UNITED STATES DEPARTMENT OF THE INTERIOR

NICKEL-GOLD DEPOSIT NEAR MOUNT VERNON, SKAGIT COUNTY WASHINGTON

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BY

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NICKEL-GOLD DEPOSIT NEAR MOUNT VERNON, SKAGIT COUNTY, WASHINGTON

By S. W. Hobbs and W. T. Pecora

ABSTRACT

The Mount Vernon nickel-gold deposit is 4½ miles southeast of the city of Mount Vernon, Skagit County, Wash. It is a large, tabular, steeply dipping body of silica-carbonate rock which probably originated by hydrothermal alteration of serpentinized peridotite along a fault zone.

The serpentinized peridotite is intrusive into metamorphosed pre-Tertiary sedimentary rocks. These sediments and the serpentine are overlain unconformably by Eocene sandstone. The silica-carbonate rock lies along a normal fault on the south limb of a large anticlinal fold. The Eocene sandstone is everywhere the hanging wall and the serpentine the footwall of the deposit.

Locally the silica-carbonate rock is brecciated and has a cement of sulfides, quartz, and carbonates. Nickel is present in the sulfide-bearing breccia as bravoite and nickeliferous marcasite, in the main mass of silica-carbonate rock as nickeliferous ankerite and magnesite, and in the incompletely altered serpentine as nickeliferous serpentine or chlorite.

The approximate average tenor of the silica-carbonate rock, of which there are millions of tons, is 0.2-0.3 percent of nickel and about 0.02 ounce gold to the ton. The sulfide-bearing breccia, of which probably 15,000 to 50,000 tons are available, may contain a slightly higher percentage of nickel and about the same amount of gold. The silica-carbonate rock is not amenable to effective concentration so cannot at present be considered ore. The sulfide-bearing breccia can be profitably concentrated by flotation so is regarded as possible ore.

The writers believe that the nickel was originally present in the serpentinized peridotite and that it was dissolved and redistributed by ascending hydrothermal gold-bearing solutions while the serpentine was being altered into the silica-carbonate rock.

INTRODUCTION

The Mount Vernon nickel-gold deposit is a large body of mineralized rock exposed for a distance of more than 2 miles along the crest of Devils Mountain, 4½ miles southeast of the city of Mount Vernon, Skagit County, Wash. (pl. 11). Mount

Vernon is a city of about 4,000 inhabitants, located 65 miles north of Seattle. Two graded gravel roads give access to the property from Mount Vernon. One road approaches the ridge from the northeast and leads to the Devils Mountain Lookout Tower at the summit of the ridge; the other extends from U. S. Highway 99, a mile west of the property, to a point about halfway up the nose of the ridge, a mile west of the summit.

Mount Vernon is on the Great Northern Railway, which passes within 2 miles of the west end of the property; a branch of the Northern Pacific Railway runs within 2 miles of the east end of the deposit. Salt-water shipping facilities are available at the Puget Sound ports of Mount Vernon, Anacortes, and Everett.

History

The property was first prospected for gold more than 20 years ago, when an adit was driven 50 feet into the lowermost outcrop of the deposit on the west end of the ridge but was abandoned until 1935. In that year scattered areas of green coloration on the surface rocks aroused the interest of local prospectors, and analyses of the material proved the presence of nickel. The Pacific Nickel Co., organized in 1938, principally by local residents, controls about 2,100 acres which includes most of the deposit. Since 1938 tunnels aggregating about 300 feet have been driven, and in 1939-40 the deposit was tested by 27 diamond-drill holes totalling 6,375 feet.

No ore has been shipped from the property, but large samples have been collected for experimental flotation tests. In 1940 mining operations were being planned by the company, which expected to start with a 250-ton pilot mill and hoped later to operate on a much larger scale.

Previous investigations

No previous geologic report of the Mount Vernon deposit has been published. C. E. Weaver 1/ has described the general geology of a region that includes the mineral deposit, and R. D. McLellan 2/ has described the pre-Tertiary rocks of the areas directly to the northwest. A report on the coal fields of western Skagit County by Jenkins 3/ briefly describes the lithology and structure of the Eocene rocks near Mount Vernon but does not mention the occurrence of nickel.

Field work and acknowledgments

The writers were engaged in field work in the Mount Vernon district from July 15, 1940, to August 29, 1940. They are greatly indebted to the officers of the Pacific Nickel Co. for their cordial cooperation and assistance in making available the company's maps, assays, and experimental results. Especial thanks are due to Mr. R. J. Cole, the company engineer, for much information and assistance both in the office and in the field. Mr. Thomas B. Hill, of the Washington State Department of Conservation and Development, Division of Mines and Mining, also placed much information at the disposal of the writers. Mr. John W. King assisted in the topographic mapping. The authors are indebted to F. C. Calkins, of the Geological Survey, for many helpful suggestions in the preparation of this report.

Topography

The topography of the area reflects the bedrock structure. The rocks strike about N. 70° W., as does the sharp ridge of

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1/ Weaver, C. E., Tertiary stratigraphy of western Washington and northwestern Oregon: Washington Univ. [Seattle] Pub. in Geology, vol. 4, 266 pp., 1937.

2/ McLellan, R. D., The geology of the San Juan Islands: Washington Univ. [Seattle] Pub. in Geology, vol. 2, 185 pp., 1927.

3/ Jenkins, O. P., Geologic investigations of the coal fields of Skagit County, Wash.: Washington Geol. Survey Bull. 29, 60 pp., 1924.

Devils Mountain, which is carved from the resistant rock of the mineral deposit. From its highest point, at an altitude of 1,750 feet, the crest of the ridge slopes gradually to the west for about a mile and then plunges more steeply toward the Skagit River flood plain. The nose of the ridge is mantled with glacial debris to an altitude of 300 feet.

The valley on the south side of the ridge is deeply cut into the Eocene sandstones and is occupied by a small stream for most of the year. In the valley 800 feet north of the central part of the ridge is Lake Ten, which is about a third of a mile long and lies at an altitude of 1,240 feet. It was probably formed by the damming of the valley with glacial debris. The lake has a very small drainage area, and its inflow and outflow are intermittent. The lake water is available for mining purposes.

GEOLOGY

Regional geology

The rocks exposed in northwestern Washington may be divided into two main groups: (1) pre-Tertiary sedimentary and intrusive rocks ranging in age from Devonian to Cretaceous, and (2) a thick sequence of Eocene sandstones, shales, and conglomerates which overlie the older rocks with marked unconformity (fig. 5).

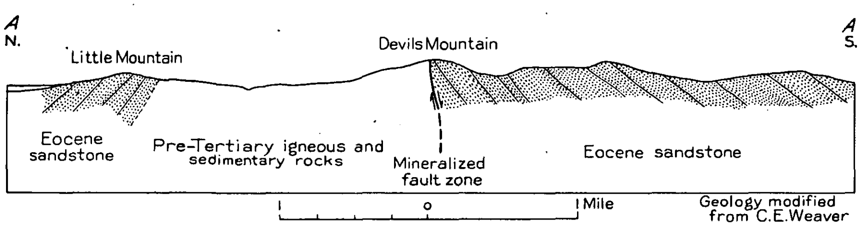
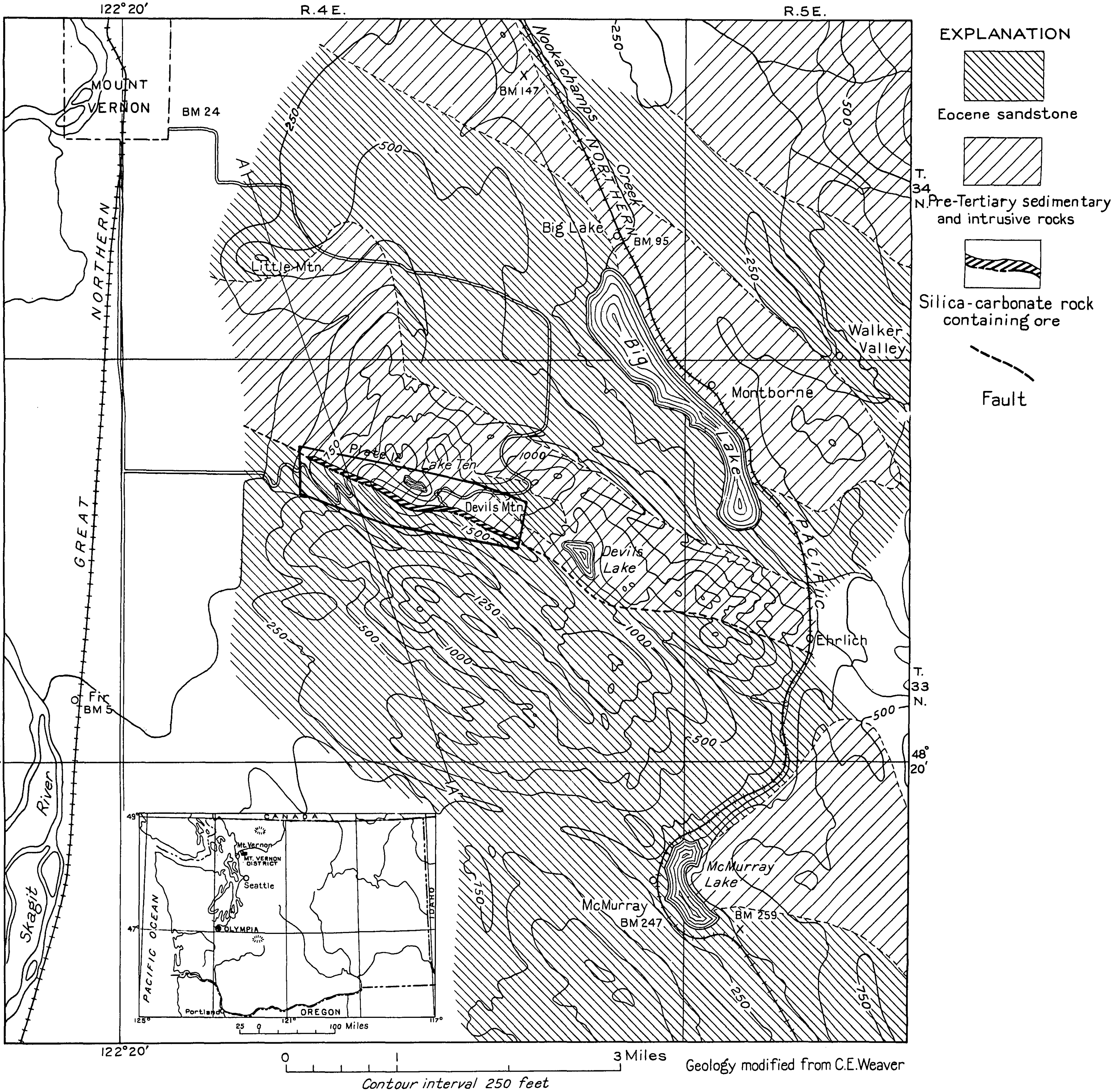
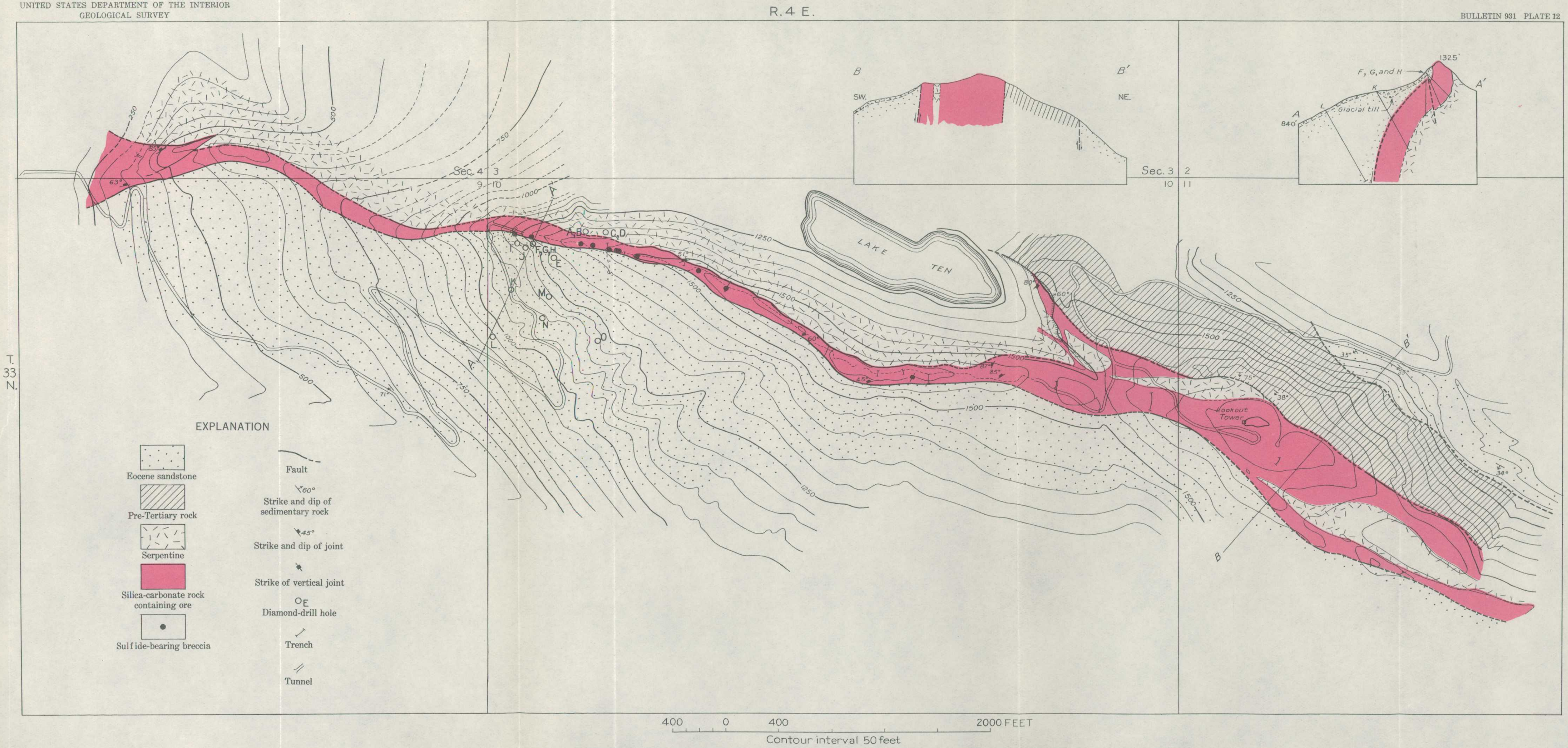


Figure 5.—Generalized cross section of western end of Mount Vernon district.

Cretaceous rocks are known on Vancouver Island and in the San Juan Islands of northern Puget Sound but are not found in the vicinity of Mount Vernon.



MAP SHOWING LOCATION AND GEOLOGIC SETTING OF THE MOUNT VERNON DISTRICT



GEOLOGIC MAP AND SECTIONS OF MOUNT VERNON NICKEL-GOLD DEPOSIT

Most of the Paleozoic and early Mesozoic sedimentary rocks have been metamorphosed to argillites, quartzites, schists, and phyllites. The Cretaceous Nanaimo formation of Vancouver Island and the Eocene Chuckanut formation of Washington, both of which contain coal seams, are unaffected by such metamorphism.

The pre-Tertiary sedimentary rocks have been intruded by a series of igneous rocks that range in composition from dunite to granite. Most of the intrusive activity in Washington occurred in late Jurassic or early Cretaceous time. Most of the peridotites in the San Juan Islands, however, are assigned to the Triassic by McLellan,[4] although some small masses of very fresh dunite are considered by him to be post-Jurassic. Post-Eocene ultrabasic rocks have not been reported in this region.

Local geology

In the area that includes Devils Mountain (pl. 12) the lithologic units exposed are pre-Tertiary sedimentary rocks, serpentine derived from peridotite, Eocene sandstone, latitic rocks, and silica-carbonate rock formed by alteration of the serpentine. As this last unit comprises the mineral deposit, it will be discussed in detail under that heading. It occupies the crest of Devils Mountain, lying between the serpentinized peridotite of the north slopes and the Eocene sandstone of the south slopes. Pre-Tertiary sediments, intruded by serpentine, occur north of Lake Ten. The contact between the Eocene sandstone and the silica-carbonate rock is a fault wherever it has been observed.

Pre-Tertiary sedimentary rocks.--The sedimentary rocks that underlie the Eocene sandstone are far from uniform in composition. They consist mainly of quartzitic sandstones and highly deformed argillite, but they include some phyllite. The individual beds are variable in thickness, but they are rarely more

4/ McLellan, R. D., op. cit., pp. 142-146.

than a few inches thick. Their dips, where observed, are steep, and in places they are vertical. These rocks are probably the same age as the pre-Cretaceous formations in the San Juan Islands that are described by McLellan.[5] They have the same northwest trend as most of the sedimentary rocks in northwestern Washington.

Serpentine.--The serpentine forms irregular masses intruded into the pre-Tertiary sedimentary complex and is in places faulted against it. Serpentine forms the footwall of the silica-carbonate rock, which encloses irregular lenses and wedges of serpentine.

The typical serpentine is dark green, coarse-grained, commonly slickensided, and veined by carbonates and chrysotile. It was originally a peridotite composed essentially of olivine and pyroxene, but these minerals have been almost entirely replaced by serpentine minerals. A black, fine-grained variety is the principal departure from the more typical green, granular rock, and is the result of alteration so complete as to have completely destroyed the original minerals and texture of the peridotite. Small chromite grains are scattered through the serpentine, and chlorite, carbonates, and quartz are present in some places.

On the south slope of Little Mountain, small bodies of serpentinized peridotite are intrusive into the metamorphosed sediments, which unconformably underlie the Eocene sandstone.

Eocene sandstone.--The Eocene sandstone unit, identified by Weaver[6] as the Chuckanut formation, is brownish gray and massive, cross-bedded, or coarsely stratified. Subordinate amounts of light-gray sandy shale, associated with some very black carbonaceous shale and thin seams of coal, are locally present. Lenses of conglomerate from a few inches to more than a hundred

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5/ McLellan, R. D., op. cit., pp. 91-112.
6/ Weaver, C. E., op. cit., pp. 76-77.

feet in thickness occur near the base of the formation and are interbedded with the sandstone above the base. The lithology of the formation is extremely variable from base to top as well as along the strike.

Fossil leaves and leaf imprints occur throughout the formation and are especially characteristic of its lower part. The stratigraphy of this formation has been discussed in detail by Weaver.[7]

Latite (?).--Northeast of the Lookout Tower and about 400 feet below the crest of the ridge is a conspicuous cliff of buff-colored fine-grained rock, which contains veinlets of carbonate. The rock has the general appearance of an altered sandstone, but microscopic study shows it to be composed of alkali feldspar and sodic plagioclase in a matrix of carbonate, sericite, and iron oxides. The feldspar constitutes 50 to 60 percent of the rock, and the feldspar laths, which are very elongate and partly distorted, have a very crude orientation suggestive of flow structure. The outcrops examined are nonporphyritic, although phenocrysts elsewhere have been reported. The rock is probably an altered latite. Its relation to the sedimentary rocks is obscure, but it may be a member of the pre-Tertiary complex.

Structure.--The local structure conforms to the general structural pattern of western Washington. Movement which has occurred at intervals since early Mesozoic time has produced a series of northwest-trending anticlines, synclines, and faults, so that now the strikes of the various rock formations are approximately parallel. The only angular unconformity observed is the marked one between the Eocene sandstone and the underlying pre-Tertiary complex.

The Eocene sandstone has been folded into an east-west anticline, the axis of which lies north of Devils Mountain and

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7/ Weaver, C. E., op. cit., pp. 77-78.

parallel to it; and the mineral deposit occupies a later strike-fault zone on the south limb of the anticline but near its crest. This fault may appropriately be called the Devils Mountain fault. Figure 5 is a generalized cross section of these structural features.

The Devils Mountain fault first produced a shear zone in the serpentine, along which alteration took place to produce the silica-carbonate rock, here considered the mineral deposit. Renewed movements, with an appreciable horizontal component, dropped the Eocene sandstone into its present position and also caused displacements within the silica-carbonate rock itself.

Other faults, of less displacement, have been observed on the north side of Devils Mountain. They may be related in age and origin to the Devils Mountain fault.

MINERAL DEPOSIT

The mineral deposit consists essentially of two kinds of rock: (1) silica-carbonate rock, and (2) sulfide-bearing breccia. The first, formed by nearly complete replacement of serpentine by quartz and carbonates, constitutes the bulk of the mineral deposit. The silica-carbonate rock was locally brecciated, and quartz, carbonate, and sulfides were introduced to form the sulfide-bearing breccia, a part of which represents the only potential ore in the deposit.

Silica-carbonate rock

The silica-carbonate rock, the most resistant to erosion of any rock on Devils Mountain, crops out continuously along its crest for a distance of 2 miles. In many places the erosion and sliding of material from the hanging walls and footwalls has left long steep-sided reefs of the silica-carbonate rock projecting as much as 50 feet above the enclosing country rock. Surface outcrops are characteristically buff to brown in color.

The resistant character of the rock is caused by the abundance of quartz, which forms a ramifying network of veins and irregular small masses.

The silica-carbonate rock consists principally of a mixture of quartz, chalcedony, and carbonates, with small amounts of iron oxides and scattered grains of chromite, which are probably remnants of the grains in the original peridotite. Near the Lookout Tower and east of Lake Ten, wedge- or lens-shaped bodies of serpentine are included in the silica-carbonate rock, and complete gradations between the two can be observed.

Three varieties of silica-carbonate rock can be recognized. The most abundant variety is hard, predominantly buff-colored, and very fine-grained; it is cut by many irregular stringers of coarse-grained carbonate and quartz. Local brecciation and irregular fracturing are evident in many places. Incompletely altered residuals of a green silicate mineral--probably a chlorite--are present in the rock. This variety is most abundant in the western half of the mineral deposit.

The dominant variety grades into a soft, earthy, very limonitic one that makes up a rather small part of the mass. This variety commonly appears at the surface as irregular bands in the dominant rock and in the partly altered small serpentine bodies within the mineral deposit. Layers of it as much as 10 or 12 feet thick have been observed in drill cores from depths of 600 to 700 feet below the crest of the hill.

A third variety, making up only a very small percentage of the deposit, is porous, flaky, and rich in a green chloritic mineral, quartz, and carbonates. This represents a less advanced stage of alteration than the first two varieties and is found most commonly in the partly altered serpentine bodies.

Sulfide-bearing breccia

The sulfide-bearing breccia is exposed at many places in the central part of the deposit. The fault contact between this

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rock and the sandstone of the hanging wall is best shown in the small crosscut adit; it is visible also in several trenches farther east. The rock is typically a hard, compact breccia. The individual angular fragments in the breccia, some of which are as much as 3 inches in diameter, are composed of highly silicified to typical silica-carbonate rock. The sulfides are fine-grained and are restricted to the interstices between fragments, although minute sulfide veinlets are present in some fragments. In places the breccia is barren of sulfides. Commonly, the sulfides in the breccia are partly or completely oxidized. The sulfides in breccia are very well exposed in a deep surface trench about 800 feet east of the crosscut adit, where the breccia is in contact with an irregular vein of shattered, glassy, bull quartz whose maximum thickness is 4 feet. Chemical tests and petrographic observations indicate that the nickel content of the sulfide-bearing breccia is not a direct function of the sulfide content.

Structural features

The silica-carbonate rock occupies a fault zone between sandstone and serpentinized peridotite. The form, thickness, and general attitude of the deposit in the central part of Devils Mountain, a typical cross section of which is shown on plate 12, was established by 16 drill holes in 12 localities. The silica-carbonate rock has a sharp fault contact with the hanging-wall sandstone and commonly also a well-defined contact with the serpentinized peridotite of the footwall. Where faulted the contact with the serpentine is very sharp. Evidence of brecciation and renewed movement is abundant.

Small cross faults are common and are best observed in the adits. The deposit is cut throughout its length by a steeply dipping set of fractures oblique to its trend. These fractures, together with nearly horizontal slickensides on the longitudinal fault fissures, suggest a strong horizontal component of movement along the main fault, at least during the last stages of faulting. Although the greatest movement occurred along the break between the serpentine and the sandstone, numerous other slippage planes are distributed through the silica-carbonate zone.

Mineralogy

The minerals identified in the deposit are the silica minerals quartz, opal, and chalcedony; the carbonates ankerite, magnesite, dolomite, and calcite; marcasite and pyrite; bravoite ((Fe, Ni) S_2); chromite ($FeCr_2O_4$); and serpentine minerals, which are hydrous magnesium silicates. Much of the rock exposed at the surface is stained with oxides of manganese and iron. The chromite and the serpentine are residual from the original serpentinized peridotite.

Marcasite is by far the most abundant of the three sulfides. A small crushed sample of unaltered marcasite, recovered from the gangue minerals by use of heavy liquids, was analyzed by Michael Fleischer, of the Geological Survey, and found to contain a trace of nickel. Bravoite is scarce and unevenly distributed, but it is so intimately associated with marcasite that both minerals probably originated under the same conditions. Bravoite cannot be detected in hand specimen, but it can easily be identified under the microscope by its lavender color. The pyrite, which occurs in small quantity, is coarser-grained than marcasite. It was formed earlier than either marcasite or bravoite. Where the sulfides have been completely oxidized a porous breccia weakly cemented with iron oxide remains.

Quartz is the most abundant gangue mineral and forms veinlets, geodes, clusters, or boxworks. Carbonates are locally abundant in the partly altered serpentinized peridotite and form veinlets or disseminated masses in the silica-carbonate rock.

In surface outcrops, silica tends to replace the carbonate minerals and to form a rock very rich in silica; carbonates, on the other hand, are abundant in the cores from deep drill holes. A sample of greenish ankerite tested by Fleischer showed an appreciable quantity of nickel, thus indicating that some of the carbonates are to a small extent nickeliferous.

Native gold has not been seen in either the silica-carbonate rock or the sulfide-bearing breccia, although it is distributed in small quantity throughout the mineral deposit. The gold is probably in the free state and although it is very fine grained, it is reported to be effectively concentrated from sulfide-bearing breccia by means of flotation of the sulfides (see p. 77).

Origin of the deposit

The unaltered wedges of serpentinized peridotite in the silica-carbonate rock, the gradations between unaltered and altered serpentine, the residual chromite grains, the association of nickel and gold, and the abundant evidence of shearing and faulting all indicate that the silica-carbonate was formed by intense alteration of serpentinized peridotite along a shear zone. The abundant carbonates and quartz and the auriferous iron-nickel sulfides were probably introduced by hydrothermal solutions.

The serpentine contains about 0.25 percent of nickel, which is about the average nickel content of serpentines elsewhere in the Coast Range province. The nickel was probably contained originally in the primary silicates, the chief of which is olivine, and was retained in the serpentine minerals to which the olivine was altered.

Much or all of the nickel, magnesia, and iron in the silica-carbonate rock could have been taken into solution by the hydrothermal attack on the serpentine, transported to new sites by the solutions, and there deposited in the form of secondary minerals. A large part of the silica itself could have resulted from a break-down of the original silicates and been transported to new sites for redeposition as quartz and chalcedony. Calcium also may have originated in the serpentine, and likewise the gold. Assay reports of the Pacific Nickel Co. indicate that the maximum gold content of the serpentine is 25 cents to the ton.

The carbon dioxide in the carbonates is much harder to explain, but its source is a significant question because of its great quantity. The problem of the origin of sulfur in the sulfide-bearing breccia, which, it will be remembered, was formed later than the silica-carbonate rock, is likewise significant. However, no conclusive evidence has been found bearing on the origin of either the carbon dioxide or the sulfur. Although the character of the quartz and chalcedony in surface outcrops suggests deposition from low-temperature supergene solutions, some of the glassy quartz which forms thick veins or boxworks in the silica-carbonate rock resembles the quartz that is characteristic of mesothermal deposits. The alteration of the serpentine, redistribution of the nickel, and introduction, from unknown sources, of at least the carbon dioxide and sulfur and possibly also a considerable part of the gold and silica are therefore attributed to hydrothermal solutions.

The sequence of geologic events that the writers believe to have caused this deposit is summarized below. Both the silica-carbonate rock and sulfide-bearing breccia are here assigned to the same post-Eocene metallogenetic epoch.

1. Serpentinization of peridotite.
2. Erosion of serpentine. Deposition of Eocene sandstone unconformably above serpentine.
3. Folding of Eocene sandstone into an anticline, and faulting to produce the Devils Mountain fault zone near the crest of the fold.
4. Formation of silica-carbonate rock along the fault zone.
    a. Alteration and replacement of the serpentine by quartz and carbonates through action of hydrothermal solutions.
    b. Renewal of fault movement, causing local brecciation of the silica-carbonate rock.

c. Introduction of quartz, carbonates, and sulfides, which cemented and replaced the brecciated fragments to form a hard rock.
d. Renewed movement and small-scale fracturing, followed by introduction of light-green to colorless carbonate, glassy quartz, and opaline quartz.
e. Renewed movement with a strong easterly component, producing gouged, grooved, and slickensided surfaces, and localized cross-fracturing in the deposit and in the adjacent Eocene sandstone. Introduction of coarse-grained calcite along the fractures.

5. General surface oxidation and leaching, the end product of which was rich in silica, and oxidation of the sulfide-bearing breccia, producing a porous limonitic residue nearly devoid of sulfides near the surface.

Surficial alteration

Weathering of the deposit has had two principal effects. Through leaching of carbonates the surface outcrops are left richer in silica (including quartz, chalcedony, and opal), and through oxidation of the sulfides much limonite has been formed, especially in the sulfide-bearing breccia. The drill cores also contain much limonite. Furthermore, drill-core recoveries ranged from 15 to 70 percent, which indicates that some parts of the deposit are either porous or friable at the depths drilled, perhaps as the result of deep weathering. It is probable that oxidation and leaching extend below the drilled part of the deposit, for the climate is humid, the water table low, and the fractured parts of the rocks permeable.

Sulfides and silicified breccia are rare in drill cores, even in those obtained directly beneath surface showings of sulfide-bearing breccia. The fact that some sulfides are present at the surface is evidence that the unfractured rock is almost impervious. The absence of sulfide-bearing breccia in the drill cores cannot readily be explained.

There is not enough evidence in hand to show whether or not a zone enriched in nickel lies below the drilled part of the deposit. This is one of the problems that should be considered in planning future exploratory work.

ORE RESERVES

Size of mineral deposit

The nickel-gold deposit near Mount Vernon is exposed for about 2 miles between altitudes of 300 and 1,750 feet. Drilling records and geologic evidence both show that the deposit is a steeply dipping tabular body ranging in thickness between 100 and 300 feet and probably extending below sea level. The bulk of the deposit is composed of hard silica-carbonate rock that cannot properly be called ore because of its low tenor and the difficulties of concentrating and extracting the little nickel that it contains. According to reports, however, the sulfide-bearing breccia can be effectively concentrated by flotation.

A vertical, longitudinal section along the strike of the deposit is shown in figure 6. Block A, estimated from the results of exploration and drilling to contain more than 15,000,000 tons, is the most favorable ground in the deposit. Only a part of block A is sulfide-bearing breccia. Block B, so far as examination of surface outcrops and of the drift adit at the west end indicates, contains no sulfide-bearing breccia. In block C partly replaced wedges and bodies of serpentine are common and outcrops of sulfide-bearing breccia are rare. The deposit as a whole must contain more than 50,000,000 tons of silica-carbonate rock.

Sampling of the deposit

The silica-carbonate rock was sampled by three different methods, which give closely similar results. The results of two programs of systematic sampling, one a State-supervised Works Progress Administration project and another by the Pacific Nickel Co. have been made available for this report. The writers themselves employed a method of "character sampling" to gain additional information concerning the general distribution of

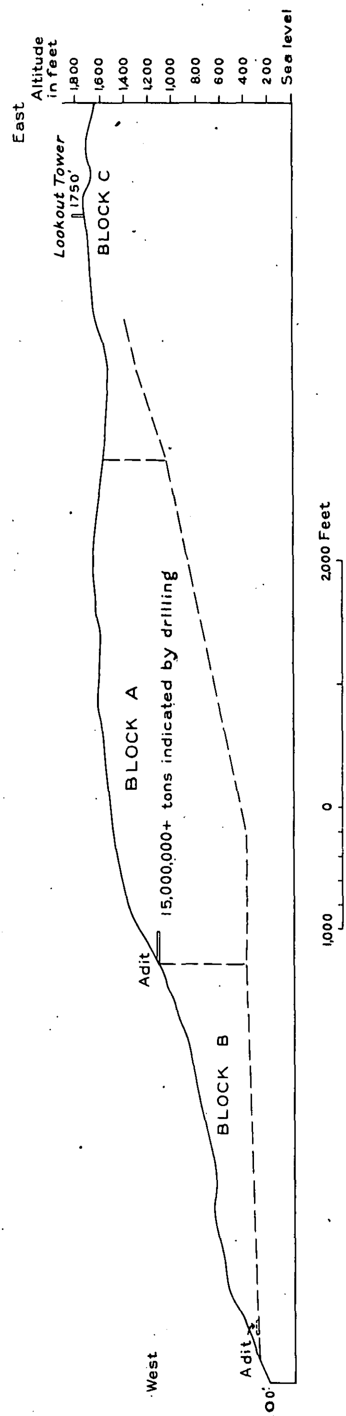

Figure 6.--Vertical longitudinal section of the Mount Vernon nickel-gold deposit.

nickel and gold in the various rock types. A comparison of the results obtained by these three methods is shown in tables 1 and 2.

Trench sampling

In 1937 the Works Progress Administration of the State of Washington, sponsored by the State Department of Conservation and Development, and the State Commissioner of Public Lands, sampled the outcrop of the Mount Vernon deposit. Under the supervision of Mr. P. E. Crane, trenches were cut across the deposit at intervals of about 400 feet and channel samples were taken from the bottom of each trench. Nickel assays were made by I. A. Pearl, but no gold assays were made. Assays representing 74 samples and 600 feet of channeling (see table 1) show a weighted average, as computed by the writers, of 0.293 percent of nickel.

Drill-core sampling

In the spring of 1940, the Pacific Nickel Co. drilled 16 holes in the area shown on plate 12. Of the 6,375 feet of drilling, 2,598 feet, in 10 holes, traversed the silica-carbonate rock, and the cores from these were split into 157 samples for assays by well-known assay companies. Core recoveries ranged from 15 to 70 percent. The average of the 157 samples, weighted according to the length of core represented by each sample and disregarding percentage of core recovery, is 0.251 percent of nickel. The unweighted average for gold is 0.0195 ounces to the ton. It is possible that part of the sulfides enclosed in porous rock may have been lost during extraction of the drill cores. The results from both trench and core samples are shown in table 1.

Table 1.--Assays of trench and drill-core samples from the nickel-gold deposit near Mount Vernon

Trench samples				Drill-core samples						
				Nickel				Gold		
Nickel (percent)	No. of As-says	Length of sample (feet)	Weighted average (percent)	Nickel (percent)	No. of As-says	Length of core (feet)	Weighted average (percent)	Gold (ounces per ton)	No. of As-says	Average (ounces per ton) 1/
0.10-0.20	16	125	0.155	0.10-0.20	22	316	0.184	0.01-0.02	67	0.012
.20- .30	31	225	.245	.20- .30	105	1,829	.225	.02- .03	65	.020
.30- .40	16	150	.343	.30- .40	22	334	.340	.03- .04	15	.030
.40- .50	8	70	.456	.40- .50	3	61	.466	.04- .05	8	.040
.50- .60	2	20	.555	.50- .60	2	24	.528	.05- .06	1	.06
.60- .70	0	0	---	.60- .70	0	0	---	------		
.70- .80	1	10	.70	.70- .80	1	19	.78			
.80- .90	0	0	---	.80- .90	1	10	.81			
.90-1.00	0	0	---	.90-1.00	1	5	.96			
	74	600	.293		157	2,598	.251		156	.0195

1/ Unweighted.

Table 2.--Analyses of representative nickel-bearing rocks

Description	Nickel (percent) 1/	Gold (ounces per ton) 2/	Value 3/
Serpentinized peridotite...........................	0.24	Not det.	
	.26	...do...	
Porous, flaky, buff-colored rock, in various stages of transition to silica-carbonate rock.	.21	...do...	
	.24	.01	$2.00
	.26	.01	2.00
Buff, hard, typical silica-carbonate rock..........	.15	.03	2.10
Silicified breccia with sulfides. Marcasite is predominant, but some bravoite is present in No. 4.	.19	.016	2.20
	.18	Not det.	
	.22	.022	2.75
	.47	Not det.	
Oxidized sulfide rock..............................	.20	.07	3.80

1/ Assays by Michael Fleischer.
2/ Assays by Ledoux and Co., New York.
3/ Nickel calculated at 35 cents a pound and gold at $35 an ounce.

"Character" sampling

During the course of the field work, the writers collected samples representing typical serpentinized peridotite, the several varieties of silica-carbonate rock, and the sulfide-bearing breccia. Some of these samples were assayed by Michael Fleischer, of the Geological Survey, for nickel and by Ledoux & Co. for gold. The results are shown in table 2, which also shows the approximate value at present prices of 35 cents a pound for nickel and $35 an ounce for gold. Mr. R. J. Cole reported that a composite sample of sulfide-bearing breccia ore, collected by him for metallurgical tests, contained 1.07 percent of nickel and 0.015 ounces of gold to the ton and that the sulfide concentrate from this sample contained about 6 percent of nickel and 0.16 ounces of gold to the ton.

Significance of sampling

The accumulated assay figures for the entire deposit indicate that in general the serpentinized peridotite contains more nickel than the silica-carbonate rock. The nickel content is greatest in some of the sulfide-bearing breccia, probably because that rock contains unevenly distributed bravoite and nickeliferous marcasite. The silica-carbonate rock cannot be considered nickel ore, first because the nickel content is low and second because the nickel is divided between carbonate, sulfide, and silicate rather than concentrated in a single mineral. This rock, however, may possibly be regarded as submarginal gold ore, and some of the sulfide-bearing breccia may be regarded as potential ore by virtue of the combined nickel and gold content.

Quantity of sulfide ore

Exposures indicate that the deposit contains at least 15,000 tons, and possibly as much as 50,000 tons, of sulfide-bearing breccia. As to tenor, all that can be said with any assurance is that the breccia averages more than 0.20 percent of nickel and about 0.02 ounces of gold to the ton. Its silver content is negligible. At the present market prices of 35 cents a pound for nickel and $35 an ounce for gold, the gross value of this material would thus be at least $2.00 a short ton.

In a large trench immediately east of the crosscut adit, a shoot of hard, brown, sulfide-bearing breccia a foot thick, with a few auxiliary shoots, is exposed in the buff silica-carbonate rock. It strikes obliquely to the mineral deposit and dips northwest. The breccia here is of the same character as that in the crosscut adit. The sulfide-bearing breccia is discontinuously exposed along the crest of the ridge for about 1,500 feet east of this trench. The largest exposure, about 800 feet east of the crosscut adit, has been proved by trenching to be 30 feet wide and appears from surface observations to be more than 60 feet long. No drilling has been done below this large exposure. None of the shoots of sulfide-bearing breccia exposed east of the drilled area are more than a few feet wide.

The most favorable localities for other shoots of sulfide-bearing breccia may be immediately beneath surface outcrops of sulfides. Such localities have not been investigated thoroughly. Future exploration may also reveal other sulfide-bearing breccia ore shoots within the silica-carbonate rock. The known exposures of sulfides would indicate that a surface mining method would be most advantageous.

Experimental flotation tests

Experimental flotation tests on a selected sample of sulfide-bearing breccia, made by Mr. W. H. Marquette, of Seattle, Wash., for the Pacific Nickel Co., indicate a high concentration ratio. The results of tests on a sample of several hundred pounds of ore collected by Mr. R. J. Cole are shown in table 3. The assays were made by private companies.

Table 3.--Results of flotation tests on sulfide-bearing breccia

	Weight (percent)	Gold (ounces per ton)	Silver (ounces per ton)	Nickel (percent)	Value per ton
Heads	100.0	0.015	0.26	1.07	$8.20
Concentrates	2.9	.16	1.46	6.26	50.39
Rough concentrates	.8	.08	1.04	2.84	23.42
Tails	96.3	.0025	.06	.08	.19

The most encouraging results of tests made by Mr. Marquette on a large sample of silica-carbonate rock selected by Mr. Cole are shown in table 4. It is not known whether this sample contained sulfides. The presence of 0.68 percent of nickel suggests the presence of sulfides or nickeliferous carbonates.

Table 4.--Results of flotation tests on silica-carbonate rock

	Weight (percent)	Gold (ounces per ton)	Nickel (percent)	Value per ton
Heads	100	0.015	0.68	$5.29
Concentrates	1.4	.20	8.21	64.48
Tails	98.4	.005	.45	3.32

Outlook

The silica-carbonate rock on Devils Mountain cannot properly be considered a large potential nickel reserve. At best, if selective large scale low-cost mining methods and favorable means of concentration are employed, it might be considered a marginal to submarginal gold deposit, whose value would be slightly enhanced by the small amount of nickel recoverable from the sulfide minerals of the concentrates.

The sulfide-bearing breccia, because of its uneven tenor and small tonnage, cannot be depended upon to sustain any long mining operation. Some of it, however, might be mined at a profit under present economic conditions. This sulfide ore could best be mined selectively, on a small scale, and concentrated by flotation, to which the ore is well adapted.

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