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NICKEL INVESTIGATIONS IN SOUTHEASTERN ALASKA

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By George C. Kennedy and Matt S. Walton, Jr.

ABSTRACT

During 1942 and 1943 the nickel-copper deposits on Yakobi Island, the west coast of Chichagof Island, and a small prospect on Baranof Island near Sitka were further studied by the Geological Survey in connection with investigations on strategic and critical war minerals in Alaska.

Yakobi Island deposits.—The oldest rocks on Yakobi Island consist of a thick sequence of volcanic rocks and graywacke. These were intruded by plutonic rocks, which were later sheared and metamorphosed, largely to albite granite gneiss and amphibolite. The largest known nickel-copper deposits are in Bohemia Basin and are segregations from norite bodies, parts of a postmetamorphic composite stock.

The nickel-copper deposits on which exploratory work has been concentrated are parts of a norite body that contains pentlandite, chalcopyrite, and pyrrhotite. The norite body is surrounded by hornfels, gabbro, and quartz diorite, and the sulfide-bearing parts of the body crop out near its periphery. Drill holes and magnetic data indicate that the norite body is basin-shaped and that it is underlain largely by gabbro and hornfels. The sulfide-bearing rock forms a trough-shaped deposit lying above the lower contact of the norite.

Available evidence indicates that the sulfide minerals in the form of immiscible droplets were concentrated by gravity in the lower parts of the norite body at a time when most of the silicate minerals in the norite had crystallized.

Earlier estimates on the basis of the scant data then available were that 2,400,000 tons of material containing 0.44 percent of nickel and 0.29 percent of copper were present in the Tunnel, East Tripod, and West Tripod bodies; 1,042,000 tons of material containing 0.25 percent of nickel and 0.25 percent of copper in the Muskeg and Side Hill bodies; and 2,400,000 tons of material containing 0.31 percent of nickel and 0.25 percent of copper in the Takanis bodies. The interpretations of drill tests by the Bureau of Mines furnish the basis for a revised estimate of 10,300,000 tons of indicated material in the Tunnel and Tripod bodies, with an average grade of 0.37 percent of nickel and 0.20 percent of copper. Drill data from Bureau of Mines work and magnetic data furnish the basis for a revised estimate of 8,100,000 tons of inferred material in the Muskeg and Side Hill bodies, with an average grade of about 0.27 percent of nickel and 0.20 percent of copper. No additional data are available on the Takanis bodies. Estimated reserves therefore total 20,700,000 tons of indicated and inferred material. The average grade is about 0.33 percent of nickel and 0.21 percent of copper. Approximately 35 percent of the material included in estimates of tonnage in the Tunnel and Tripod bodies is virtually barren; if this were excluded by some process of selective mining, the grade would be increased to about 0.51 percent of nickel and 0.27 percent of copper. Presumably similar percentages of barren material are present in the other bodies.

Chichagof Island deposits.—Several nickel-copper deposits are known in a small area in the vicinity of Mirror Harbor on the west coast of Chichagof Island. The deposits are sulfide-bearing parts of a norite body which is part of a much larger composite stock intrusive into metamorphosed greenstone and graywacke.

The sulfide minerals in the norite are pentlandite, pyrrhotite and chalcopyrite. In one place these minerals are disseminated through the norite, forming a large deposit of very low grade. Numerous small relatively rich pods, ranging in length from a few inches to a few feet, form bodies of somewhat higher grade.

The largest concentrated-sulfide deposit crops out on the north shore of Fleming Island. This deposit is of oval outcrop, is pipelike and extends to a depth of about 110 feet, where it probably is cut off by a fault. The body contains about 8,000 tons of material with an average grade of about 1.57 percent of nickel and 0.88 percent of copper. Three other concentrated-sulfide deposits lie near the head of Davison Bay about 3,000 feet from the Fleming Island deposit. The largest of these contains only a few tons of concentrated-sulfide material.

The large disseminated-sulfide deposit, about 1,000 feet long and a hundred or more feet thick, crops out about 1,000 feet southeast of the concentrated-sulfide deposits at Davison Bay. Meager evidence indicates that the body dips west at about 20°. This deposit probably contains several million tons of material with an average grade of about 0.2 percent of nickel and 0.1 percent of copper.

Baranof Island deposit.—The deposit on Baranof Island near Sitka contains only a few tons of nickel-bearing rock and was not studied in detail.

INTRODUCTION

During 1942 and 1943 the Geological Survey continued its investigations of the nickel-copper deposits of Yakobi Island begun by Reed and Dorr,[1] and studies of the west coast of Chichagof Island begun by Pecora.[2] These deposits, which constitute the largest known reserves of nickel in the possessions of the United States, were studied as part of the program of war-minerals investigations carried out by the Geological Survey.

In this investigation Kennedy is principally responsible for the geologic work on Yakobi Island and Chichagof Island, and Walton is largely responsible for the magnetic survey at Bohemia Basin.

The first section of this report describes briefly the nickel-copper deposits of Yakobi Island, southeastern Alaska, as well as the general geology of the island. It includes an interpretation and summation of the geologic data obtained during drilling tests in 1941 and 1942 by the Bureau of Mines, and magnetometer exploration of the nickel-copper deposits in 1943 by the Geological Survey. These deposits have been described by Reed and Dorr, and much detail available in their bulletin has been omitted from this report.

The second section of this report describes three nickel-copper deposits on the west coast of Chichagof Island, southeastern Alaska, and

[1] Reed, J. C., and Dorr, J. V. N., 2d, Nickel deposits of Bohemia Basin and vicinity, Yakobi Island, Alaska: U. S. Geol. Survey Bull. 931–F, pp. 105–138, 1942.

[2] Pecora, W. T., Nickel-copper deposits on the west coast of Chichagof Island, Alaska: U. S. Geol. Survey Bull. 936–I, pp. 221–243, 1942.

supplements Pecora's report. The present report is based on new geologic information obtained by the Geological Survey in 1942 in conjunction with an exploratory project by the Bureau of Mines.

The final section of this report deals with a brief investigation of a nickel-copper deposit near Sitka, southeastern Alaska.

NICKEL-COPPER DEPOSITS OF YAKOBI ISLAND

GEOGRAPHY

Yakobi Island is a small island off the northwest corner of Chichagof Island, in latitude 58° N., longitude 136°30′ W. (See fig. 4.) The

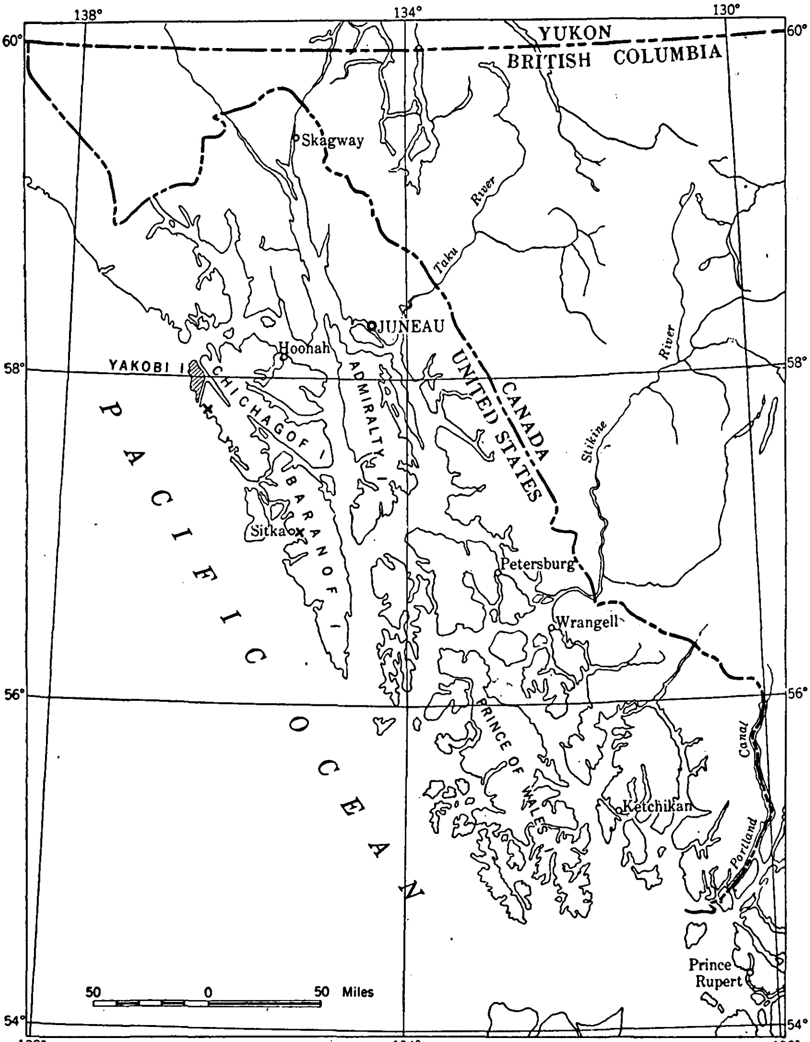

FIGURE 4.—Index map of southeastern Alaska showing location of Yakobi Island and nickel-copper deposits on Chichagof and Baranof Islands.

island is about 18 miles long and 10 miles wide at its widest part. It is bounded by Lisianski Strait on the east and by the Pacific Ocean on the west. The nearest settlement, Pelican, which contains a cold-storage plant, general store, and post office, is about 5 miles east of Yakobi Island on the northeast side of Lisianski Inlet.

The nickel-copper deposits of Yakobi Island are a short distance east of the geographic center of the island. They are about 2 miles from tidewater near the head of Bohemia Basin, the local name for the open valley of Bohemia Creek. The deposits are relatively accessible, as both Lisianski Strait and Lisianski Inlet have protected anchorages for boats of moderate tonnage, and the deposits can be reached easily from the beach by way of the valley of Bohemia Creek. There is at present (1944) no regular means of transportation to Yakobi Island, but it can be reached by small boat from Juneau, 130 miles by water to the east, or from Sitka, 80 miles to the south.

The climate in general is mild, with temperatures rarely lower than 15° F. or higher than 70° F. Precipitation is heavy, principally in the form of rain. At Sitka the mean annual temperature is approximately 44° and the average annual precipitation about 86 inches.

Yakobi Island consists of two topographic belts, a coastal belt and a mountainous belt. (See pl. 9.)

The coastal belt is on the west side of the island and is from 1 mile to 4 miles wide. It has a maximum relief of about 400 feet. Eastward the mountains rise abruptly from the coastal belt and reach altitudes of more than 2,000 feet.

HISTORY OF THE DEPOSITS

The nickel-copper deposits of Bohemia Basin are reported to have been discovered in 1921 by S. H. P. Vevelstad. The first claims were staked in that year, and additional claims have been staked from time to time since then. The North Takanis and South Takanis bodies are believed to be included in the Mayflower and Portia groups of claims; and the North Muskeg, South Muskeg, Side Hill, Tunnel, East Tripod, and West Tripod bodies are believed to be included in the Yakobi, formerly the Bohemia, group of claims. There are probably more than a hundred claims in the district. The ownership of the claims is said to be involved, and some controversies are understood to have arisen as to titles and options on some of them. At an early date a tunnel was started in the Tunnel body. This has been lengthened from time to time until in 1943 it was 166 feet long. No ore has been shipped from the district.

FIELD WORK

The nickel-copper deposits of Bohemia Basin were studied during the summer of 1940 by John C. Reed and J. V. N. Dorr, 2d, of the

Geological Survey. Their findings, with detailed geologic and topographic maps, were referred to the Bureau of Mines and have been the basis for subsequent work by both the Geological Survey and the Bureau of Mines.

Diamond drilling of the Bohemia Basin deposits by the Bureau of Mines began in November 1941, but after the completion of two holes was interrupted by inclement weather. Drilling was resumed in May 1942, and the project was completed the following August.

During the latter part of the drilling in the fall of 1941 and until late June 1942, George O. Gates represented the Geological Survey on the project. During July and August 1942, George C. Kennedy visited the project for 2 or 3 days each week. These men gave such assistance as comes within the field of the Geological Survey, including logging the cores, making visual estimates of the grade of material in the cores, marking the units of core to be sampled, and advising as to the location and length of holes.

During the summer of 1942 a Geological Survey field party consisting of George C. Kennedy and R. E. L. Rutledge mapped the western part of Yakobi Island in the hope of finding sulfide-bearing deposits in addition to those described by Reed and Dorr. [3]

Late in June 1943, Matt S. Walton, Jr., and George C. Kennedy spent a week in Bohemia Basin tracing a sulfide-bearing body under covered areas by means of a magnetometer survey. At that time eight traverses were made with an Askania vertical-intensity magnetometer.

REGIONAL GEOLOGY

The oldest rocks on Yakobi Island consist of a thick sequence of pre-Triassic (?) greenstone, believed to be originally basalt flows, with some intercalated graywacke. (See pl. 9.) The greenstone occupies the northeastern part of Yakobi Island. The greenstone has been tentatively correlated with the greenstone schist mapped by Reed and Coats [4] in the Chichagof mining district. This correlation is based on lithology and structural relations.

Overlying the greenstone are Triassic(?) rocks which form an almost continuous belt 1 to 2 miles wide extending for about 13 miles through the island The Triassic(?) sequence is composed of graphitic schist, greenstone, graywacke, chert, and limestone. In general the amount of volcanic material in these rocks increases from south to north, and the lower strata contain more volcanic material than the upper. A few lenses of limestone extend for short distances.

[3] Reed, J. C., and Dorr, J. V. N., 2d, op. cit.

[4] Reed, J. C., and Coats, R. R., Geology and ore deposits of the Chichagof mining district, Alaska: U. S. Geol. Survey Bull. 929, 1941.

The southern part of Yakobi Island adjoining Lisianski Strait is underlain by graywacke of Cretaceous(?) age. Similar rocks occupy a smaller area on the west side of the island north of Surge Bay. The graywacke is made up largely of clastic sedimentary material with considerable amounts of volcanic material. Over much of its extent the graywacke is metamorphosed to quartz-biotite schist. Included volcanic material has been metamorphosed to amphibole schist and amphibole-epidote-chlorite schist.

The stratified rocks strike northwest and in general dip steeply eastward. The steep eastward dip suggests that the beds have been isoclinally folded and overturned.

In Cretaceous(?) time plutonic rocks intruded the stratified rocks. These plutonic rocks are believed to be related to the Coast Range batholith. Igneous invasion was accompanied and followed by metamorphism and shearing of both the stratified and plutonic rocks. The intrusive rocks were altered to albite granite gneiss and to amphibole gneiss. In the map unit the amphibole gneiss is included with the albite granite gneiss. (See pl. 9.) Some evidence indicates that much of the amphibole gneiss is metamorphosed greenstone.

Most of central and western Yakobi Island is occupied by a large composite stock. This stock is unfoliated and was intruded after metamorphism. The rocks of the stock have been separated into a quartz diorite group and a gabbro group.

The rocks of the quartz diorite group range from granite to diorite, though most of the rocks are biotite-quartz diorite and hornblende-quartz diorite. The percentage of dark minerals in these rocks ranges widely and changes abruptly. Darker phases of the quartz diorite are cut by lighter phases.

The rocks of the gabbro group range in composition from gabbro to norite and pyroxenite. Norite, although it constitutes a relatively small proportion of the rocks of this group, contains all the known nickel-copper deposits on the island.

Available evidence indicates that the stock was emplaced quiescently. The field relations and a study of thin sections indicate that much of the quartz diorite, at least around the margins of the stock, was formed by granitization or some related process. Contacts are gradational, and igneous textures have developed in many places in the stratified rocks surrounding the quartz diorite. Near the margins of the stock much of the diorite contains numerous inclusions. These inclusions are partly digested sedimentary and volcanic rocks, and locally they constitute more than half of the mass. The stratification of many inclusions is parallel to relict stratification structures in the quartz diorite, and the inclusions are apparently patches of partly granitized stratified rocks surrounded by more completely granitized material. Other inclusions are randomly oriented and sharply bounded.

GEOLOGY OF PART OF BOHEMIA BASIN

The largest known nickel-copper deposits on Yakobi Island, and the most intensively prospected bodies, are in Bohemia Basin. These deposits are in a norite body of elliptical outcrop (see pl. 10), part of the much larger composite stock. Around the western part of the norite body gabbro is in contact with norite, whereas around the eastern part amphibole schist and quartz diorite bound the norite. The norite has altered the amphibole schist to hornfels for a short distance away from the contact.

The norite ranges widely in texture and proportions of constituent minerals. Within a few feet the rock ranges from fine- to coarse-grained, and the feldspar content from about 70 percent to almost none. Actually the unit mapped as norite includes not only norite but some gabbro, amphibolite, hypersthenite, and basic pegmatite. These rocks are gradational local differentiates of the norite and show no systematic arrangement within the norite body. Inclusions of hornfels as much as 100 feet thick are present within the norite mass. Some evidence indicates that they tend to be oriented parallel to the contacts of the norite. The norite is cut by numerous fine-grained andesitic dikes as much as 30 feet thick, which over some areas a few hundred feet square may quantitatively exceed the norite.

The nickel-copper deposits of Bohemia Basin are sulfide-bearing portions of the norite masses. The explored bodies lie in two main groups. One of these, the Takanis group, includes the North Takanis and the South Takanis bodies. The other group (see pl. 10) includes the Tunnel, East and West Tripod, North and South Muskeg, and Side Hill bodies. Deposits of this group have been explored by diamond drilling and magnetometer prospecting. These deposits are in the western part of Bohemia Basin, in an area about 1,600 feet long in an east-west direction and about 1,200 feet wide in a north-south direction. The western part of this area, which embraces a small valley where the drilling was concentrated and where the greatest reserves of mineralized material are indicated, contains the East Tripod, West Tripod, and Tunnel bodies. These bodies, actually believed to be part of a single deposit, crop out around this small valley.

Richer concentrations of sulfide minerals cannot be correlated with any particular unit of the norite group. Amphibolitic, gabbroic, and other types are all locally as mineralized as the more typical norite. Coarse-grained basic pegmatite is the only member of the group in which no appreciable quantities of sulfide minerals have been found.

MINERALOGY

The only metallic minerals in appreciable quantities within these deposits are pyrrhotite, pentlandite, chalcopyrite, and magnetite. Although Buddington[5] reports small amounts of bravoite, ($(Fe, Ni) S_2$), all significant quantities of nickel are believed to be in pentlandite.

An average of 4.6 percent of sulfide minerals by weight was contained in 61 samples collected by Reed and Dorr.[6] Of this, 48 percent was pyrrhotite, 35 percent pentlandite, and 17 percent chalcopyrite. These data are believed to be representative of the entire district.

The sulfide minerals form small blebs erratically distributed within the norite. Abrupt changes in the percentage of sulfide minerals in the bodies are typical.

STRUCTURE

The known nickel-copper deposits of Yakobi Island lie near the margins of norite bodies and appear to parallel those margins. The deposits in Bohemia Basin which have been explored by diamond drilling and magnetometer prospecting (see pls. 10 and 14) are marginal portions of a norite mass of elliptical outcrop. The evidence from drill cores and from magnetometer prospecting, although not conclusive, indicates that the bottom of the norite mass is basin-shaped, and that the deposits dip inward toward a common center at angles ranging from 45° to 70°. Essentially all of the sulfide-bearing norite lies within 250 feet of the norite contact. This norite body is underlain by gabbro and amphibole schist. Locally younger diorite is in contact with the norite. Gabbro, norite, and diorite are believed to be succeeding differentiates of the magma of the composite stock.

In the western part of the norite body the deposits appear to form a blanket 100 to 200 feet thick above the base of this body, with as much as 40 feet of barren norite between the mineralized norite and the underlying gabbro.

ORIGIN OF THE DEPOSITS

The available evidence indicates that these deposits were formed by late-magmatic separation of immiscible sulfide droplets from a cooling norite magma. The sulfide droplets were concentrated by gravity in the lower parts of the norite. Such an origin is similar to that inferred for deposits at the base of noritic and gabbroic bodies elsewhere.

Separation of the sulfide droplets from the norite magma is believed to have taken place so late in the consolidation period of the norite

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[5] Buddington, A. F., Mineral investigations in southeastern Alaska: U. S. Geol. Survey Bull. 773, pp. 103–105, 1925.

[6] Reed, J. C., and Dorr, J. V. N., 2d, op. cit., p. 119.

that most of the silicate minerals had crystallized. The sulfide droplets apparently separated from the residual magma and, influenced by gravity, migrated downward through the interstices between the crystals of the largely consolidated norite until these droplets became trapped in the lower part of the body. The sulfide minerals did not entirely crystallize until after the norite had consolidated sufficiently to permit a little fracturing to take place. Some of these late fractures, in both the norite and adjacent rocks, contain sulfide minerals.

The content of sulfide minerals in the sulfide-bearing parts of the norite ranges widely and abruptly. The differences in grade may be due to differences in the permeability of the norite at the time the sulfide droplets were settling from the overlying norite. The permeability was a function of grain size, degree of consolidation, and other factors. The sulfide minerals would accumulate in the partly crystalline norite, which during the period of sulfide separation had a permeability great enough to permit the sulfide drops to enter but not great enough to permit most of the drops to pass through into the norite below.

DESCRIPTIONS OF SULFIDE-BEARING BODIES

TUNNEL AND TRIPOD BODIES

The East and West bodies are believed to be outcropping parts of one limb, and the Tunnel body of the other limb (see pls. 11 and 12) of a single trough-shaped deposit of mineralized norite which plunges northeast. (See pl. 13.) Not enough diamond drilling has been done to prove conclusively that the two limbs join at depth, or that the trough is complete, with no barren gaps between the bodies.

The outcrop and drill holes 4 and 4–A indicate that the West Tripod body dips southeast about 65°. Drill holes in the Tunnel body show that it dips northeast about 45°. Drill holes which were directed to intersect the inferred synclinal structure near the bottom of the trough indicate that the bottom of the trough plunges northeast about 35°.

Barren dikes and hornfels inclusions locally constitute a large proportion of these bodies. Drill hole 4–A in the West Tripod body (see pls. 10 and 11) passed through a dike swarm which amounted to 60 percent of the material encountered within the sulfide zone. Hornfels inclusions generally constitute less than 10 percent of a drill core from the mineralized zone. However, 150 feet of drill hole 2 in the Tunnel body (see pls. 10 and 12) was in hornfels, and only a fraction of the nickeliferous material expected was penetrated by this hole.

MUSKEG AND SIDE HILL BODIES

In the eastern part of the norite body, where exposures are relatively scarce and where only three holes have been drilled, the continuity of a sulfide-bearing zone above the base of the norite, here underlain by hornfels, is inferred largely from magnetic data.

The results of the magnetometer traverses are plotted graphically on the cross sections along the traverse lines. (See pl. 14.) The corrected magnetic values are listed in the following table.

TABLE 1.—*Vertical intensity anomalies in gammas (regional intensity approximate)*

Station No.	Traverse							
	1	2	3	4	5	6	7	8
1	−33	46	10	45	39	24	28	69
2	5	90	51	44	58	162	17	135
3	−53	63	74	120	378	392	213	240
4	−35	78	102	136	354	12	546	262
5	−91	161	178	−5	81	24	190	164
6	−11	233	29	−32	34		−130	155
7	−35	117			−44		−9	167
8		0					−9	185
9								80
10								184
11								164
12								181

The readings show that rocks which contain pyrrhotite affect the local vertical magnetic intensity more than rocks that are pyrrhotite free.

Traverses 2 to 7 inclusive strongly indicate that the sulfide-bearing zone is a continuous body in the area between them, for in each a significant increase in vertical intensity was recorded along a trend compatible with available geologic information on the probable structure and position of the sulfide zone and the norite mass.

The magnetic profile along traverse 1 shows only minor fluctuations, and those are not in alinement with the trend shown by the other traverses. All but one of the readings along traverse 1 are approximate regional values of vertical intensity. The sulfide-bearing zone apparently is absent beneath this traverse. The traverse indicates that the sulfide zone of the Muskeg bodies is not continuous with that of the East Tripod body. The trend established by traverses 2, 3, and 4 suggests that the zone of the Muskeg bodies passes north of traverse 1. It cannot extend much farther west, however, as it is not present in the well-exposed area north of that shown in plate 14. An offset, therefore, is indicated between the zone of the Muskeg bodies and that of the East Tripod body. Whether this offset is caused by faulting or is an original discontinuity is not known.

Traverse 8 indicates sparse sulfide minerals in the norite between the Muskeg and the Side Hill bodies. The values along this traverse are all higher than the assumed regional value of vertical intensity.

The norite between the Tunnel and Side Hill bodies contains appreciable pyrrhotite but too little to designate it a sulfide-bearing body. The high vertical intensity values along traverse 8, although inconclusive, suggest that the zone of the Muskeg bodies may widen and merge with the zone of sparsely disseminated pyrrhotite just mentioned.

An inward, westerly dip of about 75° for the North Muskeg body, and about 45° for the South Muskeg body as exposed, is indicated by one drill hole in each and by the inferred positions of the contacts at the surface.

The magnetic profiles, except 1 and 8, show not only the continuity and extension of the Muskeg deposit, but for the most part an abrupt change in vertical intensity near the outer ends of the profiles away from the norite mass and a more gradual change inward. Thus the profiles are consistent with a general inward dip of the whole body, unless the barren norite itself has a higher magnetic susceptibility than the surrounding rocks.

The magnetic traverses, the outcrops, and 2 drill holes fix the position of the outer (lower) contact of the body within fairly narrow limits. The inner contact of the sulfide zone cannot be placed as closely because most of the profiles show a relatively gradual change in magnetic intensity over the inner contact of the zone. The width of outcrop of the sulfide body as inferred from the magnetic profiles is sketched on plate 14.

The thickness of the zone at the North Muskeg body is calculated from drill hole 7–A and from the magnetic data to be about 80 feet. Similarly the zone at the South Muskeg body is calculated to be about 100 feet thick. The zone northwest of the North Muskeg body is computed from the magnetic data to be about as thick as the North Muskeg body.

Assuming that the susceptibility of the barren norite and the surrounding rocks is approximately the same, and knowing that the deposit dips inward, the fact that the relatively abrupt change in magnetic intensity is for the most part on the outward end of magnetic profiles 2 to 7 indicates that the vertical extent of the deposit is substantially greater than its width on the surface. The two drill holes in the Muskeg bodies prove that the deposit at those two places extends down the dip at least 180 feet.

The fact that the magnetic intensity changes so abruptly near the inferred contact of the sulfide-bearing zone indicates that the cover of moraine and muskeg over the deposit is not more than a few tens of feet thick. If the deposit were buried by a much greater thickness of cover the magnetic effects of the deposit would be dampened, and the abrupt change in magnetic intensity as revealed by the profiles would not occur.

TAKANIS BODIES

The Takanis bodies have not been explored by diamond-drill holes or magnetometer prospecting. Their surface features have been described by Reed and Dorr.[7] For the most part these bodies are marginal to a norite mass, and it is believed that exploration might reveal structural relationships analagous to those of the Tunnel, Tripod, Side Hill, and Muskeg bodies.

OTHER BODIES

At least six other unprospected bodies of sulfide-bearing norite are present on Yakobi Island. (See pl. 9.) Four of these have been described by Reed and Dorr,[8] and no additional information about them is available.

Sulfide-bearing norite was observed at two localities in the western part of Yakobi Island. At both of these places rock exposures are poor, and the size of the deposits could not be estimated.

RESERVES

On the basis of surface sampling and mapping of outcrops, Reed and Dorr estimated for the entire district 5,800,000 tons of sulfide-bearing material with a nickel content of 0.36 percent and a copper content of 0.27 percent. They predicted that further development and exploration would probably increase the estimate of tonnage in these bodies, but that there was no reason to believe that any additional tonnage would have a metallic content of a different order of magnitude from the material they sampled. This prediction is confirmed.

TUNNEL AND TRIPOD BODIES

GRADE OF ORE

Analyses for nickel and copper in the diamond-drill cores were made by the Bureau of Mines. The parts of the cores to be analyzed were selected by the Geological Survey, but if these exceeded 5 feet in length the Bureau of Mines divided them into 5-foot sections, each of which was analyzed separately. The analyses were furnished the Geological Survey and these, averaged by holes, provided the data for table 2. The data in the first half of the table refer to the sulfide-bearing deposit as a whole; the data in the second half refer to the richer parts only. For location of the drill holes see plate 10. The two holes in the Muskeg deposit, Nos. 7–A and 13, are discussed further in the section of this report on that deposit.

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[7] Reed, J. C., and Dorr, J. V. N., 2d, op. cit., p. 125 and pl. 22.

[8] Reed, J. C., and Dorr, J. V. N., 2d, op. cit., pp. 125–126.

TABLE 2.—*Data from diamond-drill holes in Bohemia Basin nickel-bearing deposits*

Number of hole	Total of hole in sulfide-bearing body				Hole exclusive of barren material			
	Length (feet)	Distance from collar (feet)	Nickel (percent)	Copper (percent)	Length (feet)	Distance from collar (feet)	Nickel (percent)	Copper (percent)
1	122.5	29–151.5	0.337	0.202	87	29–44 58–130	0.392	0.212
1-A	133	65–198	.466	.202	123	65–188	.501	.214
2	93	196–289	.188	.105	22	198–209 227–238	.395	.235
4	125	66–191	.413	.205	68	102–146 158–168 177–191	.700	.348
4-A [1]	223	82–305	.216	.139	97	82–126 225–265 292–305	.422	.266
7-A	171	119–290	.230	.145	65	136–186 275–290	.353	.221
11	116	74–190	.482	.208	66	74–140	.700	.265
11-A	194	40–234	.415	.334	92	40–85 95–131 161–172	.875	.710
12	336	54–390	.288	.149	147	70–98 138–165 255–347	.516	.247
13	127	10–137	.385	.166	68	10–50 109–137	.610	.212
14	106	116–222	.348	.171	106	116–222	.348	.171
15	104	277–381	.125	.87	----	----	----	----
16	125	283–408	.245	.114	----	----	----	----
17	100	383–483	----	----	----	----	----	----

[1] Hole 4-A was assigned relatively little weight in calculation of reserves, as it intersects a zone of dikes not believed to be representative of the body.

The second column of the table shows the distance from the collar of the hole to the place where material with significant sulfide minerals was first encountered, and the distance from the collar to the place where it was last cut. The difference, shown in the first column, is the length of the part of the hole that is in the body.

Low-grade material and small local concentrations of sulfide minerals border the mineralized body, and the determination of its exact limits is therefore largely arbitrary. Material with a nickel content of less than 0.15 percent is generally considered to lie outside the deposit.

In calculating the grade of the material and in determining the length of the part of each hole that is within the sulfide-bearing deposit, barren norite, dikes, and hornfels inclusions lying within the deposit are considered as parts of the deposit. Inclusion of these barren zones in the calculations decreases the computed average grade and increases the computed tonnage of material within the deposit. If the barren zones within the deposit were eliminated from the calculations, the computed tonnage would be smaller but of higher grade.

The calculations of tenor of material from each drill hole, the results of which are given in the last two columns of table 2, have been made on the arbitrary assumption that sulfide-bearing masses 10 feet or more thick could be selectively mined, and that barren zones, here defined as zones containing less than 0.25 percent of nickel, if 10 feet or more thick, could be discarded.

The average nickel content of the deposits, as calculated from the data in table 2, is 0.37 percent, which agrees closely with the 0.36 percent average calculated by Reed and Dorr [9] from analyses made by the Geological Survey.

The copper content as indicated by different groups of analyses varies widely. The average copper content of the deposits as calculated by Reed and Dorr is 0.27 percent, whereas that calculated from the Bureau of Mines data as given in table 2 is 0.20 percent. Analyses of 90 feet of channel samples cut in the tunnel in the Tunnel body, made by the Territorial Assay Office [10] in Ketchikan, indicate an average of 0.63 percent of nickel and 1.21 percent of copper. Analyses of samples cut in the same tunnel and in essentially the same places by Reed and Dorr show an average of 0.52 percent of nickel and 0.30 percent of copper. Analyses of core from a drill hole parallel to and only a few feet from the tunnel indicate an average nickel content of 0.50 percent and a copper content of 0.214 percent.

The samples taken by Reed and Dorr, except those from the tunnel, were taken at the surface. The difference between the average copper content as determined from the Geological Survey analyses and as determined from the Bureau of Mines analyses possibly reflects a small amount of secondary enrichment of copper, although no secondary copper minerals were seen. Possibly some of the differences in various copper analyses are due in part to differences in analytical methods. That there has been appreciable leaching of nickel appears doubtful, because analyses of fresh core material show almost the same nickel content as analyses of material from surface cuts. Furthermore, the area has been so recently glaciated that fresh sulfide minerals are common on natural exposures. The nickel content of the deposits, therefore, seems much better established than the copper content.

TONNAGE

The number of tons of mineralized norite present in each limb of the trough-shaped deposit has been estimated. The deposit is arbitrarily limited on the east by a vertical plane connecting the most easterly exposures of the East Tripod and the Tunnel bodies (see pl. 10), and on the west by a plane connecting the most westerly exposures of the West Tripod and the Tunnel bodies.

Drill holes 15, 16, and 17 (see pls. 11 and 12) show diminished nickel content immediately east of the eastern limiting plane. There are no drill data for the part of the body lying west of the western plane,

[9] Reed, J. C., and Dorr, J. V. N., 2d, op. cit., p. 129.

[10] East, J. H., Jr., Bohemia Basin nickel deposit, Yakobi Island, Alaska: U. S. Dept. of the Interior, Bur. Mines. Interim Report, 1942.

but a few exposures indicate that it probably does not continue far beyond that plane.

The tonnage of sulfide-bearing material that is known completely enough to be called measurable is relatively so small that it is not estimated here. The sulfide-bearing material in the trough between the outcrops of the Tunnel body and the Tripod bodies, and limited by the arbitrary bounding planes, is classed as indicated material.

The outcrop length of each of the two limbs of the deposit was determined by direct measurements from the map, and it was assumed that each of these lengths is the average for the corresponding limb, although this is only approximately true. (See pl. 10.) Each of the two limbs of the deposit was projected beyond the drill information to the inferred bottom of the trough, and the average distance down the dip was determined from the projections.

The average thickness of the body within the limiting planes was determined geometrically from drill and some outcrop information. In the following calculations two average thicknesses for each limb were used, one including dikes, hornfels inclusions, and barren norite (table 2, col. 2), the other including only the richer material (table 2, col. 6). In all tonnage calculations the specific gravity of the material is assumed to be 3.

The grade data from each drill hole have been weighted according to the approximate proportional part of the limb of the body represented by the hole.

TABLE 3.—*Tonnage and grade of material in the Tripod and Tunnel bodies, Bohemia Basin*

	Including barren and low-grade material	Excluding barren and low-grade material
East and West Tripod bodies (north limb of trough):		
Average thickness feet	124	88
Outcrop length do	700	700
Average distance down dip do	510	510
Total material tons	4,400,000	2,900,000
Average grade:		
Nickel percent	.38	.44
Copper do	.19	.23
Tunnel body (south limb trough):		
Average thickness feet	147	90
Outcrop length do	570	570
Average distance down dip do	760	760
Total material tons	5,900,000	3,600,000
Average grade:		
Nickel percent	.37	.57
Copper do	.21	.31

The total tonnage of sulfide-bearing norite in this trough-shaped deposit, as estimated from data in table 3, is 10,300,000 tons of indicated material with an average grade of approximately 0.37 percent of nickel and 0.20 percent of copper, or 6,500,000 tons of material with a grade of 0.51 percent of nickel and 0.27 percent of copper.

The length of holes in the bodies as shown in table 2, and the length within the limits of the deposit as shown in plates 11 and 12, do not in every case agree. The sulfide content of the core alone determines the length recorded in table 2, whereas geologic data are used in determining the generalized limits of the deposit as recorded in plates 10, 11, and 12.

MUSKEG AND SIDE HILL BODIES

GRADE OF ORE

The Muskeg bodies have been tested both by diamond-drill holes and channel samples.[11] Channel samples from the Muskeg and Side Hill bodies aggregating 399 feet indicate an average grade of 0.25 percent of nickel and 0.25 percent of copper. Drill cores from holes 7–A and 13 (see table 2) aggregate 298 feet and indicate an average grade of 0.293 percent of nickel and 0.154 percent of copper. The analyses of nickel from the channel samples and from the drill cores are comparable, but it is difficult to explain the wide differences in the copper analyses. The highest-grade material encountered in the entire drilling program was in hole 13 in the South Muskeg body where a 6.5-foot length of core contained 3.08 percent of nickel and 0.9 percent of copper.

The magnetic data used in this report do not in themselves yield information on the nickel-copper content of the deposit. Observed anomalies where the deposit is not exposed appear consistent with those where the deposit is exposed, and with the theoretical anomaly calculated on the basis of an average pyrrhotite content of 2.2 percent for all of the deposit, and on simplified assumptions of its shape and extent based on geology.

The ratio of the sulfide minerals pentlandite, chalcopyrite, and pyrrhotite is remarkably constant. Therefore the grade of material indicated solely by magnetometer traverses is presumed to be comparable to that indicated in the better known parts of the deposit by analyses of drill cores and channel samples.

TONNAGE

Information obtained from the magnetic observations and from the few exposures of the Muskeg deposit indicates a band of sulfide-bearing norite continuous for about 1,500 feet from the westernmost exposure of sulfide-bearing material in the Side Hill body to a point halfway between traverses Nos. 1 and 2, arbitrarily assumed to be the northwestern limit of the Muskeg deposit. The assumption is made, in this estimate of length of outcrop of the deposit, that the high magnetic anomalies observed along traverse 8 between the Side Hill body

[11] Reed, J. C., and Dorr, J. V. N., 2d, op. cit. p. 129.

and the South Muskeg body indicates a local area of sparsely distributed sulfide minerals connecting the two bodies, and not an actual discontinuity in the deposit. Tonnage estimates have been reduced by 10 percent as an allowance for this and for probable other low-grade or barren parts of the deposit. Data obtained from surface exposures, diamond-drill holes, and the magnetometer traverses indicate that the average thickness of the deposit is about 80 feet. No evidence is available concerning the maximum dip length of the deposit. For purposes of tonnage calculations a dip length of 750 feet, half the strike length of the deposit, is assumed.

Thus it is estimated that approximately 8,100,000 tons of sulfide-bearing material is contained in the Muskeg and Side Hill bodies.

TAKANIS BODIES

Reed and Dorr [12] have estimated 2,400,000 tons of sulfide-bearing material in the Takanis bodies. These bodies have not been drilled by the Bureau of Mines, nor explored by any geophysical method, and no revisions of these earlier estimates are possible. By analogy with the deposits described, additional exploration might greatly increase this estimate of tonnage.

SUMMARY OF RESERVES

The present estimate of the amount of sulfide-bearing material available on Yakobi Island, principally in Bohemia Basin, is 10,300,000 tons of indicated material in the Tunnel and Tripod bodies, 8,100,000 tons of inferred material in the Muskeg and Side Hill bodies, and 2,400,000 tons of indicated material in the Takanis bodies; a total of 20,800,000 tons. The average grade is about 0.33 percent of nickel and 0.21 percent of copper. Approximately 35 percent of this material is probably barren; if this were excluded by some process of selective mining the grade would be increased to about 0.45 percent of nickel and 0.28 percent of copper.

Certain features of these deposits should be emphasized, as they would affect any scheme of mining.

The deposits are large. Rough calculations indicate that the removal of approximately 4,000,000 tons of barren norite and overburden from the trough above the western part of the deposit would expose about 9,000,000 of the 10,300,000 tons of indicated sulfide-bearing material.

A few small, higher-grade bodies of material were encountered in the drilling, with a nickel content of as much as 3.08 percent. However, these higher-grade bodies have no known regularity and cannot be projected from one drill hole to the next.

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[12] Reed, J. C., and Dorr, J. V. N., 2d, op. cit., p. 129.

Other factors pertaining to the general economics of exploitation and operation have been discussed by Reed and Dorr.[13]

RECOMMENDATIONS FOR FURTHER EXPLORATION

Enough exploratory work has been done to form a reasonably safe basis for analysis of the various factors that require preliminary consideration as to whether the deposits are worth developing. If prospecting is to be continued in the Bohemia Basin the norite near its contact with the underlying rocks is the most hopeful zone to test. A better idea of grade of material in the covered areas may be obtained from pits or short drill holes through the moraine. However, exploration in areas covered by moraine is difficult. The ground is saturated, so that pits rapidly fill with water. The thickness of morainal cover varies widely, and accurate predictions of thickness are difficult.

The Takanis bodies have not been explored by diamond-drilling or by geophysical prospecting, and further exploration would undoubtedly reveal greatly increased reserves. Sulfide-bearing norite is known on Yakobi Island in six localities (see pl. 10) other than those detailed in the preceding sections of this report, and exploration of some of these localities may be warranted.

There is no reason to believe that any additional tonnage which might be located would have a nickel or copper content significantly higher than that of the material already indicated.

NICKEL-COPPER DEPOSITS ON THE WEST COAST OF CHICHAGOF ISLAND

GEOLOGY

Pecora[14] has summarized the general geology and the characteristics of the deposits on the west coast of Chichagof Island as follows:

> On the west coast of Chichagof Island, southeastern Alaska, are three nickel-copper deposits that consist of norite containing the sulfide minerals pyrrhotite, pentlandite, and chalcopyrite. The deposits are within less than a mile of each other and are, by water, 160 miles southwest of Juneau and 70 miles northwest of Sitka. The norite is part of a stock, about 5 square miles of which is above sea level. Other rocks of the stock are amphibolite, amphibolitic norite, gabbro, diorite, quartz diorite, monzonite, granite, pegmatites, quartz veins, and schist inclusions. The stock is intrusive into a Lower Cretaceous (?) graywacke formation and an Upper Triassic (?) greenstone formation, both of which are now metamorphosed to schist.
>
> The deposits are of two kinds: (1) A disseminated-sulfide deposit, in which the sulfide minerals are distributed throughout the mass of the norite, and (2) concentrated-sulfide deposits, in which the sulfide minerals are in distinct podlike

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[13] Reed, J. C., and Dorr, J. V. N., 2d, op. cit., pp. 130–132.

[14] Pecora, W. T., Nickel-copper deposits on the west coast of Chichagof Island, Alaska U. S. Geol. Survey Bull. 936–I, p. 221, 1942.

masses of sulfide rich norite. The deposits of type 2 are coarser-grained, smaller, and higher in nickel and copper than those of type 1.

Two of the three deposits described are of the concentrated-sulfide variety.

One of these two is on the northern tip of Fleming Island, the other is about 3,000 feet southeast. Pecora says further:

The deposit composed of norite with disseminated sulfides is exposed about 1,000 feet southeast of the second deposit of concentrated sulfides.

Pecora's generalized geologic map of a part of western Chicagof Island and his geologic map of the stock near Davison Bay are given as figure 5 and plate 15.

MINERALOGY

The sulfide minerals in the norite are pyrrhotite, pentlandite, and chalcopyrite, intimately intergrown. They were the last minerals to crystallize and are interstitial to the silicate minerals. Pyroxene, amphibole, and plagioclase feldspar are the chief gangue minerals. The ratio of sulfide minerals to silicate minerals in the rock varies widely, but the ratio between the different sulfide minerals is fairly constant. The percentage of sulfide minerals is higher, and the minerals are more coarsely crystalline in the concentrated-sulfide deposits than in the disseminated-sulfide deposit.

Numerous small fractures in the norite are filled with graphite which may have come from inclusions of carbonaceous graywacke in the norite.

CONCENTRATED-SULFIDE DEPOSITS

ON FLEMING ISLAND

A small concentrated-sulfide deposit crops out on the northern tip of Fleming Island (see pls. 15 and 16), and at high tide much of the body is flooded. The Bureau of Mines explored this deposit by five diamond-drill holes. Private reports on the property by J. C. Rogers and R. L. Healy were made available to the Geological Survey by the Bureau of Mines and have been of value, as they contain maps and descriptions of the underground workings which in 1942 were inaccessible because flooded.

Old workings consist of a shaft and 150 feet of drifts and crosscuts. The shaft, about 50 feet east of the deposit, is reported by Healy to be 180 feet deep. At the time of the investigation during the summer of 1942 it was flooded to within a few feet of its collar. Although the shaft is only about 60 feet from the ocean, the water in it is fresh. During a few days of moderate pumping the water-level was lowered about 40 feet. Probably no undue difficulty would be experienced in unwatering the workings. The outcrop of the body measures about 30 by 40 feet. A thin covering of brick-red oxidized sulfide minerals

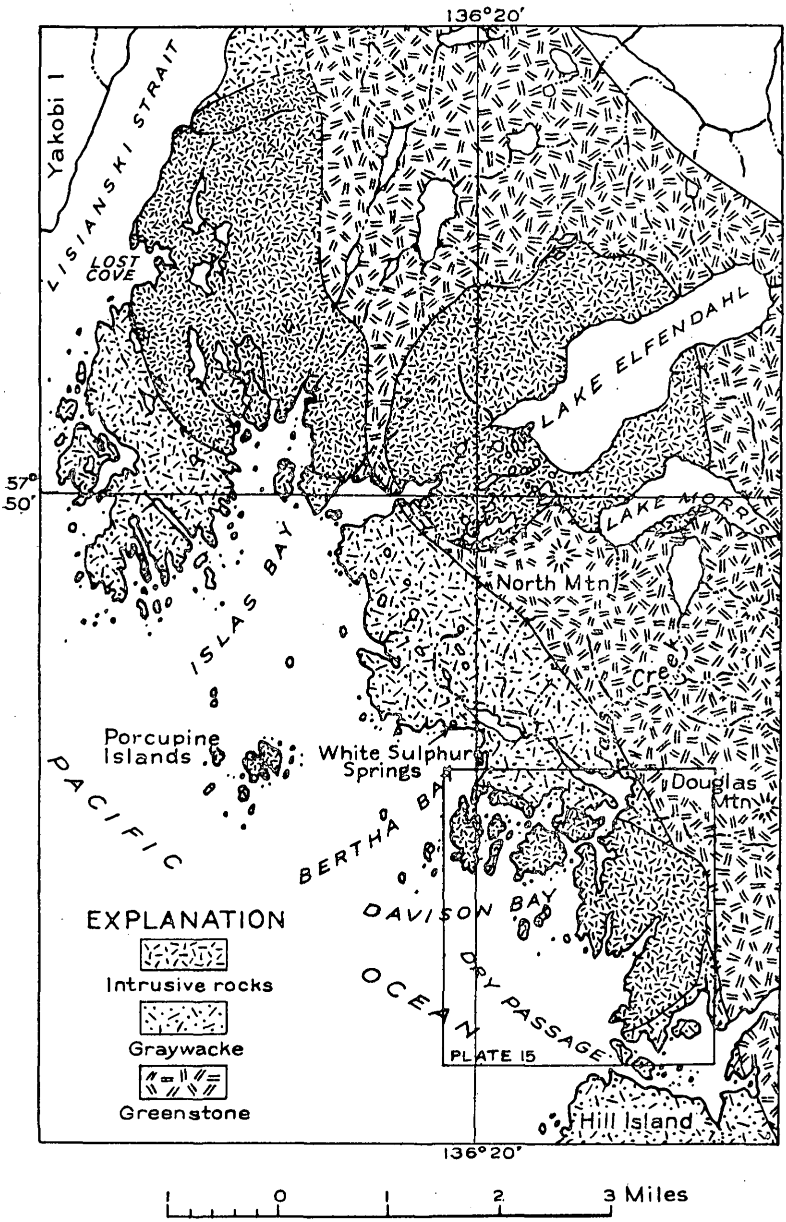

FIGURE 5.—Generalized geologic map of a part of western Chichagof Island, Alaska. (After Pecora.)

makes the outcrop readily distinguishable from the surrounding barren norite. A sketch map of the deposit, underground workings, and horizontal projections of the diamond-drill holes is shown on plate 16. The sulfide minerals are largely concentrated in small pods surrounded by nearly barren norite. These pods are generally only a few inches long. They contain an average of about 3 percent of nickel and 2 percent of copper, in contrast to the enclosing norite which generally contains less than 0.1 percent of nickel. Pods of concentrated-sulfide appear to constitute a little more than half of the body.

The maps prepared by Healy indicate that 37 feet of the workings on the 80–foot level are in the sulfide body. Sulfide minerals probably are sparse in workings on the 180–foot level. A prominent fault, which strikes N. 80° E. and dips 75° N., was mapped by Healy on the 180–foot level. It is believed that this fault was intersected in diamond-drill holes 4, 5, and 6 (see pls. 16 and 17), where zones of finely comminuted rock 1 foot to 2 feet wide were encountered.

Information based on the diamond-drill holes, surface maps, and Healy's maps of the underground workings indicates that the sulfide-bearing body pitches southeast at about 75°. Drill holes 4 and 6, which intersect the body near the 80–foot level, suggest that the cross section of the body is slightly smaller at that level than on the surface, although the evidence is not conclusive. With the exception of 3½ feet of concentrated-sulfide minerals intersected in hole 6, no sulfide minerals were found on the footwall side of the fault. Holes 7 and 8 were directed to intersect the sulfide-bearing body beyond the fault, but neither hole encountered the body. The body therefore is believed either to have been displaced a considerable distance along the fault, or to lens out a short distance below the fault.

Norite containing disseminated sulfide minerals was reported both by Healy and Rogers on the 180-foot level on the footwall side of the fault. These disseminated-sulfide minerals possibly are part of a small low-grade body which has no connection with the body on the 80-foot level.

NEAR HEAD OF DAVISON BAY

Concentrated-sulfide deposits crop out at three localities on the south shore of a protected cove near the head of Davison Bay. (See fig. 6.) These deposits are similar mineralogically to the one at Fleming Island, though much smaller.

At locality A (fig. 6) a conspicuous outcrop of concentrated-sulfide minerals projects a few feet above the surrounding norite. This body consists of a few pods of sulfide minerals arranged in an erratic pattern in norite that contains some dissiminated-sulfide minerals (see fig. 7). A hole drilled downward at an angle of 36° intersected 1.2 feet of concentrated-sulfide minerals at a depth of 4 feet below the surface. The deposit is much too small to be of commercial interest.

Other even smaller concentrations of sulfide minerals are present at localities B and C (fig. 6). A short drill hole directed under the outcrop of pods of sulfide minerals at locality B failed to intersect any sulfide minerals.

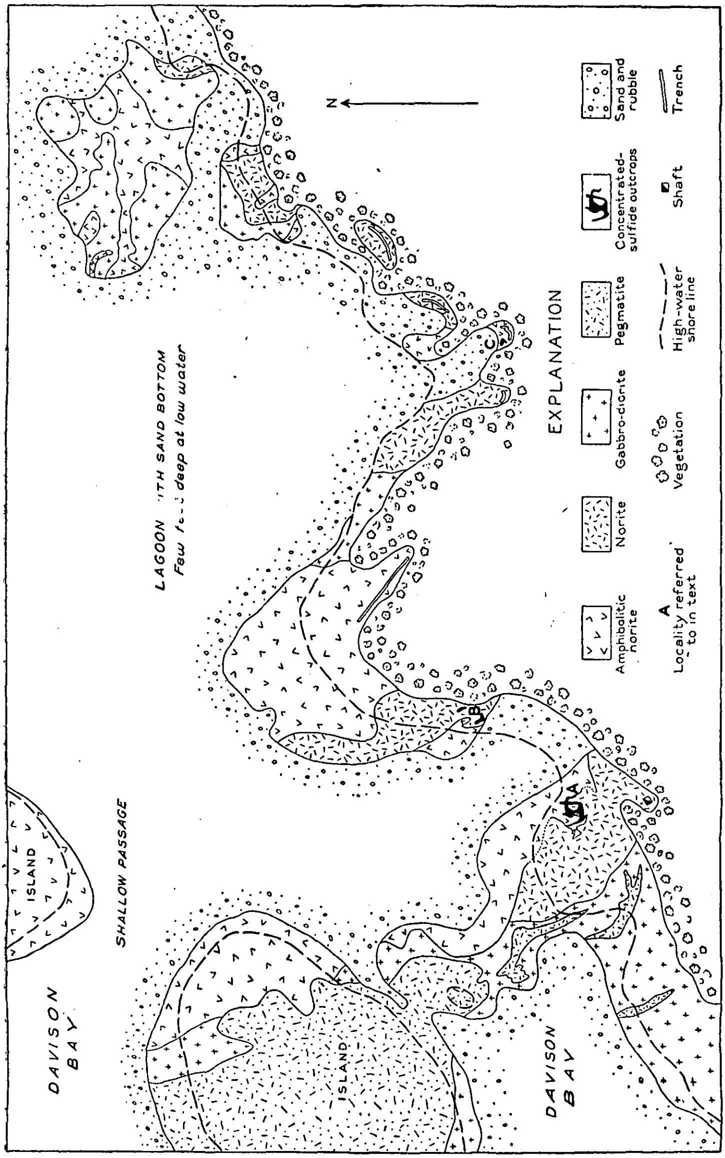

FIGURE 6.—Geologic map of the south shore of a protected cove near the head of Davison Bay, Chichagof Island, Alaska.

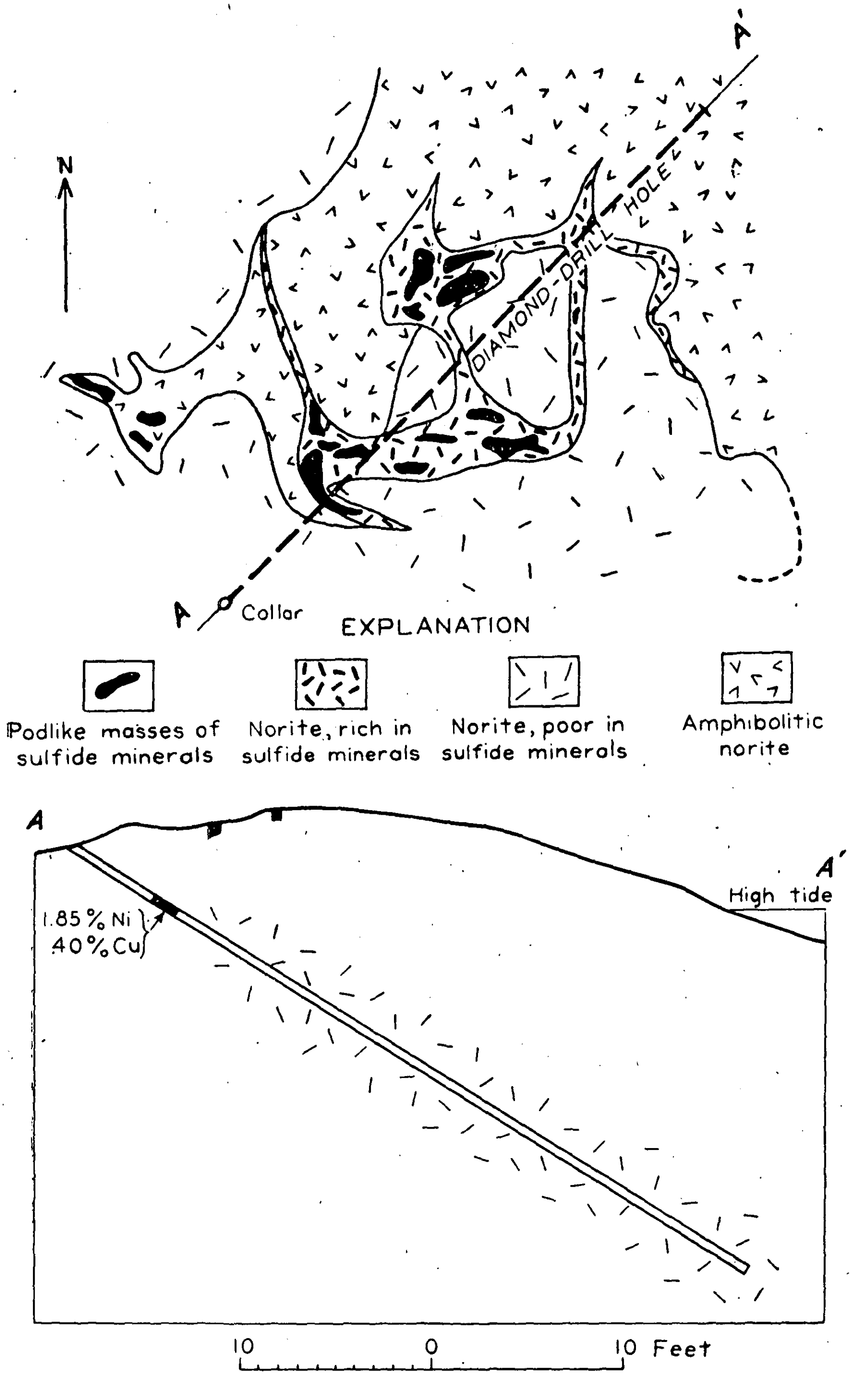

FIGURE 7.—Sketch map and cross section through drill hole in concentrated-sulfide deposit, Davison Bay, Chichagof Island, Alaska.

DISSEMINATED-SULFIDE DEPOSIT

A large disseminated-sulfide deposit lies about 1,000 feet southeast of the concentrated-sulfide deposit near the head of Davison Bay. (See pl. 15.) During the summer of 1941 numerous pits and trenches were dug by the claim owners, and the body was sampled by W. T. Pecora. (See pl. 18.) The rocks exposed in the pits are mainly norite, gabbro, and amphibolite. The gabbro and amphibolite contain some sulfide minerals, but their nickel and copper content is generally very low. Most of the sulfide minerals are contained in a coarse-grained phase of the norite. The outline of this disseminated deposit is very irregular, but in general it extends up small stream valleys in such a manner as to suggest that the deposit lies relatively flat. A single hole was drilled in this deposit. (See pl. 18.) In the vicinity of this hole the body appears to be about 100 feet thick and to dip southwest at an angle of about 20°.

ORIGIN OF THE DEPOSITS

Immiscible sulfide droplets may have separated from the cooling norite magma at a time when most of the silicate minerals in the norite had crystallized. Some of these droplets were concentrated by gravity into zones and were retained in the crystallizing norite to form the disseminated-sulfide deposit; others collected and in some places were injected into the partly solidified norite to form the pipelike concentrated-sulfide deposit of Fleming Island and the small irregularly shaped deposits of Davison Bay.

RESERVES

CONCENTRATED-SULFIDE DEPOSITS

The Fleming Island deposit has an outcrop area of about 750 square feet and is believed to extend to an average depth of about 110 feet and to be cut off by the fault shown on plates 16 and 17. According to this interpretation the deposit contains about 80,000 cubic feet of concentrated-sulfide material. Assuming 10 cubic feet to the ton, the body contains about 8,000 tons. Analyses of diamond-drill cores and of surface samples have been supplied by the Bureau of Mines. An average grade of 1.57 percent of nickel and 0.88 percent of copper is indicated by 72.5 feet of core from the parts of drill holes 4, 5, and 6 in the deposit. A channel sample 29 feet long from the outcrop of the body indicates an average grade of 1.52 percent of nickel and 0.68 percent of copper. The drill-hole information is believed representative of the lower part of the ore body, and the channel sample representative of the upper part. The indicated average grade is therefore 1.54 percent of nickel and 0.78 percent of copper. Pecora[15] reports

[15] Pecora, W. T., op. cit., p. 232.

0.58 percent of nickel and 1.15 percent of copper in material collected from the partly weathered outcrop. This sample is not included in estimates of grade of the deposit, as it appears inconsistent with other samples, presumably because it contains weathered material.

The largest concentrated-sulfide deposit at Davison Bay contains only a few tons of sulfide-bearing material with a grade of approximately 1.5 percent of nickel and 0.8 percent of copper.

DISSEMINATED-SULFIDE DEPOSIT

The disseminated-sulfide deposit has an outcrop area of several acres, and, according to Pecora,[16] contains 13,500 tons of sulfide-bearing material per foot of depth. A single drill hole proves that the deposit extends to a depth of about 60 feet, and it probably extends much beyond that depth. There are doubtless several million tons of sulfide-bearing material in this deposit, but the body has not been explored adequately enough to make an accurate estimate of its tonnage or grade. The sulfide-bearing material encountered in the drill hole contains an average of 0.16 percent of nickel and 0.03 percent of copper, as calculated from data furnished by the Bureau of Mines. Surface samples indicate that the average tenor of the sulfide-bearing body is considerably higher than is indicated by this drill hole. Pecora[17] estimates an average grade of about 0.2 percent of nickel and 0.1 percent of copper, based on samples taken from 34 test pits on the body. Check samples by the Bureau of Mines corroborate these figures.

RECOMMENDATIONS FOR FUTURE WORK

No further exploration of these deposits is recommended. The Fleming Island deposit appears well enough known to afford a basis of judgment as to whether it is minable. The larger disseminated deposit contains less nickel and copper and is smaller than similar deposits on Yakobi Island about 15 miles northwest of Mirror Harbor.

NICKEL-COPPER PROSPECT NEAR SITKA, BARANOF ISLAND

A nickel-copper prospect, said to be covered by two claims belonging to Charles Haley and William Hanlon of Sitka, lies at an altitude of about 850 feet, approximately 1,500 feet from the shore of Salmon Cove, a small indentation on the northeast shore of Silver Bay about 5 miles east from Sitka. The deposit is in a fault that strikes N. 10° W. and dips 80° E. and cuts hornblendite. A 15-foot adit has been driven southward on this fault.

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[16] Pecora, W. T., op. cit., p. 241.
[17] Pecora, W. T., op. cit., p. 241.

Sulfide minerals, largely pyrrhotite with minor amounts of chalcopyrite, have been introduced along the fault. These minerals occur as small, irregularly distributed masses in the fault. The largest pod of massive sulfide minerals seen is about 10 inches wide and 2 to 3 feet long. Minor amounts of pyrrhotite and chalcopyrite have been deposited in the hornblendite near the fault. Slight sulfide mineralization was noted at outcrops about 50 feet southwest of the tunnel portal.

A sample of the massive sulfide minerals in the fault was collected by John C. Reed in 1941 and analyzed by K. J. Murata of the Geological Survey. It contained 0.99 percent of copper, 0.20 percent of nickel, 0.09 percent of cobalt, and no silver.

The deposit appears to have no economic significance.