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

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BUREAU OF MINES  
JAMES BOYD, DIRECTOR

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REPORT OF INVESTIGATIONS

CLE ELUM IRON-NICKEL DEPOSITS  
KITITITAS COUNTY, WASH.



BY

S. W. ZOLDOK



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ERRATUM

For paragraph 1, page 1, read the following:

The Cle Elum nickeliferous iron deposits occur on an unconformable contact between the serpentine and overlying Swauk sandstone formation and extend about 2 miles along the Cle Elum River in Kittitas County, Wash.



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## REPORT OF INVESTIGATIONS

### UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

#### CLE ELUM IRON-NICKEL DEPOSITS, KITTITAS COUNTY, WASH.<sup>1/</sup>

By S. W. Zoldok<sup>2/</sup>

#### INTRODUCTION

The Cle Elum nickeliferous iron deposits occur in a serpentine formation extending about 20 miles along the Cle Elum River in Kittitas County, Wash.

The linear extent of the deposits and their proximity to a large source of low-cost electric power and coal supply indicated that a development program was in order to determine the probable grade, extent of the ore bodies, and a suitable metallurgical process for recovering the iron, nickel, and chromium from the ore.

The northern portion of the serpentine formation was investigated by the Bureau of Mines from August to December 1943 and from August to October 1944. The investigation consisted of road building, diamond drilling, sampling, and metallurgical tests.

The Geological Survey assisted with logging of cores and made geologic and topographic maps.

#### ACKNOWLEDGMENTS

In its program of investigations of mineral deposits, the Bureau of Mines has as its primary objective the more effective utilization of our mineral resources to the end that they make the greatest possible contribution to national security and economy. It is the policy of the Bureau to publish the facts developed by each project as soon as practicable after its conclusion. The Mining Branch, under the direction of Lowell B. Moon, chief, conducts preliminary examinations; performs the actual development work, and prepares the final report. The Metallurgical Branch, under the direction of O. C. Ralston, chief, analyzes samples and performs beneficiation tests.

#### LOCATION AND ACCESSIBILITY

The Cle Elum iron-nickel deposits are in secs. 26, 34, and 35, T. 23 N., R. 14 E., and in secs. 2 and 3, T. 22 N., R. 14 E., about 26 miles north of Cle Elum, Kittitas County, Wash.

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<sup>1/</sup> The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Report of Investigations 4189."

<sup>2/</sup> Mining engineer, Albany Division, Mining Branch, Bureau of Mines.

A paved secondary road connects Cle Elum, Roslyn, and Ronald. From a point 2 miles north of Ronald a good dirt road goes to the properties. The nearest railway shipping point is Roslyn, the terminus of the Roslyn spur of the Northern Pacific Railway, about 22 miles south of the deposits.

#### HISTORY AND OWNERSHIP

Iron deposits were discovered in the Cle Elum district in the early eighties, and considerable prospecting was done up to about 1903. The unusual nature of this iron ore containing nickel and chromium became evident, but no further attempts were made to develop the deposits until World War II started. To date, no ore has been produced.

Nineteen patented mining claims and one unpatented mining claim are owned by the Balfour-Guthrie Investment Co., Dexter Horton Building, Seattle, Wash.

One patented claim, the Iron King, is jointly owned by O. B. Brown of Kennimore, Wash., and Henry R. Spedden, Seattle, Wash.

#### PHYSICAL FEATURES AND CLIMATE

The area investigated by the Bureau lies in a broad river valley approximately 3,000 feet in elevation. The deposits extend eastward from the Cle Elum River for about 20 miles through rugged parts of the mountain range attaining altitudes up to 7,500 feet.

The climate is mild and dry during the summer, but there are heavy snowfalls during the winter. The temperature seldom drops below 0° F.

Water and timber are abundant in the district.

#### LABOR AND LIVING CONDITIONS

The property is 20 to 26 miles from the nearest coal-mining communities of Ronald, Roslyn, and Cle Elum to the south. A limited supply of skilled labor is available. The prevailing local wage rate (1944) for skilled underground labor is \$8.00 to \$10.00 per day, depending upon the degree of skill and type of work. The rate for unskilled labor is \$7.50 per day.

No living accommodations are available at the property. A limited number of persons can be housed in abandoned cabins.

#### DESCRIPTION OF DEPOSITS

The principal rocks exposed in the district are a basal pre-Tertiary serpentinitized peridotite overlain by the iron formation, Tertiary Swauk sandstone, and post-Swauk basic and acidic dikes and sills. The dikes and sills are small and not very numerous in the area drilled.

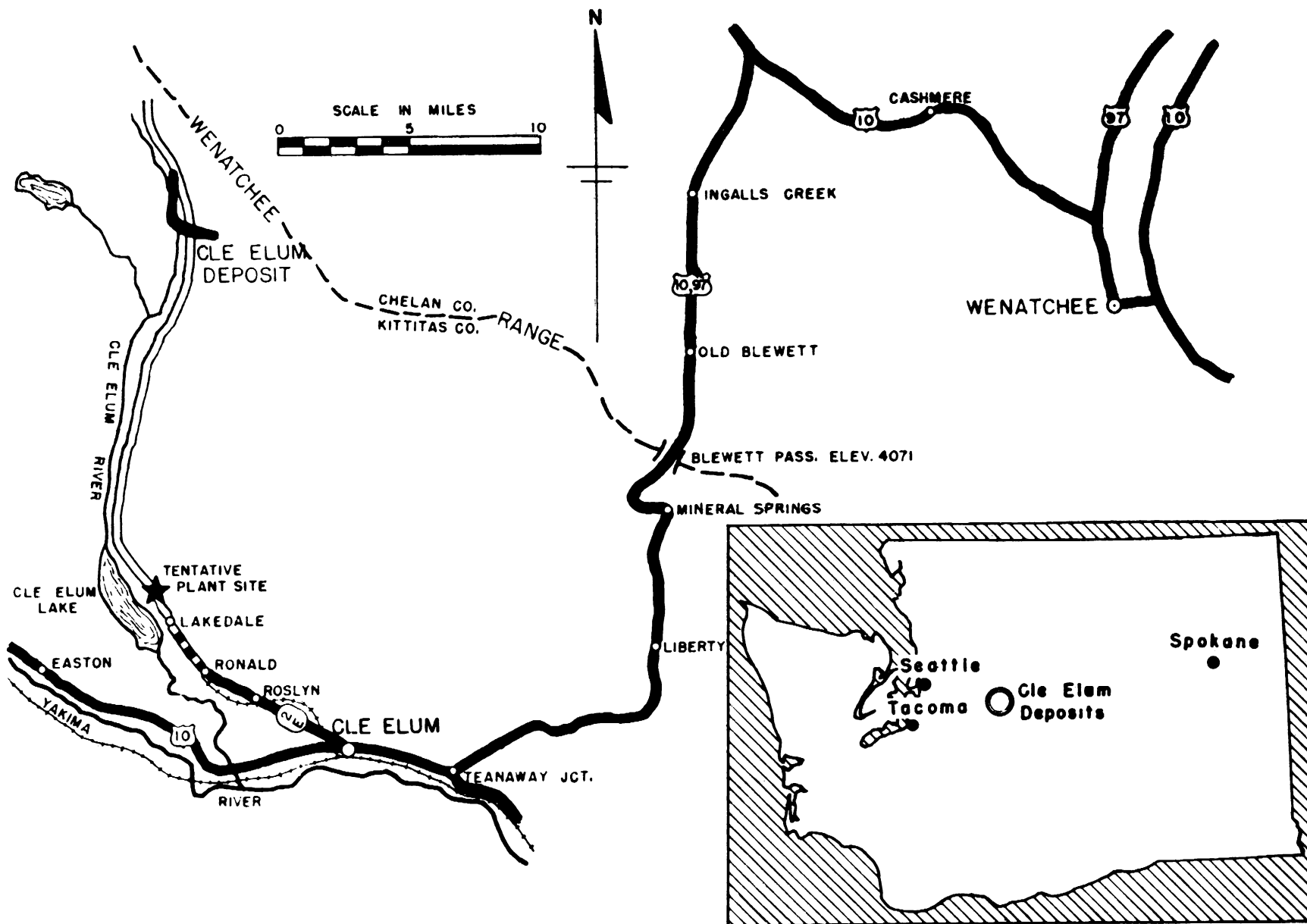


Figure 1. - Index map of Washington, showing location of Cle-Elum nickel-iron deposit.





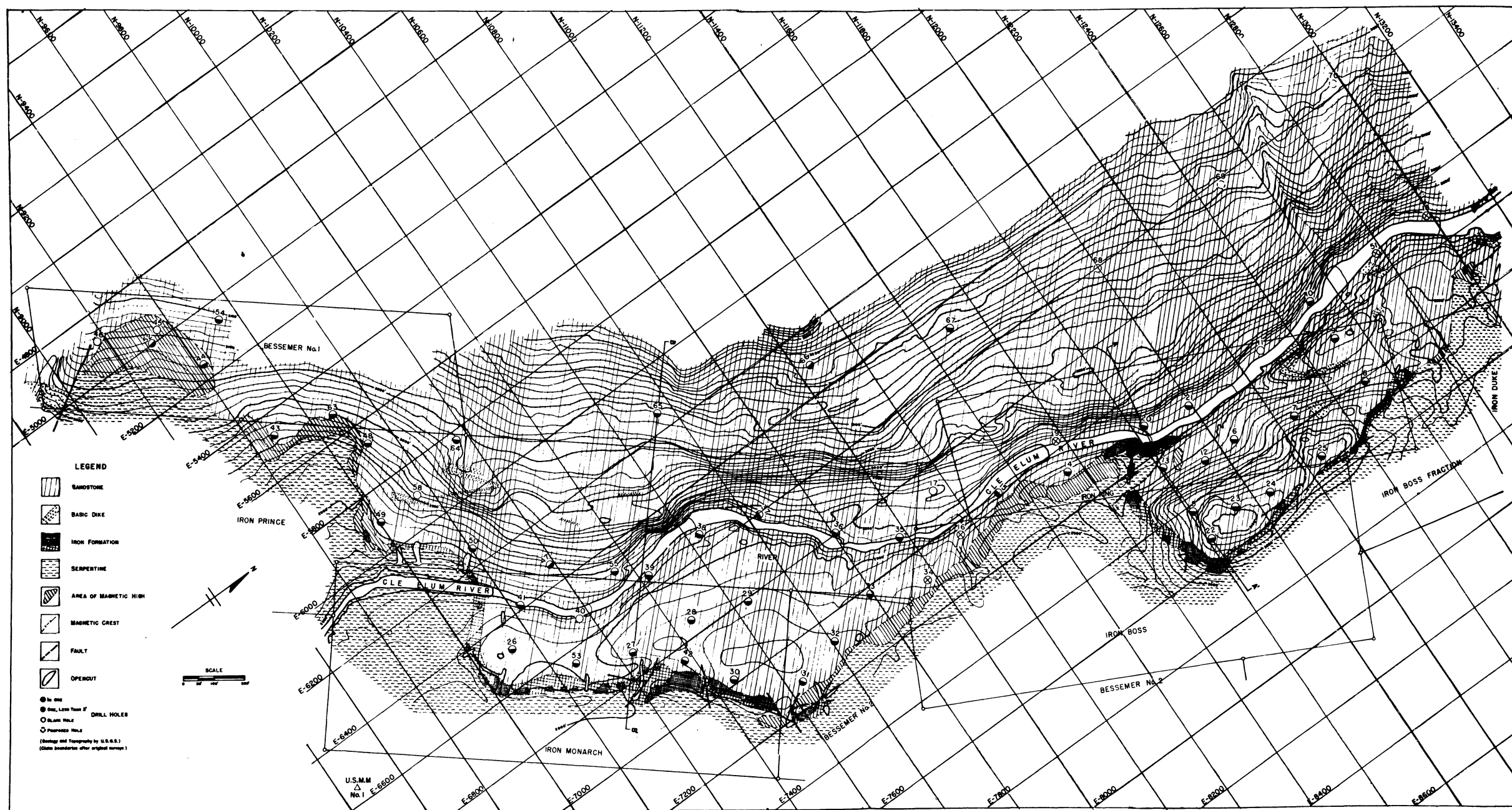


Figure 2. - Claim map, geology, and location of drill holes.



The iron formation is derived from weathering of the parent serpentine rock and originated as a residual deposit of a porous lateritic blanket on the surface of the serpentine. Numerous small catch basins received local drainage charged with sediments from the residual laterite, resulting in increased thickness of the laterite in the basins and decreased thickness, or total removal, of laterite in areas surrounding these basins. This would account for the present lenticular shape of the iron formation. A variation in the depth of weathering due to other physical or chemical factors would also affect the present shape of the iron formation. Although reworking of the laterites is believed to be purely local within the area drilled, enough evidence exists to indicate that the reworking was very extensive in other portions of the deposits. Following the process of weathering and reworking, the laterites became deeply buried under sandstone and were compressed and partly metamorphosed into a dense, nickeliferous iron ore.

The ore shows excellent continuity along both strike and dip between coordinates N. 9,600 and N. 12,700 (fig. 1). The ore in this area has an average dip of approximately  $30^{\circ}$  to the west and an average mining thickness of 14.6 feet, excluding drill holes showing a thickness of less than 4 feet and a grade less than 40 percent iron. Including all material above 30 percent iron increases the average mining thickness to 16.8 feet. South of coordinate N. 9,600 and west of the Cle Elum River several diamond-drill holes and the dip-needle survey indicate that the iron formation is extremely lenticular, with long, barren areas between the individual lenses of ore.

The iron formation has been displaced by both thrust and normal faults, causing in some places repetition and others omission of the ore. All faults encountered in drill holes are apparently of small displacement (fig. 2).

The serpentine weathering surface, on which the iron formation occurs, is continuous for 20 miles eastward.<sup>4/5/6/</sup> The extent of ore deposits on this formation is not known, but an examination of several points on this formation for a distance of approximately 10 miles eastward indicates that the iron formation is extremely erratic in occurrence. Much of the laterite in the areas now exposed was removed by erosion during or preceding the period of Swauk sedimentation.

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- 4/ Smith, George Otis, Mt. Stuart Folio, Washington: Geol. Survey Atlas of the United States, Folio 106, 1904.
  - 5/ Broughton, W. A., Economic Aspects of Blewett-Cle Elum Iron Ore Zone, Chelan and Kittitas Counties, Wash. State of Washington, Division of Geology, Rept. of Investigations 12, 1944.
  - 6/ Lupper, R. L., Stratigraphic Aspects of the Blewett-Cle Elum Iron Ore Zone, Chelan and Kittitas Counties, Wash. State of Washington, Division of Geology, Rept. of Investigations 11, 1944.

## CHARACTER OF ORE

In general, the ore is lamellar at the base, massive toward the center, and oolitic and often amorphous toward the top but may be massive or oolitic throughout, depending upon the iron and alumina content. The oolitic ore is low in iron and nickel and high in alumina, while the massive and laminated ores are high in iron and nickel and low in alumina. The amorphous texture observed in the upper half of some portions of the iron formation is due to the presence of amorphous graphite, which also occurs extensively in the overlying sediments. (See fig. 3.)

The principal iron minerals are magnetite, hematite, and limonite, which occur intermixed and are intimately associated with serpentine, olivine, and rock decomposition products. Nickel in the form of garnierite occurs intermixed with the olivine-serpentine gangue. The chromium in the ore appears to be present as an impure chrome bearing spinel.

A diagram illustrating the relative percentages of iron, nickel,  $\text{Cr}_2\text{O}_3$ , alumina, and silica through the iron formation is shown in figure 4. The iron increases from 25 percent at the top to 45.5 percent at the center and 47 percent at the bottom. Nickel increases progressively from 0.35 percent at the top to 1.40 percent at the bottom. The  $\text{Cr}_2\text{O}_3$  curve in general follows that of iron and increases from 1.56 percent at the top to 2.88 percent at the bottom. Alumina decreases progressively from 36.5 percent at the top to 4.5 percent at the bottom. Silica decreases from 14.0 percent at the top to 7.4 percent at the center and again increases to 10.6 percent at the bottom. The increase in silica content from the center to the bottom of the iron formation may be due to the lamellar structure of the ore, since the laminations are formed by alternate "stringers" of iron oxides and gangue material.

In many of the drill holes the serpentine underlying the iron formation was found to contain a concentration of nickel values of a grade comparable to that in the lower portion of the iron formation. The areas of nickel concentration in the serpentine appear to cluster near fault zones, although all fault zones do not have these concentrations.

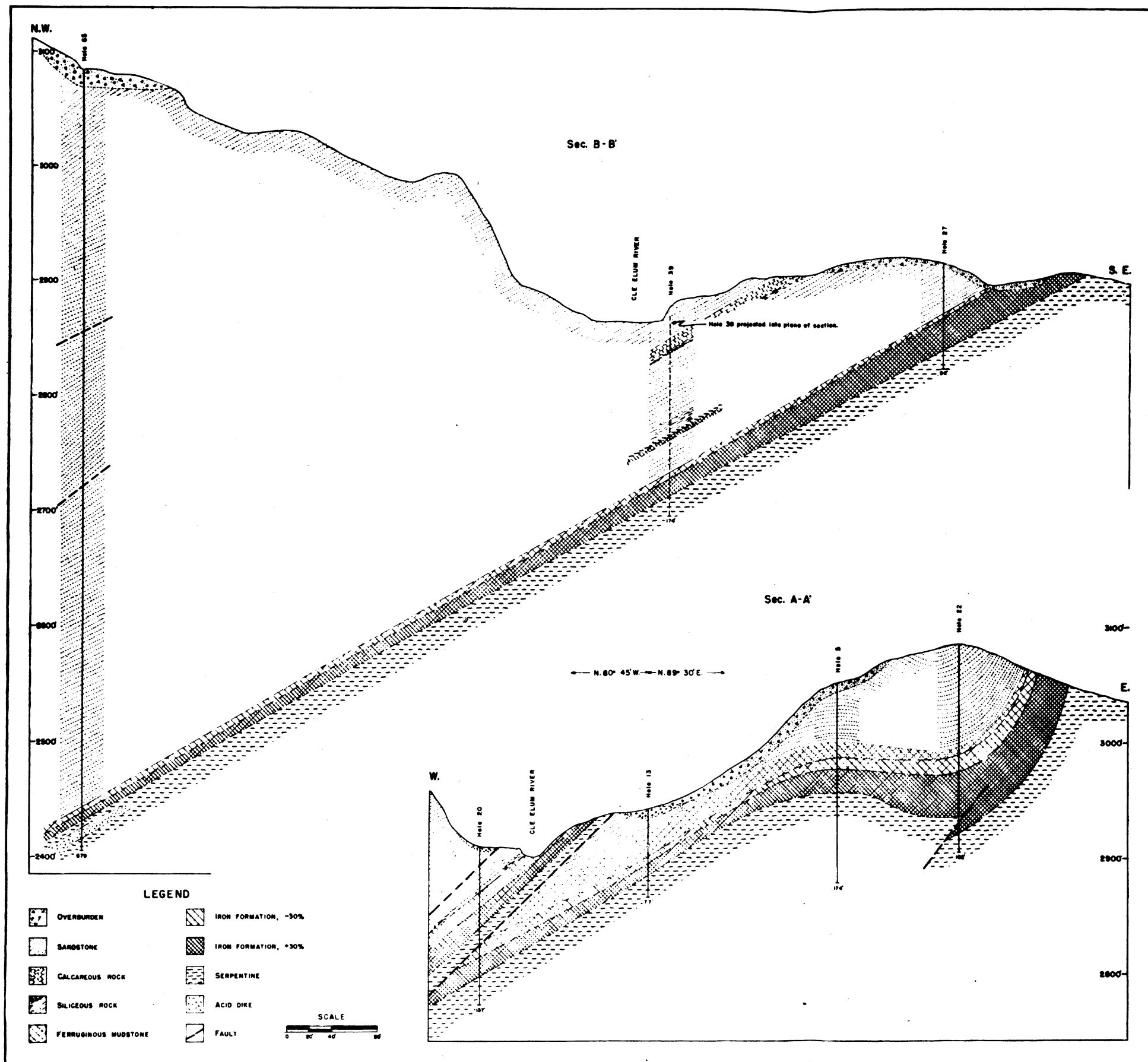
## MINE WORKINGS AND EQUIPMENT

The deposits were extensively explored by surface trenches, test pits, and several adits between 1890 and 1903. The majority of these old workings are now caved. In addition, the deposits were explored at depth with four diamond-drill holes during the same period. All drill-hole records are reported to have been lost in the San Francisco earthquake and fire of 1906.

## WORK PERFORMED BY BUREAU OF MINES

### Diamond Drilling

The Bureau's exploratory program was carried out during August to December 1943 and August to October 1944. During these periods 57 vertical





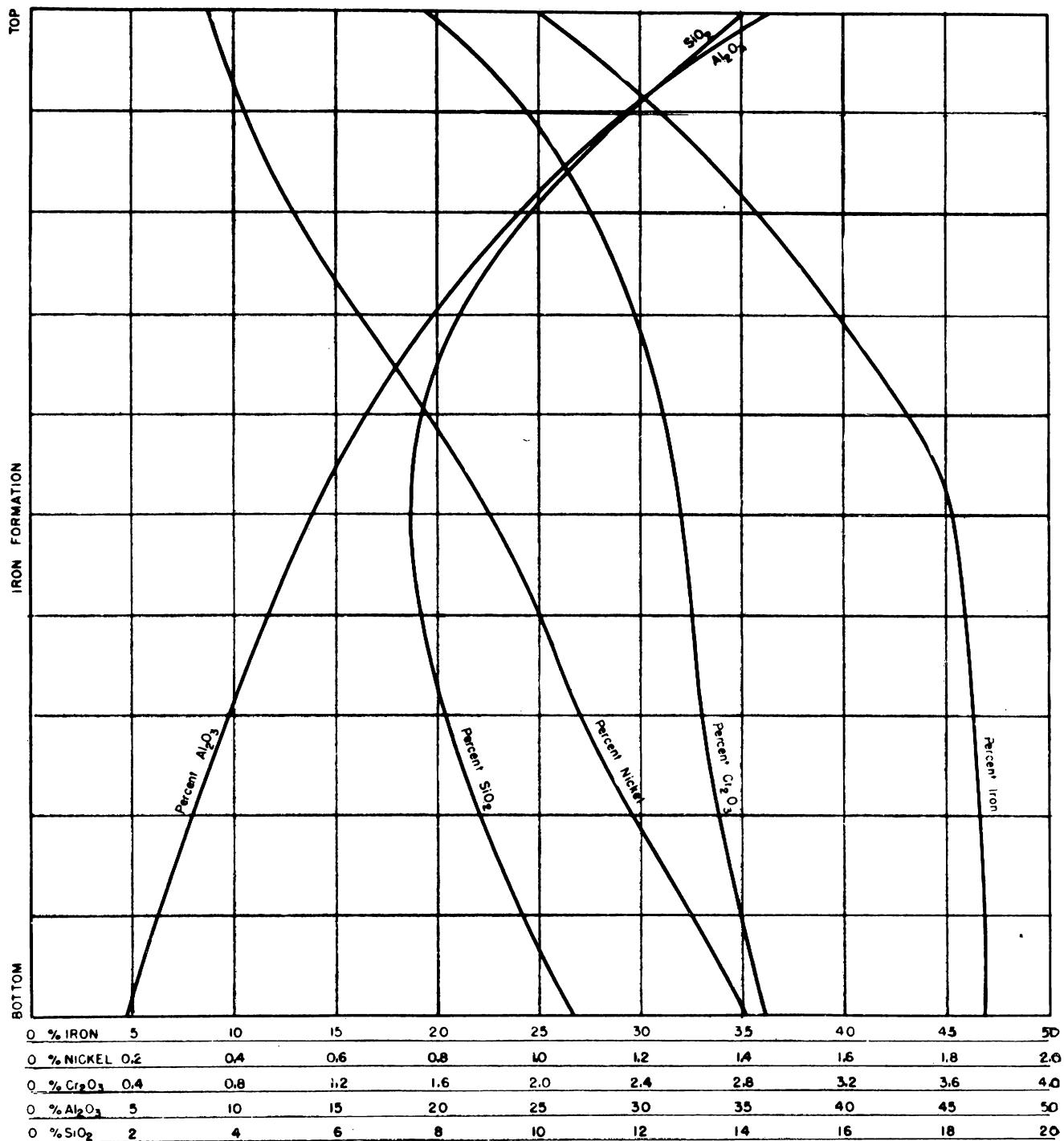


Figure 4. - Diagram illustrating percentages - iron, nickel,  $\text{Cr}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{SiO}_2$  through the iron formation.





holes, totaling 11,219 feet, were drilled from surface stations. Drill holes varied in depth from 54 feet to 811 feet. Acid etch surveys indicated that the deep holes deviated from 1° to 7° at their maximum depths. Only holes exceeding 500 feet in depth were surveyed.

Of the 11,219 feet drilled at the project, 469 feet or 4 percent was standpipe, 525 feet or 5 percent was BX core, 7,263 feet or 65 percent was AX core, 2,512 feet or 22 percent was AX plug bit, and 450 feet or 4 percent was EX core. Standard practice was to drill up to 15 feet into bedrock with BX size to get a good seal and then to complete the hole with AX size. Under exceptionally difficult conditions AX holes were cased and completed with EX size. Core recovery was excellent throughout, except in a few holes where faulting had crushed the iron formation. Water return was good as only 651 feet or 6 percent of total footage was cemented.

### Sampling

During the drilling program, 446 diamond-drill samples were taken for assay purposes. In addition, approximately 15 tons of ore was shipped to the metallurgical laboratory at Salt Lake City, Utah, and 17 tons to the metallurgical laboratory at Albany, Oreg., for test purposes. It is further planned to ship enough nickeliferous serpentine to the Albany laboratory for metallurgical testing.

### Miscellaneous

During 1943 10 temporary bridge structures were built across the Cle Elum River to afford access to drill sites west of the river. In 1944 it was necessary to build a permanent bridge with a span of 72 feet and a minimum load capacity of 20 tons.

During both seasons a bulldozer was rented from the Bonneville Power Administration, United States Department of the Interior. During the rental period, 22,080 feet of roads were built, and numerous drill stations were excavated to expedite drilling operations. Approximately 60 percent of roads built was through talus material having large boulders and covered by a dense growth of "buck-brush."

A Government boarding house was operated in conjunction with the project during both seasons.

### METALLURGY

The Metallurgical Branch of the Bureau of Mines has made an extensive metallurgical investigation of the Cle Elum ores. This work has resulted in the development of an electric smelting process by which the nickel can be recovered on a high-grade nickel-iron alloy and the iron can be recovered in a low-chromium steel.

The process is fully described in a Report of Investigations, 4122, Electric Smelting of Low-Grade Nickel Ores, by Ravitz, S. F., metallurgist, Salt Lake City Division, Metallurgical Branch, which is now in press.

TABLE 1. - Sample analyses - Cle Elum project

Hole No.	From	To	Feet	Analyses, percent						
				Fe	Ni	Cr <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	S	P
5	75.0	96.0	21.0	39.91	0.68	2.38	15.6	6.9	0.102	0.036
6	54.0	82.5	28.5	43.32	.78	2.48	16.3	6.5	.038	.036
7	119.0	124.0	5.0	48.69	.87	2.59	9.7	7.2	.106	.015
8	30.0	35.0	5.0	36.69	.55	2.08	19.7	9.9	.048	.027
	35.0	40.0	5.0	42.00	1.03	2.42	13.1	11.0	.004	.044
9	144.0	159.0	15.0	46.56	.84	3.25	10.3	8.2	.150	.034
10	186.0	191.0	5.0	32.21	.35	1.92	22.8	13.1	.008	.048
	191.0	201.0	10.0	44.15	.93	2.19	9.3	11.9	.007	.017
12	28.0	49.9	21.9	44.50	.80	2.55	16.0	5.8	.028	.040
13	42.0	47.0	5.0	32.10	.32	3.20	23.0	12.8	.059	.074
	47.0	57.0	10.0	49.18	.72	3.18	8.6	7.8	.018	.029
14	40.0	50.0	10.0	30.60	.56	1.62	26.4	13.5	.065	.073
15	55.0	61.0	6.0	34.01	.36	1.95	30.1	8.5	.032	.095
	61.0	76.0	15.0	45.61	.97	2.04	10.6	7.2	.012	.021
20	42.0	52.0	10.0	31.15	.32	2.78	29.5	10.2	.016	.073
	52.0	72.0								
	96.0	112.0	36.0	46.66	.95	2.23	8.8	9.7	.015	.023
21	109.0	114.0								
	116.8	122.5	10.7	47.46	1.26	2.11	7.5	8.5	.024	.025
22	100.0	111.0	11.0	36.80	.22	2.63	27.5	6.5	.024	.044
	111.0	151.0	40.0	46.56	.95	2.85	12.2	5.9	.032	.024
23	130.0	136.8								
	142.2	177.0	41.6	38.00	.44	1.61	28.5	5.0	.020	.032
24	69.5	120.0	50.5	45.27	1.18	2.32	8.8	9.6	.032	.040
25	77.0	85.0	8.0	32.54	.45	1.33	21.5	17.5	.073	.015
26	53.3	61.0	7.7	36.20	.69	2.30	22.9	11.5	.158	.059
	61.0	82.0	21.0	43.91	.96	2.84	10.9	6.5	.055	.049
27	47.0	76.0	29.0	44.27	1.15	2.69	6.9	8.7	.021	.020
28	108.0	116.5	8.5	40.44	.86	3.64	10.1	11.6	.212	.046
29	190.0	199.0	9.0	33.50	.39	2.02	29.9	9.3	.019	.168
	199.0	203.0	4.0	47.01	1.27	3.64	6.4	9.4	.076	.030
30	20.0	35.0	15.0	48.52	1.43	2.80	7.2	10.0	.056	.017
31	27.0	46.5	19.5	46.78	.89	2.46	15.9	5.4	.076	.033
32	48.0	54.7	6.7	41.77	1.02	1.51	5.3	10.3	.024	.015
33	79.0	84.6	5.6	42.80	1.21	2.22	7.1	6.4	.570	.027
35	114.0	118.5	4.5	44.19	.88	2.01	12.2	7.7	.160	.015
36	181.5	192.0	10.5	45.17	1.18	2.78	10.1	7.4	.017	.033
37	267.0	275.5	8.5	32.77	.27	1.39	38.2	9.7	.040	.065
	275.5	289.1	13.6	45.62	1.30	2.75	11.9	8.4	.017	.022
38	225.1	234.6	9.5	49.63	1.23	2.73	7.8	6.4	.059	.029
39	104.2	107.5								
	139.5	155.5	19.2	47.57	.94	2.82	9.2	7.0	.051	.022
41	48.3	77.2	28.9	41.50	.84	2.96	16.6	9.7	.091	.062
42	22.0	26.0	4.0	32.13	.33	1.67	29.1	9.0	.013	.034
	26.0	37.5	11.5	49.96	1.23	2.75	6.2	5.7	.010	.017

TABLE 1. - Sample analyses - Cle Elum project (cont'd.)

Hole No.	From	To	Feet	Analyses, percent						
				Fe	Ni	Cr <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	S	P
43	49.6	53.6	4.0	37.75	.62	2.53	14.4	12.1	0.064	0.065
	53.6	59.0	5.4	48.12	1.17	3.15	7.8	7.4	.023	.054
44	115.4	132.0	16.6	41.84	1.16	3.13	8.0	10.8	.049	.032
	132.0	136.1	4.1	33.70	1.28	2.75	3.7	15.8	.015	.025
47	188.0	201.0								
	275.0	278.0	16.0	36.00	.64	2.10	18.6	11.7	.170	.068
	201.0	225.5								
	268.0	275.0	31.5	45.69	.91	2.78	12.8	6.4	.047	.064
48	375.0	387.0	12.0	32.98	.51	1.94	25.2	13.9	.070	.090
	387.0	421.0	34.0	46.12	1.10	2.89	13.0	8.2	.025	.045
49	70.0	83.0	13.0	35.02	.66	2.25	22.2	12.9	.159	.102
	83.0	104.0	21.0	44.25	.84	2.63	13.4	6.8	.015	.084
50	31.8	42.0	10.2	47.92	1.18	2.92	7.2	8.3	.126	.035
52	44.9	49.3	4.4	51.77	1.43	2.91	5.2	7.5	.027	.033
53	44.0	54.0	10.0	46.35	1.11	2.73	7.1	7.1	.143	.234
54	259.3	264.9	5.6	36.48	.75	2.29	15.4	15.4	.035	.086
55	181.3	191.7	10.4	48.55	1.09	2.69	7.3	7.2	.093	.022
63	65.0	71.0	6.0	40.79	.32	2.61	15.6	10.2	.030	.053
64	482.0	493.0								
	493.5	495.0	12.5	49.21	1.23	2.88	6.8	5.6	.090	.034
65	642.0	647.0	5.0	32.69	.50	1.86	22.1	13.5	.024	.057
	647.0	653.7	6.7	51.34	1.27	3.10	7.6	5.6	.069	.027
66	778.0	784.3	6.3	35.71	1.00	2.43	13.8	13.2	.058	.055
67	694.0	700.0	6.0	30.02	1.06	1.94	12.7	19.6	.076	.110

TABLE 2. - Nickeliferous serpentine sample analyses -  
Cle Elum project

Hole No.	From	To	Feet	Nickel, percent
6	82.5	91.0	8.5	0.76
	91.0	102.0	11.0	1.09
7	124.0	157.0	33.0	1.00
8	40.0	81.0	41.0	.79
9	159.0	170.0	11.0	1.28
10	201.0	216.0	15.0	1.28
12	49.9	77.0	27.1	1.58
13	57.0	77.0	20.0	.60
14	50.0	77.0	27.0	.61
15	76.0	94.0	18.0	.77
20	72.0	96.0	24.0	.63
21	122.5	137.0	14.5	.60
22	151.0	182.0	31.0	1.09
24	120.0	137.0	17.0	.70
26	82.0	97.0	15.0	.71
27	76.0	92.0	16.0	.77
28	116.5	123.0	6.5	.77
	123.0	133.0	10.0	1.37
29	203.0	218.0	15.0	1.40
	218.0	225.0	7.0	.78
30	35.0	45.0	10.0	.91
	45.0	54.0	9.0	1.26
31	46.5	66.0	19.5	1.31
32	54.7	72.0	17.3	.72
33	84.6	95.0	10.4	.91
36	192.0	206.0	14.0	1.38
37	289.1	294.5	5.4	1.25
38	234.6	252.0	17.4	.71
39	101.0	104.3	3.3	.79
41	77.2	78.3	1.1	1.93
42	37.5	43.0	5.5	1.16
43	59.0	71.6	12.6	.52
44	136.1	150.0	13.9	.52
49	104.0	113.0	9.0	.99
52	49.3	82.0	32.7	.85
54	264.9	273.0	8.1	.94
55	191.8	202.0	10.2	.75
63	71.0	79.0	8.0	.52
64	495.0	522.0	27.0	.66
67	700.0	704.0	4.0	.57



