23	.42
Material consisting of about 95 percent serpentine	7.18	.29	.36
Serpentine cobbles and boulders of the conglomerate	6.25	.25	.27

The material analyzed ranges widely in composition, but at least three-fourths of it contains less than 15 percent iron.

Examination of drill cores and rock exposed at the surface indicates that about three-fifths of the conglomerate is matrix and two-fifths is cobbles and boulders.

Considerable variation is shown in the average iron, nickel, and chromium content of the conglomerate from different drill holes. The richest is from hole 4, and samples from holes 60 and 62 are above average. Analyses of material that was chiefly serpentine have been omitted. Data for eight drill holes are assembled below.

Average analyses of conglomerate from drill holes, Blewett iron-nickel deposit

Hole No.	Feet of core analyzed	Composition, percent		
		Fe	Ni	Cr
2	202	13.10	0.41	0.66
3	102	13.21	.45	.69
4	197	17.56	.59	.84
57	295	11.07	.39	.52
59	49	6.41	.28	.28
60	198	14.16	.48	.62
61	114	11.86	.49	.56
62	281	14.62	.52	.66

Composite silica analyses were made by the Bureau of Mines for material from drill holes 60, 61, and 62. They gave, respectively, 34.7, 38.4, and 33.4 percent silica, or an average of 34.4 percent. The iron content of samples from these three holes is close to the average of the entire conglomerate, and it may be that the silica content also is close to the average of the entire formation.

REFERENCES CITED

BROUGHTON, W. A., 1943, The Blewett iron deposit, Chelan County, Wash., with preliminary tonnage estimates: Washington Dept. Conserv. and Devel., Div. Geology Rept. Inv. 10.

———, 1944, Economic aspects of the Blewett-Cle Elum iron ore zone, Chelan and Kittitas Counties, Wash.: Washington Dept. Conserv. and Devel., Div. Geology Rept. Inv. 12, pp. 13–16, 41–42.

JENKINS, O. P., and COOPER, H. H., 1922, A study of the iron ores of Washington: Washington Dept. Conservation, Div. Geology, Bull. No. 27 (geol. ser.), pp. 70–72.

LEITH, C. K. and MEAD, W. J., 1911, Origin of the iron ores of central and northeastern Cuba: Am. Inst. Min. Eng. Trans. vol. 42, pp. 90–102.

———, 1915, Additional data on origin of lateritic iron ores of eastern Cuba: Am. Inst. Min. Eng. Trans. vol. 53, pp. 75–78.

LUPHER, R. L., 1944, Stratigraphic aspects of the Blewett-Cle Elum iron ore zone, Chelan and Kittitas Counties, Wash.: Washington Dept. Conserv. and Devel., Div. Geology, Rept. Inv. 11.

RUSSELL, I. C., 1900, Preliminary paper on the geology of the Cascade Mountains in northern Washington: U. S. Geol. Survey 20th Ann. Rept., pt. 2, pp. 83–210.

SMITH, G. O., 1904, U. S. Geol. Survey Geol. Atlas, Mount Stuart Folio, Wash., (No. 106).

WEAVER, C. E., 1911, Geology and ore deposits of the Blewett mining district, Wash.: Washington Geol. Survey Bull. 6.

INDEX