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# GEOLOGY AND ASSOCIATED MINERAL DEPOSITS OF SOME ULTRABASIC ROCK BODIES IN SOUTHEASTERN ALASKA

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# GEOLOGY AND ASSOCIATED MINERAL DEPOSITS OF SOME ULTRABASIC ROCK BODIES IN SOUTHEASTERN ALASKA

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

## ABSTRACT

In connection with a Geological Survey project to investigate the occurrence of nickel, chromium, and refractory-grade olivine in southeastern Alaska, the authors examined several ultrabasic rock bodies during the summer of 1943. Among these were the bodies in the Lituya Bay-Mount Crillon area, central Baranof Island, Red Bluff Bay, the Blashke Islands, Kane Peak, and Mount Burnett.

In the Lituya Bay-Mount Crillon area the oldest group of rocks is a thick sequence of highly metamorphosed sedimentary and volcanic rocks which are separated by a major fault from a younger group of bedded slate and greenstone. Overlying the slate and greenstone is a thick sequence of Miocene rocks consisting of unsorted conglomerate, sandstone, shale, a few thin seams of coal, and some tuffaceous beds. A large layered basic igneous body with the bulk composition of a hypersthene gabbro or norite intrudes the metamorphosed sedimentary and volcanic rocks. This body is composed for the most part of alternating layers of norite, olivine norite, dunite, troctolite, anorthosite, bronzitite, and ilmenite.

Beach sands in the vicinity of Lituya Bay have yielded a limited amount of gold and some platinum; the platinum may have been derived from the basic intrusive. The lowermost outcrops of the basic body contain abundant sulfide minerals, principally chalcopyrite and pyrrhotite, and the ilmenitic sheets in the body are rich in sulfide minerals. No chromite was observed in place, although chromite float has been reported on the glaciers.

In the central part of Baranof Island, in the area between Red Bluff Bay and Silver Bay, numerous discontinuous sills of highly serpentinized dunite crop out. Chromite is abundant in the sills, occurring as scattered grains, as crystal aggregates as much as 3 inches long, and as streaks and seams as much as 3 feet long and a few inches wide. No concentration of chromite was found of sufficient size and grade to constitute an ore body.

At Red Bluff Bay, Baranof Island a body of chromite crops out in the northeastern part of the ultrabasic mass. This chromite contains sufficient iron to be appreciably magnetic. A series of magnetometer observations was made in a small area immediately south of the northern segment of the deposit to detect, if possible, a southward extension of the body beneath a fault. A distinct high was noted in the magnetometer readings, which tends to indicate subsurface southward extension of the northern segment of the ore body.

A small chromite deposit, hitherto unreported, crops out in a gulch a few hundred feet west of the deposit explored by the magnetometer. This deposit contains about 80 tons of chromite with an average grade of 43.20 percent of $Cr_2O_3$.

The Blashke Islands are a group of 16 small islands made up of deformed rocks, which are intruded by an ultrabasic body of roughly circular outcrop. The bedded rocks are largely graywacke and pyroclastic rocks of Silurian age, which generally strike northwestward, but locally they roughly conform in attitude to the margin of the ultrabasic intrusive body. The core of the ultrabasic intrusive is an oval dunite mass about 6,000 by 8,000 feet in outcrop dimensions. Encircling the dunite core is a ring of pyroxenite and wehrlite 500 to 2,000 feet wide, which in turn is encircled by a ring of gabbro with local variants of hornblendite, diorite, augitite, and anorthosite. The gabbro phase is gradational into the surrounding rocks. Contacts between the various units of the ultrabasic body are approximately vertical. A small percentage of sulfide minerals, principally pyrrhotite and chalcopyrite, is locally present in the pyroxenite and the gabbro. Three analyses of samples of the sulfide-bearing material indicate that it contains 0.04 to 0.1 ounce of platinum-group metals per ton.

In the Kane Peak area, Kupreanof Island, an ultrabasic intrusive rock body is surrounded by graywacke of Cretaceous age and by biotite-quartz gneiss and monzodiorite. The ultrabasic rocks range in composition from gabbro to dunite. Wehrlite, pyroxenite, hornblendite, and mica-rich variants of these rocks are locally abundant. The distribution and rock types in the Kane Peak area are roughly similar to those at the Blashke Islands.

In the Mount Burnett area an ultrabasic rock mass about 7 miles long and 1 to 2 miles wide intrudes phyllite and schist of the Wrangell-Revillagigedo belt of metamorphic rocks. Some Tertiary conglomerate overlies the ultrabasic rock body. The ultrabasic rocks form a large composite stock made up of diorite, gabbro, hornblendite, pyroxenite, wehrlite, and dunite. A crude banding was noted within the ultrabasic body. In some places the dunite is highly serpentinized; elsewhere in the body it is very fresh, with no alteration. The olivine approximates forsterite in composition. A few tons of chromite of inferior grade are present.

Ultrabasic rocks in southeastern Alaska are known to contain nickel, copper, platinum, and chromite. In most of the ultrabasic rocks in this region nickel and copper are present in minor quantities and are believed to be of no economic importance. A further investigation of the platinum content of some of the ultrabasic bodies may reveal minable quantities of platinum-bearing rock. A few small bodies of chromite are known, but these are of relatively little importance. Large quantities of serpentine-free dunite are known, and these may be of value as a refractory. Almost unlimited quantities of dunite are available, and will be of value if efforts to perfect a process for obtaining metallic magnesium from olivine are successful.

## INTRODUCTION

War-minerals projects of the Geological Survey in southeastern Alaska have included the investigation of deposits of several minerals useful in the iron and steel and ferro-alloy industries, both for war needs and with a view to possible postwar expansion of these industries in the Pacific Northwest. The investigations have included studies of the magnetite deposits on Prince of Wales Island; of deposits of ferro-alloy metals such as nickel, tungsten, and chromium; and of refractory-grade olivine. In this connection the authors examined several bodies of ultrabasic rock (see fig. 8) during

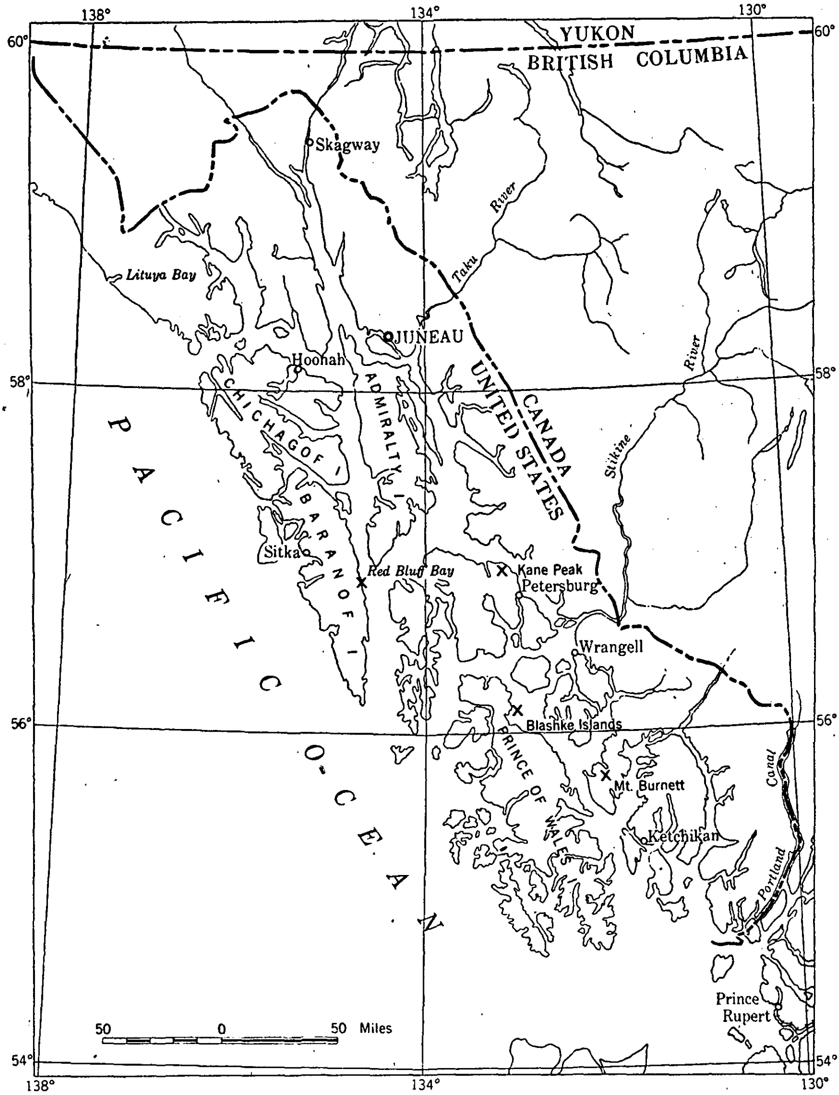


FIGURE 8.—Index map showing location of Lituya Bay, Red Bluff Bay, Blashke Islands, Kane Peak, and Mount Burnett, southeastern Alaska.

the summer of 1943. The results of some of these studies are detailed in this report.

## LITUYA BAY-MOUNT CRILLON AREA

### GENERAL FEATURES

Lituya Bay is a T-shaped fiord that indents the coast of Alaska at latitude 58°37′ N., longitude 137°39′ W. (See pl. 19.) The main arm of the bay is about 7 miles long and from 1 to 2 miles wide and trends in a southwesterly direction through a range of coastal hills. Two small arms at the head of the bay, with a combined length of about 2¾ miles and a width of slightly less than a mile, form the T. Cenotaph Island, a low, heavily timbered island almost a mile square, lies in the center of the bay. Mount Crillon, a prominent peak in the area, is about 12 miles east of the head of Lituya Bay. In 1917 Mertie[1] spent 3 days in Lituya Bay making geologic observations and collecting Tertiary fossils.

Four expeditions to Lituya Bay and vicinity were made in 1930, 1932, 1933, and 1934 and have been reported on by H. B. Washburn, Jr.,[2] and R. P. Goldthwait.[3] These expeditions carried out a varied program of geologic mapping, surveying, and glacial research. Some of the unpublished results of these expeditions have been made available to the Geological Survey by Dr. Goldthwait.

The present authors spent 5 days during July 1943 in geologic investigations in the vicinity of North Crillon and South Crillon glaciers, whose combined flow enters the south arm of Lituya Bay. (See pl. 19.)

## GEOLOGY

### BEDDED ROCKS

Three main groups of bedded rocks, ranging from intensely metamorphosed Mesozoic sediments to unaltered Tertiary sediments, crop out in the area. The oldest group of rocks is a thick sequence of highly metamorphosed sedimentary and volcanic rocks, designated on plate 19 as schist and amphibolite. The metamorphosed sediments that constitute most of this group are actinolite, staurolite, biotite-quartz, graphite, and hornblende schists. The volcanic rocks have been metamorphosed to amphibolites. These rocks lie northeast of the ice-filled trough at the head of Lituya Bay and presumably constitute much of the main part of the Fairweather Range.

In fault contact with the highly metamorphosed rocks is a group of younger rocks, designated as slate and greenstone. These are nonfossiliferous argillaceous and calcareous sedimentary material, interbedded with basic lavas. They crop out in a band about 2 miles wide parallel to the coast.

The low coast in the vicinity of Lituya Bay is underlain by a Tertiary sequence consisting of unsorted conglomerate, sandstone, shale, a few thin seams of coal, and some tuffaceous beds. The conglomerate beds contain boulders as much as 3 feet in diameter, in a

[1] Mertie, J. B., Jr., Notes on the geography and geology of Lituya Bay: U. S. Geol. Survey Bull. 836–B, 1933.

[2] Washburn, H. B., Jr., The Harvard-Dartmouth Alaskan expeditions, 1933–34: Geographical Journal, vol. 87, No. 6, pp. 481–495, 9 pls., June 1936.

[3] Goldthwait, R. P., Seismic soundings on South Crillon and Klooch glaciers: Geographical Journal, vol. 87, No. 6, pp. 406–517, 1 pl., June 1936.

matrix of sand and mud. The rock closely resembles a tillite. Fossils found near the base of this Tertiary sequence were determined by Dall to be Miocene, Astoria horizon.[4]

The rocks of the schist and amphibolite group and the slate and greenstone group are inadequately known and at present cannot be correlated with assurance with any of the rocks to the southeast. Mertie has suggested that the schist and amphibolite group may be early Paleozoic and that the slate and greenstone group may be Carboniferous or Triassic, but the present authors are inclined to believe that each group is somewhat younger. These rocks lie on the strike of rocks of somewhat similar lithology, which crop out to the southeast on Yakobi and Chichagof Islands. The two groups of bedded rocks on Yakobi and Chichagof[5] Islands are believed to be of Triassic and Cretaceous age.

Most of the bedded rocks of Lituya Bay have been considerably deformed. The rocks of the schist and amphibolite group generally strike N. 30° to 50° W. and dip southwest at steep angles. Locally they have been overturned.

Rocks of the younger slate and greenstone group strike N. 25° to 45° W. and dip steeply southwest. They are probably isoclinally folded, but little is known of their structure.

The Tertiary rocks strike about N. 40° W. and dip 30° to 60° SW. A conspicuous homoclinal sequence of the basal part of the Tertiary rocks is exposed on Cenotaph Island. No folds were noted within the Tertiary rocks, and unless faulting has repeated some of the beds the sequence is at least 12,000 feet thick.

### INTRUSIVE ROCKS

Two bodies of intrusive rock were noted by the authors. One of these, a body of horblende granite, crops out along the shore of Lituya Bay on the west side of the south arm of Lituya Bay. (See pl. 19.) The other, a large layered basic body, is 7 to 10 miles east of the ocean and forms the high ridges and peaks of Mount Crillon.

The granite body at Lituya Bay has not been adequately studied. Its area of outcrop was sketched by inspection from a boat. Specimens of the rock examined under the microscope consist mainly of albite, quartz, and hornblende.

Specimens from the large basic intrusive body of the Mount Crillon area were collected by members of the Harvard-Dartmouth Alaskan Expeditions[6] and by the authors.

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[4] Mertie, J. B., Jr., op. cit., pp. 129–131.

[5] Reed, J. C., and Coats, R. R., Geology and ore deposits of the Chicagof mining district, Alaska: U. S. Geol. Survey Bull. 929, pp. 14–35, 1941.

[6] Goldthwait, R. P., Reconnaissance geology of the Mount Crillon gabbro. Unpublished report, 1936.

The basic body appears to be similar in many respects to the layered intrusives of the Stillwater complex of Montana, the Skaergaard intrusive of Greenland, and the Bushveld complex of South Africa. The strikingly layered rocks of the Mount Crillon intrusive have not been studied in the same detail as the other petrologically interesting bodies because of the extreme ruggedness of the terrain (total relief is more than 12,000 feet) and because of the widespread cover of ice and snow. The rocks of the intrusive can be roughly subdivided into two groups, an undifferentiated border zone and a differentiated central zone.

The marginal outcrops, presumably representative of the lowermost portion of the intrusive, are made up of an apparently homogeneous undifferentiated and unlayered rock of the composition of norite or hypersthene gabbro. The border phase of the body probably has a composition close to that of the original magma, although the rock may be slightly enriched in the early forming basic minerals and probably was formed by early crystallization of the molten rock before much differentiation took place. Most petrologists infer from theoretical considerations and from field evidence that igneous bodies of this type crystallize from the bottom to the top.

A Rosiwal analysis of a typical specimen from the lower part of the body has been supplied by Goldthwait and is given below:

| | *Percent* |
|---|---|
| Labradorite | 52 |
| Olivine | 2 |
| Augite | 20 |
| Hypersthene | 13 |
| Biotite | 4 |
| Secondary hornblende | 3 |
| Opaque minerals | 5½ |

Inward and upward from the undifferentiated border zone is the critical zone,[7] composed of alternating layers of norite, olivine norite, dunite, troctolite, anorthosite, bronzitite and ilmenite. The critical zone is at least 5,000 feet thick and may be much thicker; the layers range in thickness from a few feet to a few tens of feet, and are typically flat-lying except near the contact, where they dip inward toward the center of the intrusive mass.

## MINERAL DEPOSITS

Considerable prospecting has been done at Lituya Bay, but most of it has centered around the auriferous beach sands along the ocean. Few prospectors have ventured far into the mountains.

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[7] A term proposed by Hall in 1926 to imply the critical adjustment of physico-chemical conditions that must have existed at the time of formation of a series of recurrent layers in a banded basic pluton. Hall, A. L., The Bushveld igneous complex: Jour. Chem. Met. Min. Soc. South Africa, vol. 26, pp. 160–174, 1926.

Mertie[8] estimates that between 1894 and 1917, gold worth $75,000 was recovered from the beaches northwest and southeast of Lituya Bay. Production since that date has been negligible. The auriferous sands contain some platinum, which has been recovered with the gold. The occurrence of platinum in the beach sands is interesting in view of the proximity of the large basic intrusive.

Ore minerals were noted at several localities within the Lituya Bay-Mount Crillon area. A gabbroic dike that cuts granite on the southwestern shore of the southeast arm of Lituya Bay is conspicuously iron-stained. A polished section of the gabbro shows numerous irregular veinlets and blebs of pyrrhotite cutting the rock. Associated with the pyrrhotite is a small amount of chalcopyrite. The chalcopyrite is estimated to constitute less than 1 percent of the rock.

A moraine on North Crillon Glacier at an altitude of about 2,000 feet is made up largely of fragments of amphibole-quartz schist and quartz-garnet veins. Most of this material, over large parts of the moraine, is stained with copper carbonates. The copper carbonates were not traced to their source.

The layered basic intrusive is rich in metallic minerals which in some places constitute a large percentage of the rock. A layer about 5 feet thick, composed largely of ilmenite and bronzite with lesser amounts of graphite, apatite, and sulfide minerals, crops out for several thousand feet along the south wall of the valley of North Crillon Glacier, about 3½ miles from the junction of North and South Crillon Glaciers. Ilmenite constitutes as much as 60 percent of the layer. Weathered outcrops are bright red. Polished thin sections indicate 2 to 3 percent of pyrrhotite and chalcopyrite. Many apparently similarly mineralized bands, some of much greater thickness, were seen on the cliff faces above the ice.

The lowermost outcrops of the basic body, near the contact with the schist, contain abundant sulfide minerals. Specimens collected by Goldthwait from the north wall of South Crillon Glacier at the contact between schist and gabbro contain 5 to 6 percent of sulfide minerals, principally pyrrhotite and chalcopyrite. Pentlandite was not determined in any of the specimens examined. No analyses of this material have been made. Sulfide minerals are disseminated throughout almost all layers of the intrusive. The few available specimens indicate that sulfide minerals are most abundant in the ilmenitic sheets and in the marginal parts of the body. Sulfide minerals are reported to be sparse in the upper parts of the body.

Chromite layers were not observed. However, only a small part of the intrusive body has been examined. Chromite layers may be present, for similar intrusive rocks elsewhere contain chromite. Gold-

[8] Mertie, J. B., Jr., op. cit., p. 135.

thwait has reported chromite as float on the glaciers. By analogy with other apparently similar basic bodies certain predictions can be made about any chromite deposits that may be discovered within this body. They are likely to be in the lower part of the intrusive, probably below the lowest ilmenite horizon. They will probably be low-grade, and the chromite will have a low chrome-iron ratio, analagous to that of the chromite in the Stillwater complex. Chromite deposits, if present, are likely to be in extensive sheets containing a large tonnage.

The basic body may be the source of the platimum in the beach placers. By analogy with the deposits of the Sierra Leone, West Africa, the ilmenitic layers are likely sources of the platinum. However, a single analysis of ilmenitic material showed no platinum. Platinum also may be associated with some of the sulfide-rich material in the lower part of the body.

## CENTRAL BARANOF ISLAND

In 1943 the authors made a brief geologic reconnaissance of some of the chromite-bearing sills on central Baranof Island between Red Bluff Bay and Silver Bay. (See fig. 8.) During the summer of 1941, studies of some of the chromite-bearing ultrabasic rocks of Baranof Island had been made by Guild and Balsley,[9] who summarize the general geology of these deposits as follows:

> The chromite of Baranof Island is present as small lenses, thin layers, and disseminated grains in ultramafic rocks, which intrude a sequence of phyllites and greenstone schists of Triassic (?) age. * * * The most accessible and best known of the intrusive masses is at Red Bluff Bay. Seven others are known in the central part of the island, about 10 miles west-northwest of Red Bluff Bay. * * * The masses in the interior appear to be sills. * * *

Field work by the present authors suggests that the sills are more numerous but less continuous than inferred by Guild and Balsley.

The sills (see pl. 20) strike northwest, dip from nearly vertical to 50° NE., and are concordant with the foliation of the surrounding schists and phyllites. The sills pinch and swell abruptly along their strike and crop out as lenticular masses. Foliation in the sills is pronounced, particularly near their contacts with enclosing rocks.

One of the larger sills crops out at the divide between Redoubt Lake and Red Bluff Bay as a horn-like peak about 4,600 feet high, several hundred feet higher than the general level of the divide. This sill thickens markedly in the axial part of a major fold in the enclosing schists and phyllites.

The sills, which originally were made up largely of olivine with some pyroxene, are almost completely altered to serpentine. Some

[9] Guild, P. W., and Balsley, J. R., Jr., Chromite deposits of Red Bluff Bay and vicinity, Baranof Island, Alaska: U. S. Geol. Survey Bull. 936-G, 1942.

of the sills, especially near their contacts with enclosing rocks, are veined by coarsely crystalline calcite and chalky, fine-grained magnesite. In some places these veins extend a few feet into the enclosing rocks.

The unweathered serpentinized dunite is mottled and streaked in various shades of greenish-black, green, and white. The weathered serpentine is light buff, due to surface alteration, and from a distance has a distinct orange tinge that contrasts sharply with the greenish unweathered serpentine and the gray country rock.

Contact metamorphism of the surrounding rocks by the sills is slight.

Chromite is an abundant accessory mineral in the sills. It occurs as scattered octahedral crystals, as crystal aggregates as much as 3 inches across, and as streaks and seams as much as 3 feet long and a few inches wide. The streaks and seams are parallel to the foliation in the sills. No concentration of chromite of sufficient size and grade to constitute an ore body was found.

The sills were prospected for chromite by the late Joe Hill. The ground covered by Hill's old claims is believed to be open.

## RED BLUFF BAY, BARANOF ISLAND

### MAGNETOMETER EXPLORATION OF A CHROMITE DEPOSIT AT RED BLUFF BAY

A body of chromite, designated as deposit No. 2 by Guild and Balsley,[10] crops out in the northeastern part of the ultrabasic mass at Red Bluff Bay (see pl. 20). It is about 900 feet west of tidewater at an altitude of about 350 feet.

According to Guild and Balsley:

> It consists of two masses of high-grade ore, apparently segments of one vertical, northward-trending body that is cut by a fault striking east and dipping 30° S. This southern segment is 50 feet long and 1 to 2½ feet wide but is cut off at the bottom by the fault. The northern segment is exposed for 40 feet horizontally and 42 feet vertically and is from 1.6 to 3.9 feet wide; it lies beneath the fault plane, so that the possibility of a southerly continuation and of a greater depth is increased.

The chromite from Red Bluff Bay contains sufficient iron to be appreciably magnetic. A series of magnetometer observations was made in a limited area immediately south of the northern segment of the deposit to detect, if possible, any southward extension of the body beneath the fault mapped by Guild and Balsley. The results are shown as isomagnetic lines of vertical intensity on figure 9.

[10] Guild, P. W., and Balsley, J. R., Jr., op. cit., pp. 182–183, and pl. 22.

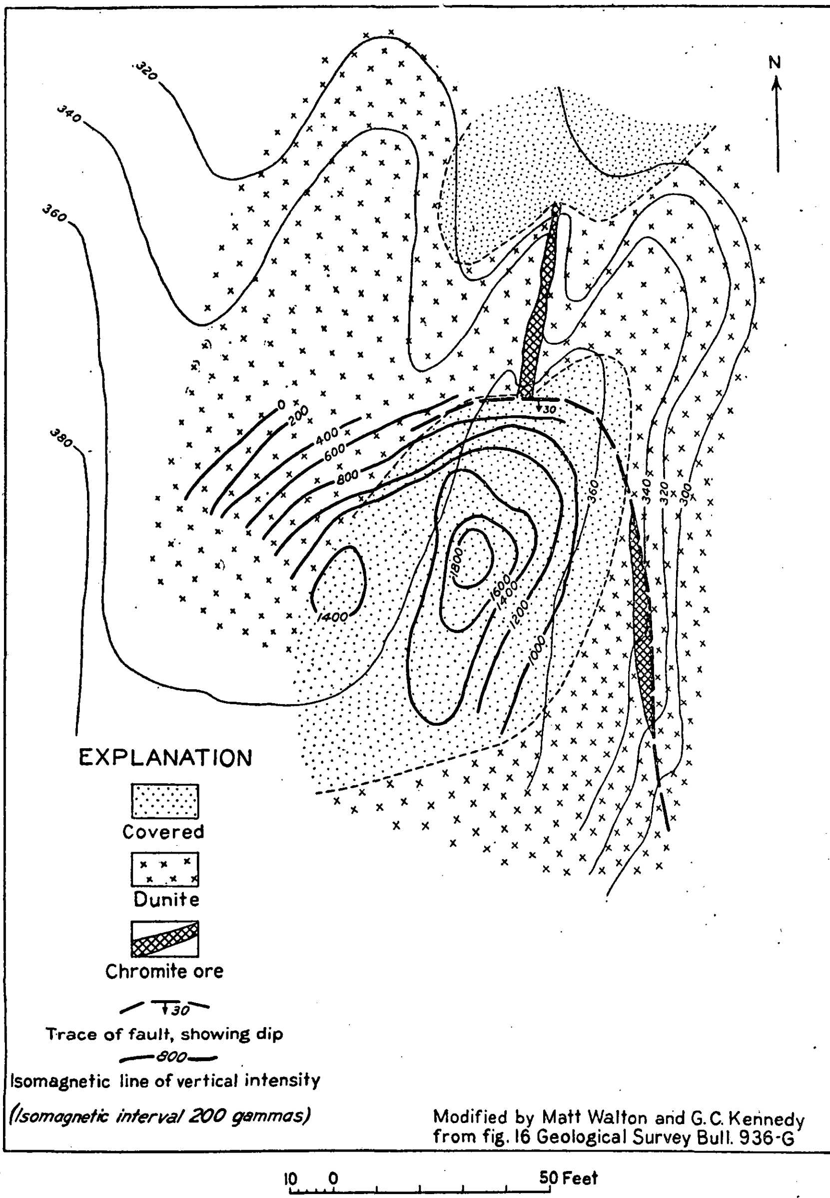


FIGURE 9.—Map showing isomagnetic lines near chromite deposit No. 2, Red Bluff Bay.

A distinct high in vertical magnetic intensity is centered about 35 feet south of the northern segment of the deposit. This high tends to confirm the existence of a buried southward extension of the northern segment. However, there are reasons for considerable caution in accepting this conclusion. The geologic evidence for the fault shown on the map (see fig. 9) is not conclusive. It rests mainly on the termination downward of the southern segment against a joint surface which, it is assumed, is the fault surface. This fault cannot be traced across to the point where it should cut off the northern segment of the deposit. Minor faulting in serpentinized dunite and pyroxenite is common where the actual plane or zone of differential movement has been obliterated because of plasticity under heat and pressure. On the other hand, chromite lenses characteristically pinch out abruptly. The two segments of this deposit may be separate chromite bodies, and the magnetic high may reveal the presence of a third body, or the trace of the fault may have been obliterated. Both interpretations are consistent with the magnetic effects observed.

A factor which adds to the uncertainty of the interpretation is that magnetite is a common alteration product in the serpentinization of peridotitic rocks. Magnetite may be present locally in sufficient amount to account for the effects observed. Magnetic anomalies even larger than those found at deposit No. 2 were observed at another body of similar rocks where it was clear that the magnetic effect was produced by secondary magnetite.

### CHROMITE DEPOSIT NEAR DEPOSIT NO. 2

A hitherto unreported deposit of massive chromite crops out in the west wall of a small gulch about 350 feet west of deposit No. 2. The deposit consists of several short, thick, lenticular masses of chromite scattered over an area approximately 75 by 30 feet. The largest mass is about 15 feet long and 4 feet wide and is estimated to contain about 60 tons of chromite. The amount of chromite in the entire deposit is estimated to be about 80 tons.

A chip sample from this deposit, collected by the authors and analyzed by J. E. Husted of the Geological Survey, contained 43.20 percent of $Cr_2O_3$. The chromite in the sample had a chrome-iron ratio of 2.34. This is the highest chrome-iron ratio yet reported for chromite from the Red Bluff Bay area.

## BLASHKE ISLANDS, KASHEVAROF PASSAGE

### GENERAL FEATURES

The Blashke Islands were briefly examined in 1923 by Buddington,[11] who described the major relations of the ultrabasic rocks. The present authors spent 2 weeks in June 1943 examining these islands.

The Blashke Islands lie between Kashevarof Passage and Clarence Strait (see fig. 8), about 8 miles south of the southernmost point of Zarembo Island. The group consists of 16 islands ranging in length from 1/8 mile to 1½ miles, and numerous smaller islands. The islands

[11] Buddington, A. F., and Chapin, Theodore, Geology and mineral deposits of southeastern Alaska: U. S. Geol. Survey Bull. 800, pp. 190–191, 1929.

have a total land area of approximately 3 square miles and are low and heavily wooded. Their highest point is 414 feet, and most of their area is less than 100 feet above sea level. The rocks that comprise the islands are well exposed along the shoreline.

A large portion of a central ultrabasic mass has been eroded to form a basin now filled by a salt lagoon. The lagoon is open to tidewater by three narrow passages, known as salt chucks, through which the tide rushes with great velocity.

## GEOLOGY

The Blashke Islands are underlain by deformed rocks intruded by an ultrabasic body of roughly circular outcrop. The rocks consist largely of graywacke and pyroclastic material, with some interbedded conglomerate, black slate, and limestone. They are part of a belt of Silurian [12] rocks throughout much of northern Prince of Wales Island. The rocks in general dip from 45° to vertical and appear to swing around the ultrabasic intrusive and to conform generally with the outline of the intrusive. In a zone of varying width around the intrusive body they have been recrystallized to a dense, fine-grained hornfels.

The southeastern part of the Blashke Islands is underlain by a roughly circular body of ultrabasic rocks about 1½ miles in diameter. (See pl. 21.)

The core of the ultrabasic intrusive body is an oval dunite mass about 6,000 by 8,000 feet in outcrop dimensions. Encircling the dunite core is a 500 to 2,000-foot ring of pyroxenite and wehrlite. The wehrlite is concentrated in irregular patches within the pyroxenite ring near the contact between the pyroxenite and the dunite.

Surrounding the pyroxenite-wehrlite ring is a gabbro ring of irregular width, with local variants of hornblendite, diorite, augitite, and anorthosite. The gabbro phase is gradational with the surrounding sediments.

The contacts between rocks of the different ultrabasic types generally are intrusive, although many of the contacts between wehrlite and pyroxenite are gradational. That the core of dunite solidified prior to the bordering ring of pyroxenite is indicated by the fact that dikes of pyroxenite cut the dunite. The pyroxenite, in turn, is cut by apophyses of the outer ring of gabbro.

The contacts between the various units of the ultrabasic body generally are approximately vertical. Thus the dunite core may be likened to a solid cylinder surrounded by concentric shells of pyroxenite-wehrlite and gabbro. Inconclusive data from a few magnetometer observations suggest that the contacts may dip steeply inward.

[12] Buddington, A. F., and Chapin, Theodore, op. cit., pp. 79–94.

The dunite core is composed of about equal proportions of olivine and serpentine. The olivine, with a mean index of refraction of 1.667, is close to forsterite in composition and contains about 93 percent of the $Mg_2SiO_4$ molecule and about 7 percent of the $Fe_2SiO_4$ molecule.

The wehrlite is made up of approximately equal proportions of medium-grained olivine and coarsely crystalline diopside. The index of refraction indicates that the olivine in the wehrlite is much richer in iron than is the olivine of the dunite core. The diopside has a mean index of refraction of 1.680 and corresponds to a member of the diopside-hedenbergite series with 88 percent of diopside molecule ($CaMgSi_2O_6$) and 12 percent of hedenbergite molecule ($CaFeSi_2O_6$).

The pyroxenite is composed principally of medium-grained diopside of about the same composition as that in the wehrlite. Textural variations in the proxenite are great. The grain size of different specimens ranges from less than a millimeter to several centimeters. The coarsely crystalline diopside is in irregular segregations of pegmatitic texture and in more or less well defined pyroxene-anorthite pegmatite dikes. Feldspar, much of which is as calcic as $An_{96}$, is locally present in the pegmatitic segregations interstitial with the diopside, and it may constitute as much as 50 percent of the basic pegmatite dikes.

The gabbro of the outer ring is made up largely of feldspar, pyroxene, and their alteration products. The feldspar is extremely calcic, typically bytownite or anorthite, ranging in composition from $An_{85}$ to $An_{93}$. The pyroxene is augite. It contains considerably more aluminum and iron than does the diopside of the pyroxenite adjacent to the gabbro. In some places diorite cuts the gabbro and is probably a late differentiate of the gabbro. The feldspar of the diorite ranges from andesine to labradorite.

The relations within each solid-solution series of minerals indicate that each ring outward was formed at a temperature somewhat lower than that of the preceding inward ring. The dunite core contains the magnesium-rich olivine, which presumably formed at higher temperature than that of the more iron-rich olivine of the wehrlite. The calcium-magnesium pyroxene of the pyroxenite presumably formed at higher temperature than did the more aluminous and more iron-rich pyroxene of the gabbro zone. Likewise, the feldspar associated with the more coarsely-crystalline phase of the pyroxenite, though present in distinctly minor amounts, is richer in calcium than that of the gabbro.

To sum up the chemical relations within the complex: From the center of the intrusive outward, the proportion of magnesium decreases abruptly and the proportions of iron, silica, and aluminum increase regularly. Calcium first appears in the pyroxinite zone and decreases outward.

### MINERAL DEPOSITS

No chromite was identified in the rocks of Blashke Islands.

Sulfide minerals, principally pyrrhotite and chalcopyrite, are locally present in the marginal phase of the pyroxenite and gabbro. At no place was more than a small percentage of sulfide minerals noted, although the tonnage of material containing between 1 and 2 percent of sulfide minerals is large. Two analyses of the typical sulfide-bearing marginal gabbro were made for nickel, copper, and platinum-group metals by Cyrus Feldman of the Chemical Laboratory of the Geological Survey, who reports as follows:

| Specimen | Cu (percent) | Ni (percent) | Platinum-group metals (oz. per ton) |
|---|---|---|---|
| 43 AK 295 | 0.0086 | 0.03 | Less than 0.1 |
| 43 AK 306 | .016 | .05 | .1 |

Spectroscopic examinations indicate that palladium is the dominant platinum-group metal present. Assuming that all the platinum-group metal present is palladium, 0.1 ounce per ton is equivalent to about $2.00 per ton of rock.

Analysis of a third specimen of sulfide-bearing gabbro (specimen 43 AK 10) was made by S. H. Cress and K. J. Murata of the Chemical Laboratory of the Geological Survey. They report the following content, in ounces per ton: Gold, 0.004; platinum, trace; palladium, 0.04.

The ultrabasic body in the Blashke Islands is very similar in structure and mineralogy to the ultrabasic bodies from which the platinum deposits of the Ural Mountains were derived.[13] However, accumulations of platinum in the Blashke Islands are believed to be slight, because of recent glaciation and because suitable places for accumulation of placer deposits are lacking.

## KANE PEAK, KUPREANOF ISLAND

### GENERAL FEATURES

The ultrabasic rocks in the vicinity of Kane Peak, Kupreanof Island were mapped in August 1943. (See fig. 8.) These rocks were briefly examined by Buddington[14] in 1923.

The ultrabasic rocks crop out over an area about 1¼ miles in diameter and extend from near the summit of Kane Peak to Frederick Sound in the vicinity of Cape Strait. (See fig. 10.) This region for the most part is covered with muskeg, brush, and timber, and outcrops are sparse except along the beach and on Kane Peak.

[13] Zavaritsky, A., The Rai-iz peridotite massif in the Arctic Urals, Moscow, Government-Scientific-Techonological-Geological-Investigational Press, 221 pages, 1932.

[14] Buddington, A. F., and Chapin, Theodore, op. cit., p. 192.

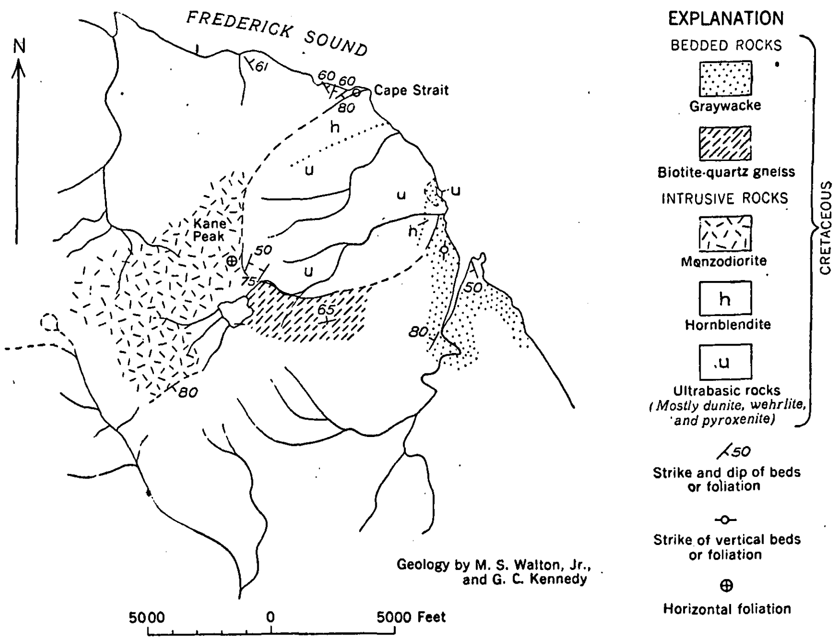


FIGURE 10.—Geologic map of Kane Peak and vicinity, Kupreanof Island, southeastern Alaska.

## GEOLOGY

The ultrabasic intrusive body is in contact with thin-bedded graywacke of Cretaceous age; biotite-quartz gneiss; and a mass of monzodiorite, which intrudes the graywacke. The graywacke crops out around the northern and southeastern margins of the ultrabasic body. It strikes, in general, northwest and dips about 60° NE., but, near the contact of the ultrabasic mass with the surrounding sedimentary rocks, the dip and strike of the foliation and bedding of the sedimentary rocks are approximately parallel to the contact with the intrusive body. Dips are usually inward toward the ultrabasic intrusive. Near the monzodiorite the graywacke has been converted to biotite-quartz schist.

The ultrabasic rocks range from gabbro to dunite. Wehrlite, pyroxenite, hornblendite, and mica-rich variants of these rocks are locally abundant, but the exact relations between these various rock types are not known.

The northern and southern margins of the intrusive body appear to be bordered by a band of hornblendite, with some hornblende gabbro, as much as 1,000 feet wide. Hornblendite was not found near the western limit of the ultrabasic body, for there a portion of the original ultrabasic intrusive is believed to have been cut away by the presumably younger monzodiorite.

The central part of the body is made up of dunite, wehrlite, and diopside pyroxenite. These rocks are extremely fresh in some places, as on Kane Peak, but at other places are so serpentinized that the original character of the rock has been completely destroyed; here and there parts of these rocks have been altered to coarse pholgopite mica.

The ultrabasic rocks that crop out on Kane Peak are largely pyroxenite, dunite, and wehrlite. The main shoulder of Kane Peak is pyroxenite that contains about 10 to 20 percent of olivine. Contacts between this mass and surrounding dunite and wehrlite are gradational, with irregular areas of dunite in the pyroxenite, and some extremely coarse diopside crystals in the dunite. Several dikelike masses of dunite cut the pyroxenite, and what appear to be schlieren of pyroxene are strung out in the dunite.

#### MINERAL DEPOSITS

No chromite was found in the vicinity of Kane Peak. Locally, the pyroxenite contains a few percent of sulfide minerals, and the weathered rock is stained brick red. A particularly conspicuous band of sulfide-bearing pyroxenite crops out on the south slope of Kane Peak and can be seen from the vicinity of a small lake south of the peak (see fig. 10), but nowhere do the sulfide minerals constitute a large proportion of the rock. Whether any of these rocks contain platinum-group metals is not known.

### MOUNT BURNETT AND VICINITY, CLEVELAND PENINSULA

#### GENERAL FEATURES

The pyroxenite that crops out along the east side of Union Bay on Cleveland Peninsula is described briefly by Buddington,[15] who spent a few days in the vicinity of Mount Burnett in 1923. Small bodies in the dunite of Mount Burnett have been reported by prospectors for a number of years, and at least one of these bodies has been staked. J. C. Reed and G. O. Gates, of the Geological Survey, briefly examined some of these bodies in 1941 and collected a representative suite of specimens from the ultrabasic intrusive mass. The present authors spent most of September 1943 in a detailed examination of parts of the ultrabasic rocks of Mount Burnett and vicinity, Cleveland Peninsula.

Mount Burnett is on the northwest side of Cleveland Peninsula, about 35 miles northwest of Ketchikan. (See fig. 8.) The ultrabasic area is accessible both from Vixen Inlet and Union Bay. The ultrabasic rocks crop out in a mass about 7 miles long and 1 to 2 miles

[15] Buddington, A. F., and Chapin, Theodore, op. cit., pp. 193–194.

wide. (See pl. 22.) For the most part they are relatively resistant to weathering and stand out as prominent rust-colored bare ridges with an average altitude of about 2,000 feet.

## GEOLOGY

The ultrabasic rocks have intruded phyllite and schist of the Wrangell-Revillagigedo belt of metamorphic rocks.[16] The metamorphic rocks for the most part are thin-bedded and range from phyllite to biotite-quartz schist. These rocks strike northwest and are isoclinally folded.

Conglomerate of Tertiary age, unconformably overlying pyroxenite and phyllite, crops out for several thousand feet along the beach of Union Bay south of Union Point. The conglomerate is made up of unsorted boulders and angular fragments of rock as much as 4 feet in diameter, consisting of pyroxenite, gabbro, and schist or phyllite. The boulders are cemented by mud and sandy material. Fossil wood is included in the matrix. In some places the conglomerate grades into poorly sorted sandstone containing numerous pebbles and some boulders several feet in diameter. These rocks have been correlated by Buddington[17] with the Eocene rocks of Port Camden.

The ultrabasic rocks form a large composite stock, which is made up of diorite, gabbro, hornblendite, pyroxenite, wehrlite, and dunite.

The diorite (not differentiated on pl. 22) crops out as a body, the limits of which have not been mapped, that bounds the ultrabasic mass to the south. It is not known whether this diorite is a part of the ultrabasic complex or is part of a younger stock that cuts the ultrabasic rocks.

A crude banding was noted within the ultrabasic mass. The central part of the body is made up largely of dunite, pyroxenite, and wehrlite. Wehrlite is much less common than pyroxenite and dunite; for the most part the rock minerals seem to have aggregated into rocks of essentially monomineralic composition. In general, the eastern part of the body appears to be largely dunite, whereas the western part is largely pyroxenite. These distinctions are not sharp because the dunite contains many irregular masses of pyroxenite and wehrlite, and the pyroxenite contains many bodies that consist largely of dunite. The central mass of pyroxenite and dunite is separated from the surrounding schists by bordering facies of pyroxenite, hornblendite, and gabbro. The marginal hornblendite and gabbro are particularly well exposed along the beach in the vicinity of the cannery on Union Bay, where the hornblendite zone is probably several thousand feet thick.

At every place where contact relations were observed, pyroxenite of the marginal zone was bordered on the outer side by hornblendite.

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[16] Buddington, A. F., and Chapin, Theodore, op. cit., pl. 1.
[17] Buddington, A. F., and Chapin, Theodore, op. cit., p. 263.

At no point was dunite noted in contact with hornblendite, nor was dunite or pyroxenite in contact with the surrounding schists and phyllites of the Wrangell-Revillagigedo belt of rocks.

The dunite was examined in considerable detail in the eastern part of the ultrabasic area. Within this area the dunite is made up almost wholly of serpentine, and of olivine with a mean index of refraction of 1.667, which indicates that the olivine consists of about 92 percent of forsterite ($Mg_2SiO_4$) and 8 percent of fayalite ($Fe_2SiO_4$). Serpentinization of the dunite is extremely variable. Much of the dunite is completely altered to serpentine, whereas some is very fresh. The dunite is believed to have been deformed after it became consolidated. Parallel shear cracks are conspicuous on surfaces of weathered dunite, and dikes of dunite that are much sheared have been squeezed into the pyroxenite.

Two varieties of pyroxenite are present. A variety of pyroxenite that lies near the outer limits of the ultrabasic body, between the dunite and the marginal hornblendite, is composed largely of diallage but contains a small amount of olivine and amphibole. The diallage has a mean index of refraction of 1.687 and therefore presumably contains a considerable amount of alumina and iron. The olivine present in minor quantities in the pyroxenite is considerably richer in iron than that of the central zone. Its mean index of refraction is 1.688, which indicates a $Fe_2SiO_4$ (fayalite) content of about 20 percent. The grain size of the pyroxenite of the border zone ranges widely; in some places veins and irregular segregations of pyroxene of pegmatitic texture, with crystals several inches in length, are surrounded by finer grained pyroxenite.

Considerable magnetite, probably titaniferous, is associated with the pyroxenite of the border zone. Most of the magnetite is interstitial to the pyroxenite and appears to have been one of the last components of the rock to crystallize. Some vein-like magnetite masses 1 inch or more in width cut the pyroxenite. The marginal pyroxenite is also cut by dikes of the nearby hornblendite and hornblende gabbro.

A second type of pyroxenite occurs in irregular masses within the central dunite, and numerous dikes of this pyroxenite cut the dunite. This pyroxenite is made up almost exclusively of diopside with an index of refraction of about 1.678, indicating that it contains about 92 percent of the diopside ($CaMgSi_2O_6$) molecule and 8 percent of the hedenbergite ($CaFeSi_2O_6$) molecule.

Irregular areas of wehrlite, gradational with dunite and with pyroxenite, are present within the dunite and pyroxenite masses of the central zone. The wehrlite is made up of diopside crystals as much as 2 inches across, in an olivine matrix. In general, however, the intermediate rock type, wehrlite, is much less common than either pyroxenite or dunite.

The hornblendite is a massive dark rock composed almost entirely of long interlocking crystals of hornblende. Medium-grained hornblendite with individual crystals as much as an inch long, is cut by numerous dikes of pegmatitic hornblendite. The dikes of pegmatitic hornblendite are typically 1 to 2 feet in width and 20 feet or more in length. They are made up of hornblende and minor amounts of feldspar. The hornblende is in the form of long crystals, some of them as much as 10 inches, oriented with the long axis of the crystal at right angles to the walls of the dike. The feldspar is generally calcic, although feldspar of intermediate composition, and even albite, was collected from the dikes. At numerous localities minor amounts of sulfide minerals are associated with hornblendite.

Outward, toward the schists and phyllites, the hornblendite grades into a hornblendite-rich gabbro. The percentage of dark minerals and the texture of this gabbro vary widely. The gabbro, in turn, grades into the surrounding schists.

### MINERAL DEPOSITS

Numerous small pods of chromite are scattered irregularly through the dunite. Most of the pods are only an inch wide and a few inches long, but in some places they are sufficiently concentrated to constitute an appreciable amount of the total rock. At point A on plate 22 about 5,000 square feet of outcrop is estimated to contain about 5 percent of irregular chromite segregations. Much of the chromite is in fractures that cut the dunite and appears to be later than the dunite. At point B on plate 22 a single body of massive chromite was found that is estimated to contain about 25 tons of chromite. The outcrop of the body is about 13 feet long by 1½ feet wide. Analyses of specimens of chromite from these two localities, made by John E. Husted of the chemical laboratory of the Geological Survey, are given below:

| Locality | Cr (percent) | Fe (percent) | $Cr_2O_3$ (percent) | Cr/Fe (ratio) |
|---|---|---|---|---|
| A | 22.62 | 17.91 | 33.03 | 1.26 |
| B | 18.50 | 37.37 | 27.01 | .50 |

Because of their small size, low grade, and the low chrome-iron ratio of the chromite, these deposits are of no commercial value at this time.

## ECONOMIC ASPECTS OF THE ULTRABASIC ROCK BODIES IN SOUTHEASTERN ALASKA

Nickel, copper, chromium, platinum-group metals, diamonds, and olivine are metals and minerals almost universally associated with basic and ultrabasic rocks. All of these, except diamonds, have been reported from the ultrabasic rock bodies in southeastern Alaska, and diamonds have been reported from similar ultrabasic bodies in nearby British Columbia.[18]

Large low-grade nickel-copper deposits associated with norite and related rock types are present on Yakobi, Chichagof, Admiralty, and Baranof Islands, and results of investigations of these bodies have been detailed in previous Geological Survey publications. No significant nickel-copper deposits have been discovered in southeastern Alaska associated with ultrabasic rocks of predominantly dunitic composition, and they are not to be expected, although they may be found with the rocks of lower olivine content, such as the layered body in the Lituya Bay-Mount Crillon area.

Chromite has been reported from several bodies of ultrabasic rock in southeastern Alaska, but only small tonnages of the ore have been located, and most of this is low grade. It appears doubtful that further exploration would reveal bodies of significantly higher grade or greater tonnage in any of the more readily accessible portions of southeastern Alaska.

Little is known about the platinum content of the ultrabasic rock bodies in southeastern Alaska. In addition to those at Kane Peak, the Blashke Islands and Mount Burnett, several bodies of ultrabasic rocks, notably those on Duke and Annette Islands, are believed to be similar in structure and mineralogy to the platinum-bearing ultrabasic rocks of the Ural Mountains in Russia; further prospecting for platinum of the sulfide-rich parts of these bodies may be warranted. The greatest production of platinum from bodies of this type elsewhere has been from placer accumulations, but the possibility of finding any sizeable placer accumulations in recently glaciated southeastern Alaska is believed to be slight.

Large dunite bodies composed almost entirely of high-magnesium olivine, aggregating hundreds of millions of tons, are known in the Blashke Islands and at Mount Burnett. Most of the dunite of the Blashke Islands is somewhat serpentinized (10 to 40 percent serpentine), but the dunite at Mount Burnett is entirely free from serpentine. The dunite of these two areas is accessible and could be mined and transported by water to Seattle or its vicinity at relatively small cost. These large deposits presumably will be of value when an economical method is devised to produce metallic magnesium from olivine.

The unserpentinized forsterite olivine of Mount Burnett is believed to be of refractory grade, and might be of value should a steel industry be established on the west coast.

[18] Camsell, Charles, Geology and mineral deposits of the Tulameen district, B. C.: Canada Dept. Mines, Geological Survey Memoir No. 26, pp. 146–152, 1913.