Information Circular 8915

Podiform Chromite Occurrences in the Caribou Mountain and Lower Kanuti River Areas, Central Alaska

Part I: Reconnaissance Investigations

By Jeffrey Y. Foley and Mark M. McDermott

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PODIFORM CHROMITE OCCURRENCES IN THE CARIBOU MOUNTAIN AND LOWER KANUTI RIVER AREAS, CENTRAL ALASKA

Part I: Reconnaissance Investigations

By Jeffrey Y. Foley [1] and Mark M. McDermott [2]

ABSTRACT

The Bureau of Mines sampled surface exposures of podiform chromite in the Caribou Mountain-Melozitna ultramafic belt in the Kokrines-Hodzana Highlands, central Alaska. Fieldwork began in 1979 as part of an assessment of the mineral potential of lands adjacent to the trans-Alaska pipeline corridor, for the Bureau of Land Management, and continued through 1981 as a Bureau of Mines investigation.

The belt comprises six complexes of which the three closest to the pipeline corridor were investigated. Concentrations of chromite disseminated in dunite host rock make up mineralized intervals ranging in thickness from less than an inch to 5 ft and in grade from 3 to 23 pct chromium. The largest occurrence has an exposed strike length of 80 ft. Bulk surface samples were collected from 10 of these exposures, and beneficiation tests on the samples produced concentrates of metallurgical, refractory, and subindustrial grades. Part I--this report--describes the fieldwork; part II--IC 8916--describes the beneficiation work.

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INTRODUCTION

The Bureau of Mines is responsible for assuring that mineral supplies are adequate to meet the Nation's industrial needs. To fulfill this responsibility, the Bureau must work cooperatively with the public and other Federal and State agencies. This investigation began in 1979 as part of an assessment of the mineral potential of lands adjacent to the trans-Alaska pipeline corridor, for the Bureau of Land Management. The investigation was continued as part of the Bureau of Mines initiative to develop more authoritative information on Alaska's critical and strategic minerals.

This report is presented in two parts. Part I summarizes a literature search and describes reconnaissance field investigations by the Bureau of Mines Alaska Field Operations Center (AFOC) near the trans-Alaska pipeline corridor in the Kokrines-Hodzana Highlands, central Alaska (figs. 1-2). Fieldwork was conducted by helicopter-supported parties. No drilling, excavating, or geophysical surveys were conducted. The Caribou Mountain and the upper and lower Kanuti River ultramafic complexes were investigated because of their proximity to the pipeline corridor. Additional exposures of similar ultramafic rocks occur to the southwest within the Caribou Mountain-Melozitna ultramafic belt (6).[3]

Part II of this report[4] presents the results of metallurgical beneficiation tests by the Bureau's Albany (Oreg.) Research Center (ALRC) on the bulk samples collected from surface exposures.

PREVIOUS WORK

Preliminary geologic investigations in the Kanuti River region by the U.S. Geological Survey (in 1970) resulted in the mapping of six ultramafic complexes and the naming of the Caribou Mountain-Melozitna ultramafic belt (figs. 2-3). Further investigation of this belt was recommended for asbestos, platinum, chromium, nickel, and other commodities (6). References to anomalous concentrations of the elements cobalt, chromium, and nickel are contained in another U.S. Geological Survey report (4) and in reports by the Alaska Division of Geological and Geophysical Surveys and the University of Alaska Mineral Industry Research Laboratories (2, 9).

Exploration by private industry resulted in the staking of eight lode claims during 1975 within the lower Kanuti River ultramafic body. These and additional claims were filed by Oil Development of Texas (now Santa Fe Energy Co.); the discovery of massive chromite in dunite was given as the reason for staking.

ACKNOWLEDGMENTS

The Bureau of Land Management provided funding for fieldwork conducted during 1979 as part of the pipeline corridor investigations. Base maps used for this study are from the U.S. Geological Survey 1:63,360-scale topographic series.

Rock and stream sediment samples collected during 1979 were analyzed for 44 elements at Los Alamos (N. Mex.) Scientific Laboratories, by a combination of

[3]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

[4]Dahlin, D. C., L. L. Brown, and J. J. Kinney. Podiform Chromite Occurrences in the Caribou Mountain and Lower Kanuti River Areas, Central Alaska. Part II: Beneficiation. BuMines IC 8916, 1983.

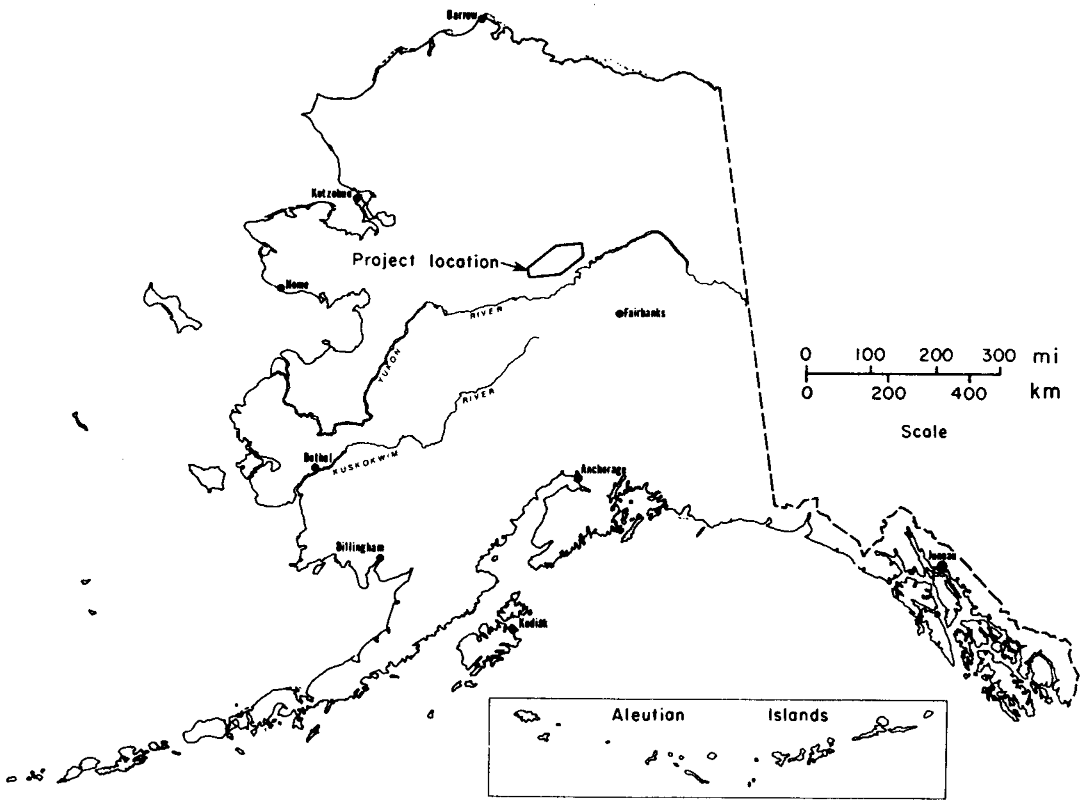


FIGURE 1. - Map of Alaska showing location of area investigated.

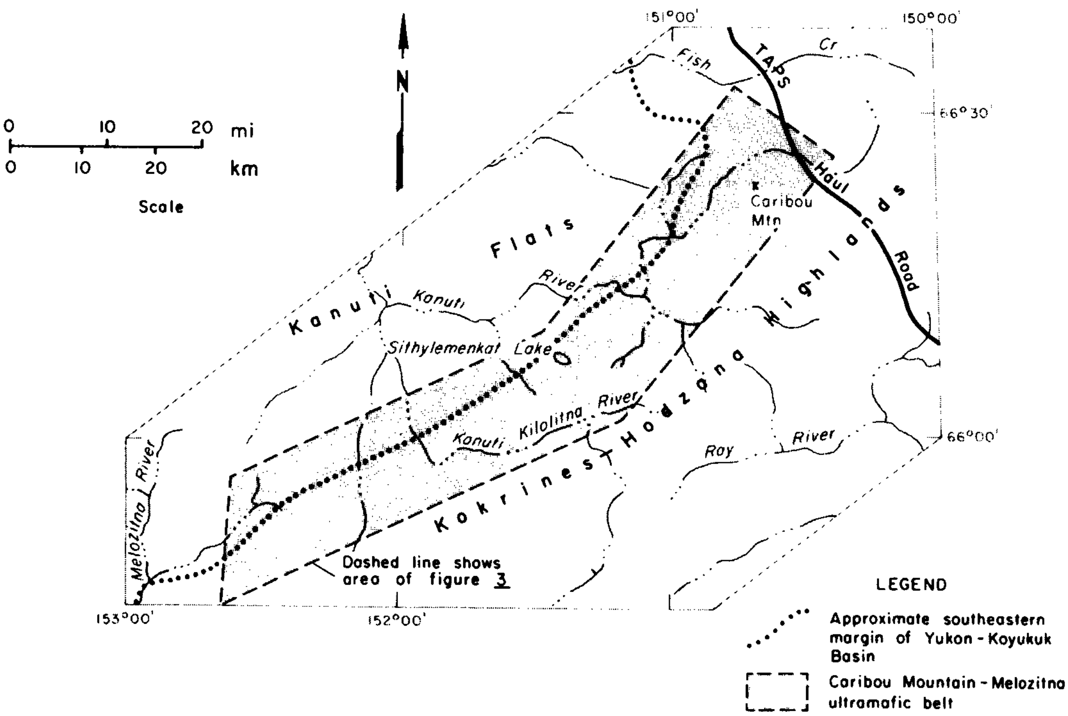


FIGURE 2. - Map showing location of Caribou Mountain-Melozitna ultramafic belt in relation to major physiographic units mentioned in the text. Adapted from figure 1 in Patton and Miller, 1970 (6).

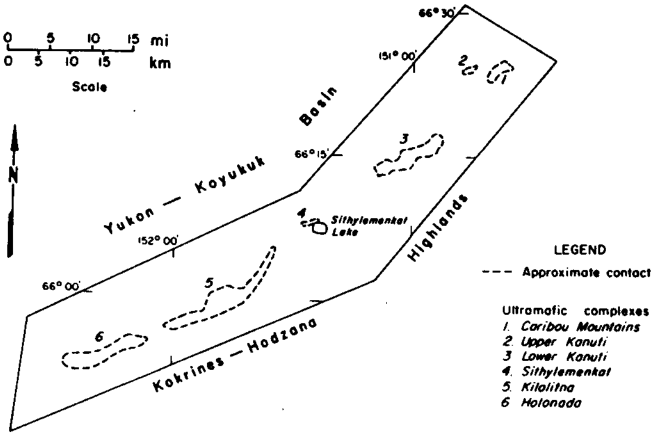


FIGURE 3. - Map showing location of the six ultramafic complexes within the Caribou Mountain-Melozitna ultramafic belt. Adapted from figure 2 in Patton and Miller, 1970 (6).

atomic absorption, neutron activation, X-ray fluorescence, and emission spectrographic techniques. Complete results of these analyses are presented in a report by the Department of Energy on mineral resource investigations in central and eastern Alaska (10). The Bureau of Mines Reno (Nev.) Research Center provided duplicate atomic absorption analyses for four elements in rock samples collected during 1979.

K. H. Clautice[5] located and sampled several occurrences of chromite in the Caribou Mountain area and one in the lower Kanuti River area in 1978. Preliminary beneficiation tests by ALRC on two of these samples yielded metallurgical-grade chromite concentrates.

PHYSIOGRAPHY

The ultramafic complexes investigated lie within the Kokrines-Hodzana Highlands, which form the headwaters of the Ray and Kanuti Rivers (11). These highlands are dominated by rounded ridge tops except where jointed slabs of granite bedrock stand resistantly at the ridge crests. These resistant slabs are referred to as tors and are characteristic of the granite terrane[6] that is prevalent in these highlands.

The highlands typically rise to elevations of 1,800 to 3,600 ft. The Ray Mountains' granite terrane to the south of the study area rises to over 5,000 ft. The areas underlain by ultramafic bedrock have smooth ridges that attain maximum elevations of just over 2,400 ft. Southern slopes in the upper and lower Kanuti River complexes are steeper than northern slopes owing to differential erosion of the northwesterly dipping bodies of ultramafic rock (fig. 4). The Caribou Mountain complex has been intruded on the south by granitic rocks of the Hot Springs pluton and does not exhibit the asymmetric profile that is characteristic of the other ultramafic complexes.

[5]Geologist, formerly with AFOC (now at the University of Alaska, Fairbanks).

The Kokrines-Hodzana Highlands constitute the divide between the Yukon River to the south and the Koyukuk River to the north. The Melozitna, Tozitna, and Ray Rivers drain southerly to the Yukon River from within the Caribou Mountain-Melozitna ultramafic belt, and the Kanuti River drains across the Kanuti Flats into the Koyukuk River.

[6]Terrane, as used here, refers to an area underlain by a specific rock type.

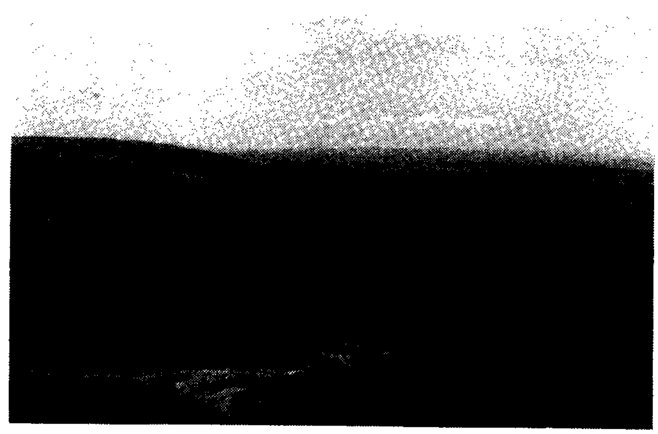


FIGURE 4. - View looking west across portion of lower Kanuti River ultramafic body. The massif in center of photograph is underlain by northwesterly dipping layers of peridotite and dunite.

There are no glaciers in the Kokrines-Hodzana Highlands, but periglacial features including altiplanation terraces, and stone polygons are abundant. The entire region is underlain by permafrost.

ACCESS

The Trans-Alaska Pipeline Service (TAPS) Haul Road is the only road near the area investigated. This road crosses the eastern side of Caribou Mountain at a point 140 air miles northwest of Fairbanks. The upper Kanuti River complex is 5 mi to the southwest of this point along the Kanuti River and may be reached by canoe when water conditions are favorable. The lower Kanuti River ultramafic complex extends from 12 to 22 mi southwest of the point where the road crosses Caribou Mountain and is accessible by helicopter.

LAND STATUS

At the outset of this investigation, the Caribou Mountain and eastern portion of the areas investigated were within the TAPS corridor. The status of the western end of the belt was uncertain, owing to pending classification of various Federal lands in Alaska. Among these withdrawals and of particular significance to the area discussed in this report was the Kanuti River Wildlife Refuge. The status of the region in general was unresolved at the time this report was written.

GEOLOGY

REGIONAL SETTING

The Caribou Mountain-Melozitna ultramafic belt trends northeast for 62 mi in the Kokrines-Hodzana Highlands and lies along the margins of two geologic provinces in central Alaska. These provinces are the Ruby Geanticline to the southeast and the Yukon-Koyukuk volcanogenic and sedimentary province to the northwest. This belt has also been referred to as the Kanuti ultramafic belt (7).

The portion of the Ruby Geanticline that underlies the Kokrines-Hodzana Highlands consists of pelitic schist, quartzite, and phyllite with subordinate marble, metamorphosed graywacke, and slate. The structural grain of these rocks trends northeast-southwest and dips to the northwest. These rocks are largely of sedimentary origin and exhibit metamorphic grades ranging from lower greenschist facies to almandine-amphibolite facies. Ages for these rocks are questionable, but Patton and Miller (6) proposed Paleozoic ages on the basis of paleontological evidence.

The metamorphosed sedimentary rocks are overlain by a sequence of mafic volcanic and intrusive rocks including pillow basalt, diabase, and gabbro with subordinate basaltic and andesitic volcaniclastic rocks, chert, and cherty mudstone. The mafic rocks are commonly altered to greenstone. Jurassic through Permian ages have been obtained on samples of the mafic rocks by potassium-argon determination (8).

It is with these mafic rocks that the ultramafic rocks of the Caribou Mountain-Melozitna belt are associated. Together, these sequences represent a dismembered ophiolite assemblage consisting of serpentinized dunite and pyroxene-peridotite, pyroxenite, gabbro, diabase, altered pillow basalt, and associated chert. The ultramafic rocks outcrop as layered masses from less than 1 to 24 sq mi in area. These have been structurally juxtaposed, probably by thrust faulting, upon Paleozoic metamorphosed sedimentary rocks and in some places upon mafic volcanics and intrusive rocks of Jurassic through Permian age. An age assignment for the ultramafic rocks of Jurassic through Permian is based upon the close spatial relationship between them and the mafic sequence (8). The above lithologies are in some places intruded by Cretaceous quartz monzonite, granite, and associated felsic igneous rocks of the Hot Springs and the Sithylemenkat plutons.

Bordering the Caribou Mountain-Melozitna ultramafic belt and the Kokrines-Hodzana Highlands on the northwest are the sedimentary and volcanic rocks of the Yukon-Koyukuk Basin and Kanuti Flats. These are Mid-Cretaceous sedimentary rocks including marine graywacke and mudstone and a younger (Late Cretaceous) sequence of nonmarine quartz conglomerate, sandstone, shale, coal, and tuffs (6). Overlying these rocks is a thick sequence of Tertiary volcanic and volcaniclastic rocks. These are rhyolitic to latitic in composition. In the Kanuti Flats and above the Yukon-Koyukuk sequence are extensive deposits of Pleistocene drift and eolian deposits with younger alluvial and lacustrine deposits.

PETROLOGY OF THE ULTRAMAFIC ROCKS

The Caribou Mountain and the upper and lower Kanuti River ultramafic complexes are petrologically similar. All three of these complexes are composed chiefly of interlayered dunite and pyroxene-peridotite; the individual layers or faulted blocks are generally tens, hundreds, or thousands of feet thick. Subordinate lithologies include gabbro, pyroxenite, serpentinite, and chromitite. Chromite is ubiquitous in the dunites and pyroxene-peridotites but seldom exceeds 1 to 2 vol-pct of the rock. The highest concentrations of chromite are found within the dunite. The ultramafic rocks grade upward into gabbroic and basaltic rocks similar to those at the margin of the Yukon-Koyukuk sequence. Comparison of tables A-1, A-2, and A-3 (in appendix A) shows the similarities in petrology among the three complexes.

Dunites are invariably fine- to medium-grained xenomorphic consisting of olivine with well-developed mesh textures defined by cross-cutting veinlets of serpentine minerals, talc, carbonate, and occasionally iddingsite (fig. 5). The effects of serpentinization range from relatively fresh olivine set in the typical mesh texture to serpentinite in which olivine is completely replaced by pseudomorphic intergrowths of serpentine, talc, carbonate, and iddingsite. Disseminated, anhedral chromite is ubiquitous in the dunites. Microscopic structures including foliation and lineation are common.

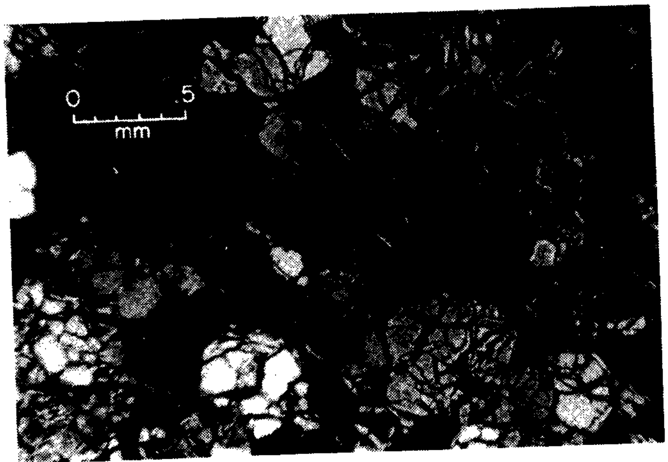


FIGURE 5. - Photomicrograph of dunite from Caribou Mountain showing mesh texture in partially serpentinized fine-grained, anhedral olivine.

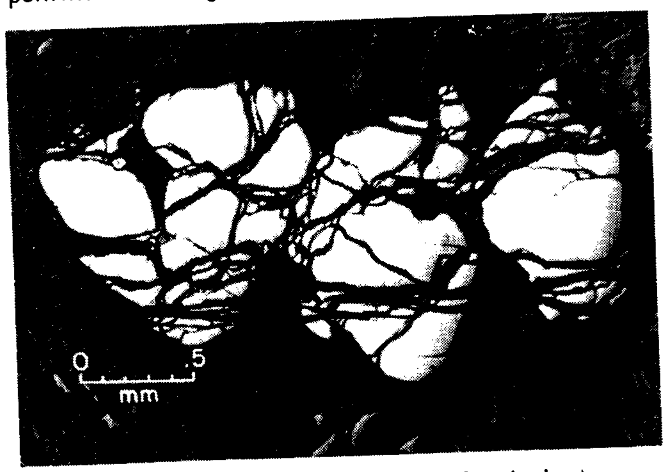


FIGURE 6. - Photomicrograph of polished section showing well-developed lineation defined by alinement of chromite grains and parallel internal fractures.

Lineations are defined by parallel, fibrous replacements of serpentine between optically continuous olivine grains, and by alinement of chromite grains with parallel internal fractures as shown in figure 6. Magnetite is also a common accessory occurring as disseminated euhedra and rimming chromite grains. The dunites weather to an orange-brown color and have a conspicuously smooth surface except where the resistant chromite grains stand out in relief.

Pyroxene-peridotites include harzburgites, lherzolites, and minor wehrlites. Textures range from an undeformed mesh texture in an olivine groundmass with coarse anhedral pyroxene grains to cataclastic, in which coarse pyroxene grains are strained or fractured and are set in a granulated groundmass of olivine and pyroxene. Euhedral grains are lacking among the essential minerals of the dunites and pyroxene-peridotites. The coarse pyroxene grains include both enstatite and diopsidic clinopyroxene. These range up to 8 mm across and are invariably anhedral with grain boundaries typically showing the effects of granulation, having interstitial, granulated pyroxene and olivine between them and other coarse clasts of pyroxene. These clasts are frequently strained, bent, or even fragmented as a result of cataclasis (fig. 7). Enstatite is in some cases replaced by serpentine minerals, and both

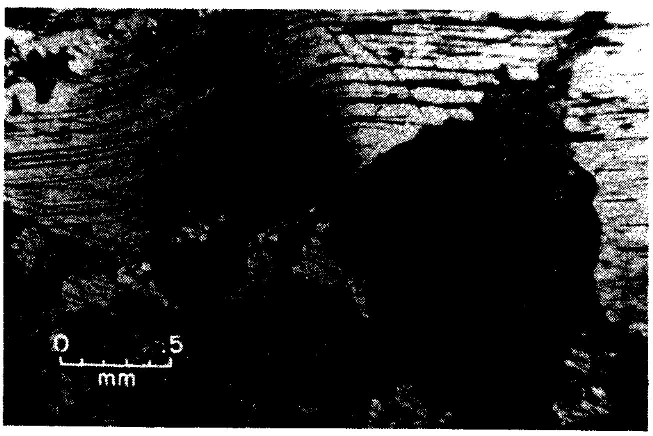


FIGURE 7. - Photomicrograph of deformed clinopyroxene grain in clinopyroxenite from upper Kanuti River ultramafic body. Groundmass consists of granulated clinopyroxene and minor olivine.

enstatite and clinopyroxene are frequently replaced by amphibole or chlorite. Accessory minerals commonly include chromite and magnetite. These occur as anhedral disseminations similar to those in the dunites. Chromite does not, however, occur in coalescent or massive concentrations within the pyroxene-peridotites.

A conspicuous feature of the harzburgites, lherzolites, and wehrlites is their tendency to weather to an olive-green color and to exhibit a rough surface that is referred to as "hobnail" peridotite (6). This rough surface is caused by the relative resistance to weathering of the coarse pyroxene grains compared with olivine. The pyroxene grains are in some cases replaced by amphibole. Pyroxene-peridotite and pyroxenite occur in dunite as segregations grading from coarse pyroxene in a granulated groundmass of olivine and pyroxene to a relatively pure intergrowth of medium-grained anhedral clinopyroxene (fig. 8). These smaller segregations occur as layers up to several inches thick, which may be either parallel or oblique to other planar features such as foliation or bands of chromitite. The pyroxene-peridotite and pyroxenite segregations also cut across the fabric of the dunite and chromitite in some instances (fig. 9). This variation in composition and fabric indicates a complex magmatic history in which pyroxene develops as cumulus and intercumulus phases and, subsequently, is injected as a fluid into a dunite or chromitite host.

In the case of the Caribou Mountain-Melozitna ultramafic bodies, emplacement has resulted in a disruption of most primary textures and an overprinting shown by extensive shearing, foliation, granulation, and lineation. Shearing is reflected in the fabric that approaches gneissic along planar features seen in outcrop. These features are local in extent, as most of the dunite and peridotite are massive on a large scale. Shearing appears to be concentrated along discrete planes that occur in sets having a northeasterly strike nearly parallel to

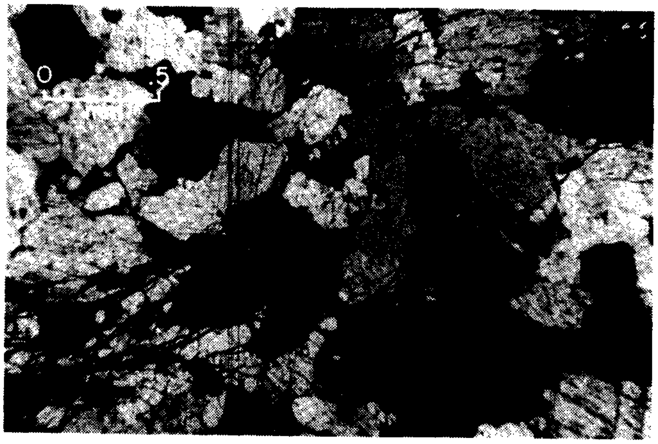


FIGURE 8. - Photomicrograph of medium-grained granular clinopyroxenite from Caribou Mountain ultramafic body.

FIGURE 9. - Magmatic segregation of coarse clinopyroxene cutting linear segregations of disseminated chromite in dunite at Caribou Mountain.

that of the units as a whole. Granulation of silicate grains and deformation of pyroxene grains as shown in figure 7 are evidence for deformation of those bodies without recrystallization. Lineation is shown by the linear arrangement of chromite grains and, furthermore, by parallel fractures in the grains themselves (fig. 6).

Gabbroic rocks occur within and adjacent to the ultramafic masses as dikes and sills up to several feet thick. The most common of these is a fine- to medium-grained, foliated rock consisting of plagioclase and hornblende. Postmagmatic deformation has resulted in an overprinting ranging from a planar orientation of plagioclase and hornblende grains to a cataclastic texture in which fractured plagioclase laths are set in a groundmass of fine, granulated hornblende, plagioclase, and epidote, with minor pyroxene and chlorite. The amphibole replaces pyroxene, and these rocks probably represent recrystallized gabbros or greenstones.

BUREAU OF MINES RECONNAISSANCE

Fieldwork was conducted by AFOC in the ultramafic belt primarily during July 1979 with short visits to the lower Kanuti River complex in September 1980 and July 1981. Rock samples were collected for petrographic examination and to determine the significance of the chromium, nickel, and cobalt anomalies reported by earlier workers. Geologic mapping and sampling of the ultramafics were undertaken to describe the occurrences of chromite in detail. Less than one day was spent at the Sithylemenkat and Kilolitna ultramafic bodies by AFOC workers.

Personnel from AFOC and ALRC visited both the lower Kanuti River and Caribou Mountain complexes in August 1980 to collect bulk surface samples from the chromite occurrences. Beneficiation tests were later conducted on these and other bulk samples by ALRC.

ROCK SAMPLING

Analyses for the elements chromium, cobalt, copper, and nickel in rocks from the three ultramafic bodies described in this report are presented in tables B-1, B-2, and B-3 (appendix B). Sample locations are shown on figures 10 through 12.

The histograms in figures 13 through 15 display the distribution of the elements cobalt, copper, and nickel in the ultramafic rock samples. The calculated averages for these three elements are close to those published elsewhere for

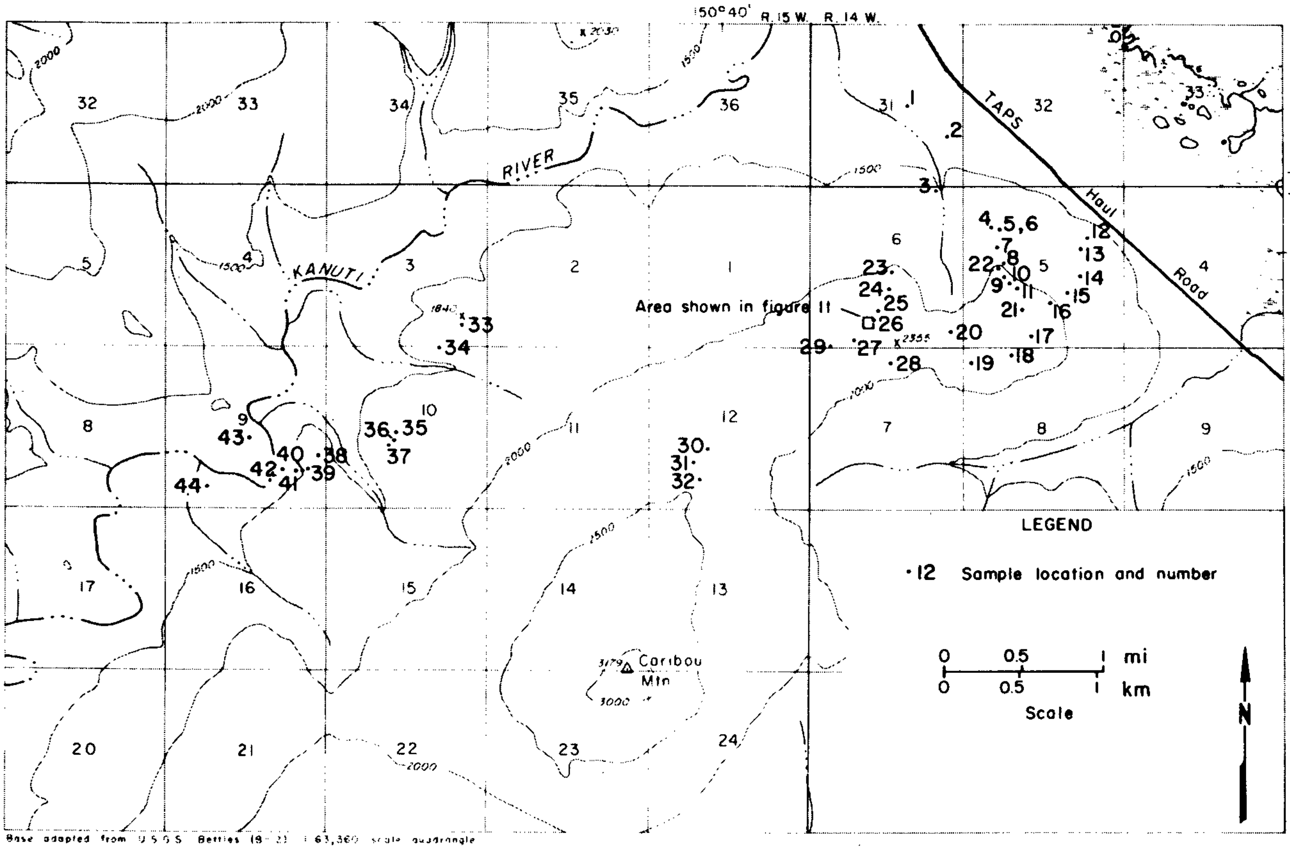


FIGURE 10. - Rock sample location map for Caribou Mountain and upper Kanuti River areas. Sample numbers are referenced in the appendixes.

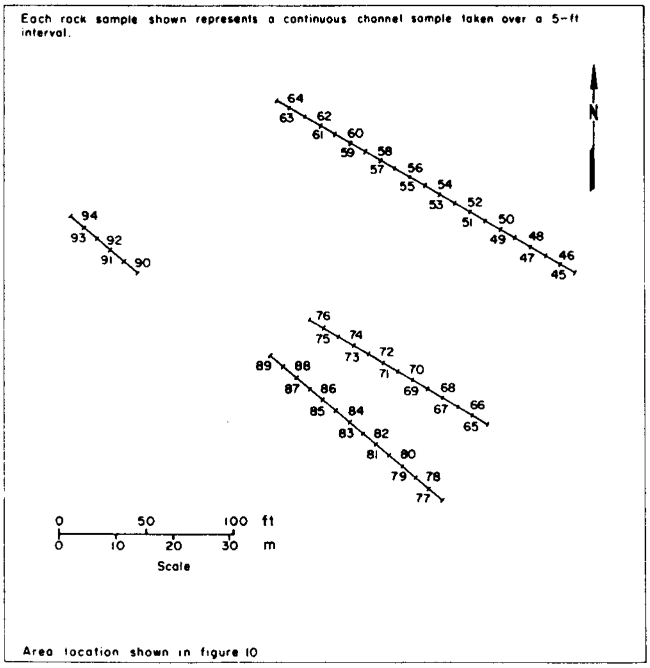


FIGURE 11. - Location map for colluvium samples at Caribou Mountain.

ultramafic rocks in general (1, 3). Apparently no enrichment of cobalt, copper, or nickel has occurred in the dunites or pyroxene-peridotites. Sulfide minerals are seldom present in these ultramafic rocks.

The distribution of chromium in 103 rock samples is illustrated in figure 16. This distribution shows a mean (x) of 1.7 pct chromium with a range of less than 0.25 to greater than 23 pct. The mean of 1.7 pct chromium is higher than the average of 0.26 pct reported by Patton and Miller for nine samples from the Kilolitna and lower Kanuti River complexes. The higher mean may reflect a biased sampling because attention was focused on mineralized rocks. Perhaps of more significance than an average value in this case is the high standard deviation (s = 3.1), which reflects the erratic grades characterizing podiform chromite deposits.

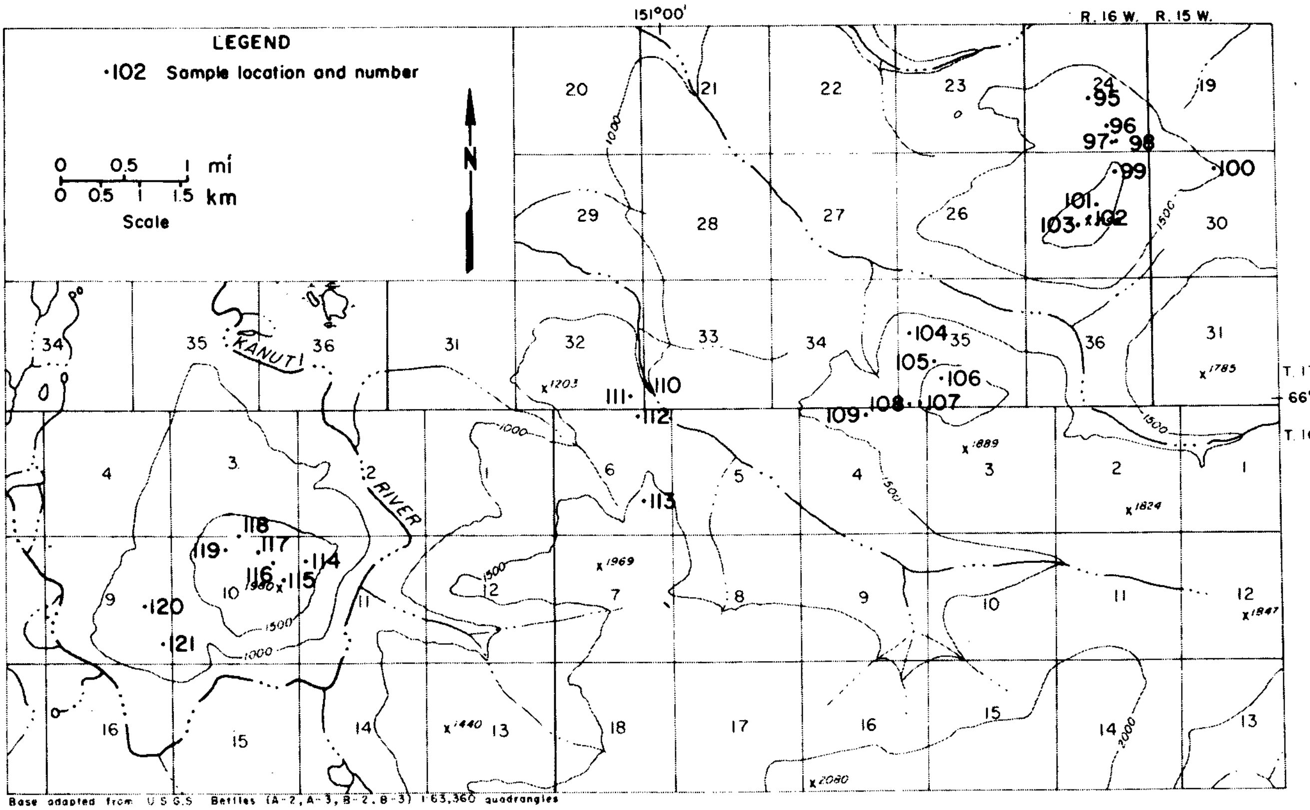


FIGURE 12. - Rock sample location map for lower Kanuti River area. Sample numbers are referenced in the appendixes.

Analyses for gold, silver, platinum, and palladium revealed no anomalous concentrations of these elements. Most results were near or below the lower detection limits, which are 0.05 ppm for silver and 0.01 oz/ton for gold, platinum, and palladium. Silver was analyzed by neutron activation methods, and gold and platinum-group metals were analyzed using fire assay procedures.

DESCRIPTION OF CHROMITE OCCURRENCES

Twenty-four chromite occurrences were located in two of the three ultramafic bodies studied and are shown schematically on figures 17 and 18 along with the local geology. For the purpose of this report, an occurrence is defined as a pod or layer of chromium spinel including chromite or magnesian chromohercynite[7] in the dunites and pyroxene-peridotites. Of these occurrences, at least seven are of sufficient size and concentration to warrant further investigation (greater than 3 pct chromite found consistently over an area several square yards in size). In general, these concentrations are irregular in shape and discontinuous. The degree of exposure of a given occurrence is variable, but frost heaving and solifluction have generally resulted in a downslope movement of material and extensive mixing of mineralized and barren rocks. For this reason, an exposure frequently yields minimal information regarding the actual form, size, or concentration of an occurrence. The chromite generally occurs as disseminated or coalescent grains in dunite gangue. Massive chromitite occurs more rarely, as do well-layered bands of the ore minerals.

[7]Magnesian chromohercynite was identified in a bulk surface sample from Caribou Mountain by ALRC.

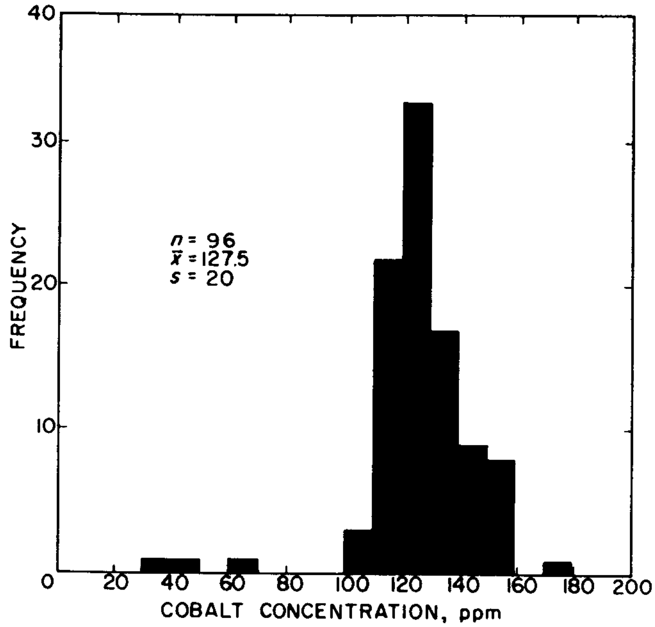


FIGURE 13. - Histogram for cobalt in 96 rock samples.

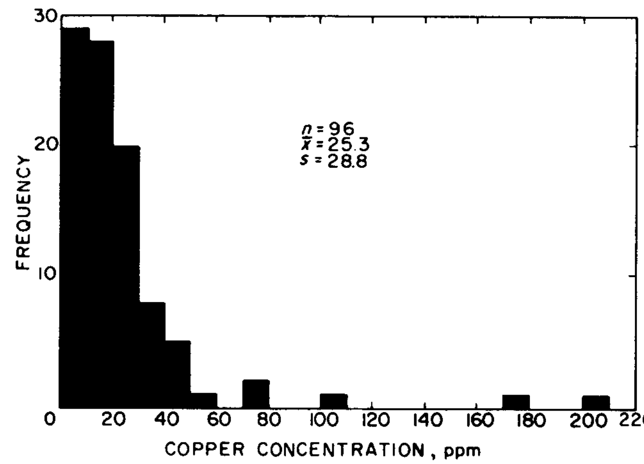


FIGURE 14. - Histogram for copper in 96 rock samples.

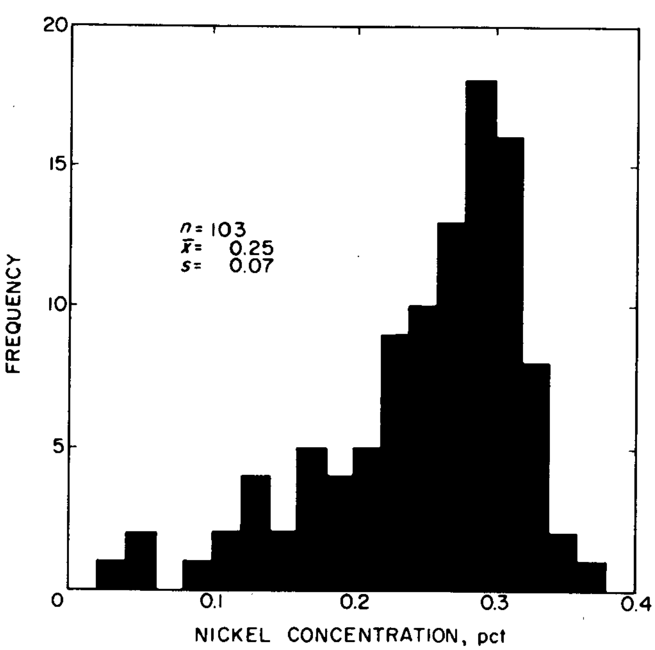


FIGURE 15. - Histogram for nickel in 103 rock samples.

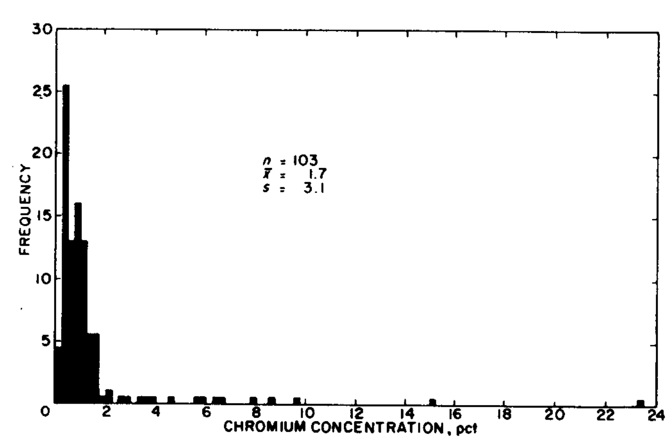


FIGURE 16. - Histogram for chromium in 103 rock samples.

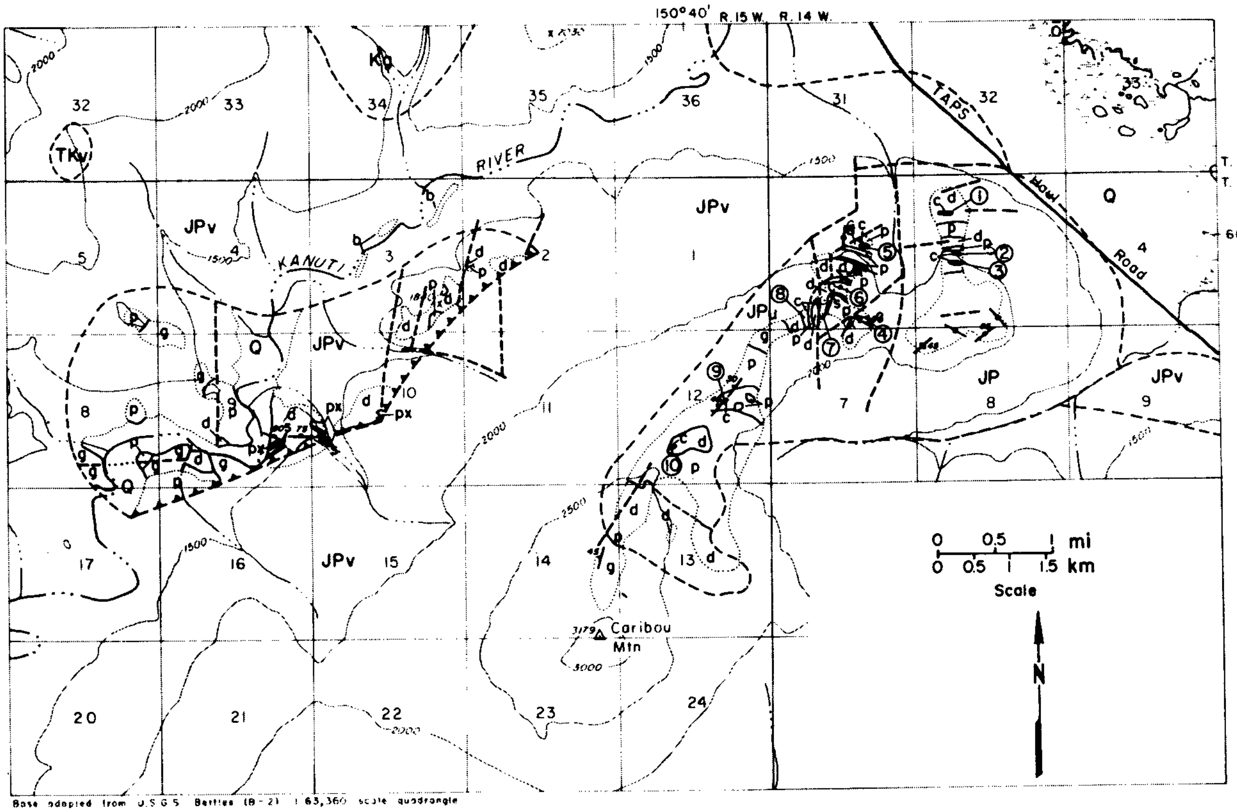


FIGURE 17. - Chromite occurrences and geologic map of Caribou Mountain and upper Kanuti River complexes.

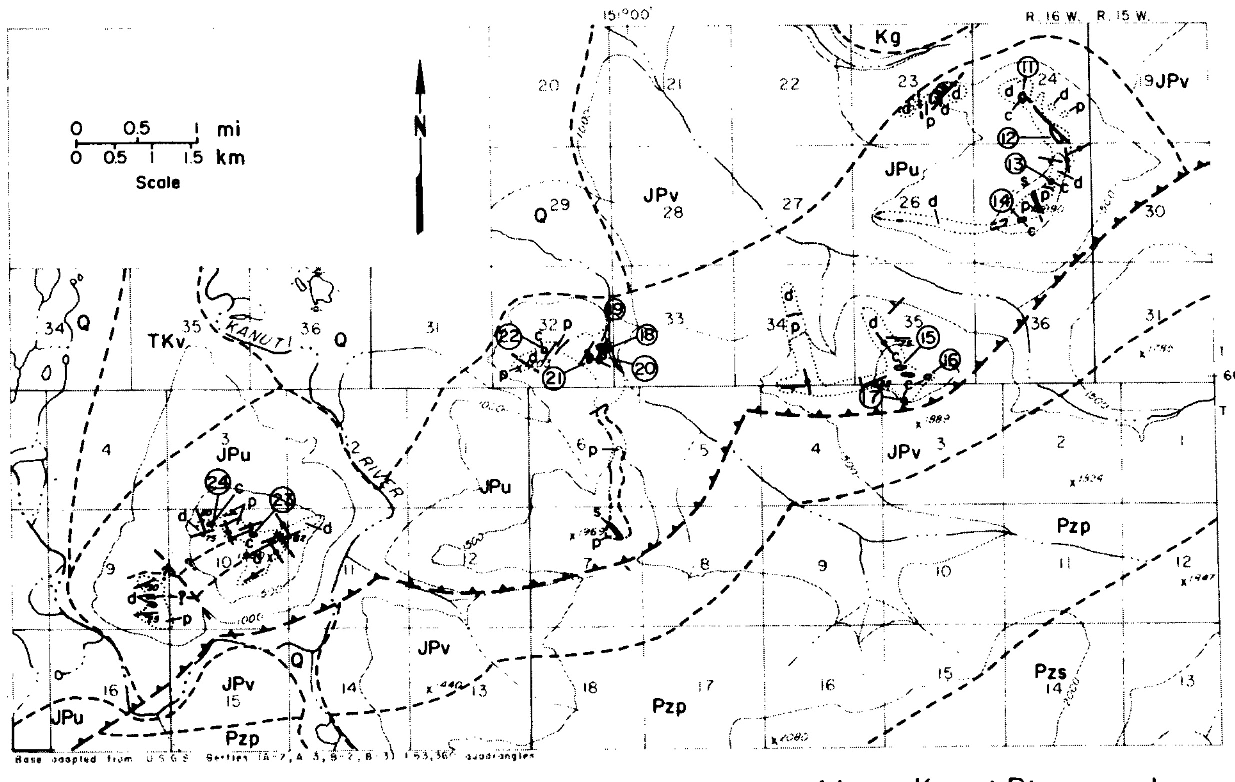
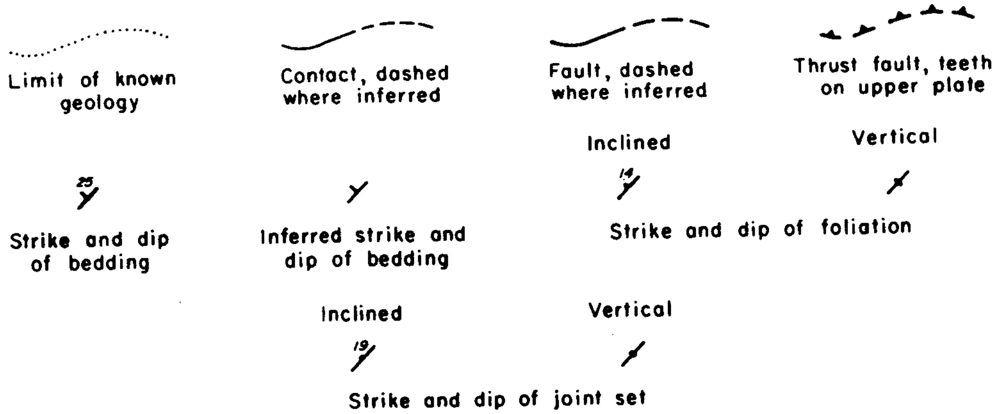


FIGURE 18. - Chromite occurrences and geologic map of lower Kanuti River complex.

LEGEND FOR FIGURES 17 AND 18

Q	Undifferentiated Quaternary surficial deposits.
TKv	Tertiary felsic intrusive and volcanic rocks.
Kg	Cretaceous granitic rocks.
JPv	Permian(?) through Jurassic(?) mafic volcanic rocks diabase and gabbro with subordinate volcaniclastic rocks and associated chert. Mafic rocks are typically altered to greenstone.
b	Dark-green, aphanitic olivine basalt; locally serpentinized.
g	Dark-green, fine- to medium-grained gabbro consisting of 30-45 pct plagioclase and 50-70 pct clinopyroxene.
JPu	Permian(?) through Jurassic(?) ultramafic rocks including serpentinite and variably serpentinized dunite and peridotite.
px	Pyroxenite. Fresh, black websterite intruding dunite and periodotite. Medium-grained, hypidiomorphic granular. Contains minor plagioclase.
s	Serpentinite. Occurs as dikes and sheets or as extensively altered rocks along faulted margins of dunite and peridotite.
d	Dunite. Dark-green to brown on fresh surfaces. Weathers to distinct orange-brown color with smooth surface. Accessory chromite and magnetite.
p	Peridotite. Dark-green on fresh surface. Weathers to olive or medium-brown color. Coarse pyroxene grains exhibit resistance to weathering resulting in a rough surface. Accessory chromite and magnetite.
c 12	Chromite occurrences. Disseminated and massive chromite in dunite. Occurrences are shown schematically. See text for descriptions of individual occurrences.
Pzp	Phyllite. Dark-gray to black phyllite and subordinate fine-grained meta-graywacke. Abundant white vein quartz. Age is uncertain but probably Devonian or late Paleozoic.
Pzs	Pelitic schist. Quartz-mica schist, chlorite schist, quartzo-feldspathic schist and subordinate quartzite. Metamorphic grade ranges from lower greenschist to almandine-amphibolite facies. At least part Paleozoic in age but may include rocks as old as Precambrian.



(Geology adapted from Patton and Miller, 1973 (5).)

Caribou Mountain Complex

Ten chromite occurrences were located on the ridge of Caribou Mountain nearest the TAPS Haul Road. These are referred to by the numerals 1 through 10 in this section and on figure 17.

Chromite occurrences 1 through 3 consist largely of massive chromitite in frost-heaved rubble and are believed to be the surface expression of three pods of massive chromitite. These pods occur in alternating dunite layers and layers of pyroxene-peridotite; they strike east and dip to the south. This attitude is unique for the peridotite layers throughout the three ultramafic bodies investigated. Elsewhere in the three complexes, the rocks generally dip to the northwest.

The largest of these first three occurrences (3 on fig. 17) measures 50 ft in exposed strike length and ranges from 5 to 10 ft in exposed width. Pieces of massive, frost-riven chromitite rubble weighing up to 5 lb were readily collected for the beneficiation tests. Sample A (PT 16641R) was collected in this manner from occurrence 3 for beneficiation tests by ALRC.[8]

Occurrences 4 and 5 consist of wispy concentrations of disseminated chromite grains in dunite; these occurrences were not sampled for beneficiation tests. This particular type of occurrence is common throughout the three ultramafic bodies investigated. Sample PB 12917R (23, fig. 10, and table B-1) was a chip sample collected at occurrence 5, and splits contained 3.7 and 3.8 pct chromium.

Occurrences 6, 7, and 8 are three curvilinear-shaped areas having conspicuous concentrations of disseminated and massive chromite in frost-heaved dunite rubble. These three areas are concentrically located about the north and west side of the summit of hill 2355 (approximately 1.5 mi west of the Haul Road). Occurrence 6 contains an abundance of massive chromitite in frost-heaved rubble, and bulk sample B (PB 15787R) was collected for beneficiation tests. Figure 19 is a photomicrograph of the massive variety of chromite found at the same location.

Occurrence 7 contains abundant chromite disseminated in dunite rather than massive chromitite. Figure 11 includes the area of this occurrence and shows the locations where 50 channel samples were collected along northwest-striking sample lines 5 ft in length. These samples averaged about 1 pct chromium content and are listed in table B-1. Sample PB 12921R (26, fig. 10) was a chip sample collected at the same location from a 50-ft interval trending N 55° W. This sample contained 6 pct chromium. Sample C (PT 16637R) was collected at occurrence 7 for beneficiation tests.

Chromite occurrences 8, 9, and 10 are very similar to occurrence 7, because abundant chromite grains are disseminated in dunite. Sample PB 15789R (27, fig. 10) was a representative sample from occurrence 8 and contained 1.3 pct chromium. Occurrences 7 and 8 are separated by a 150-ft interval of pyroxene-peridotite containing only accessory chromite. The western margin of occurrence 8 is intensely serpentinized and is bordered by a pyroxene-peridotite unit.

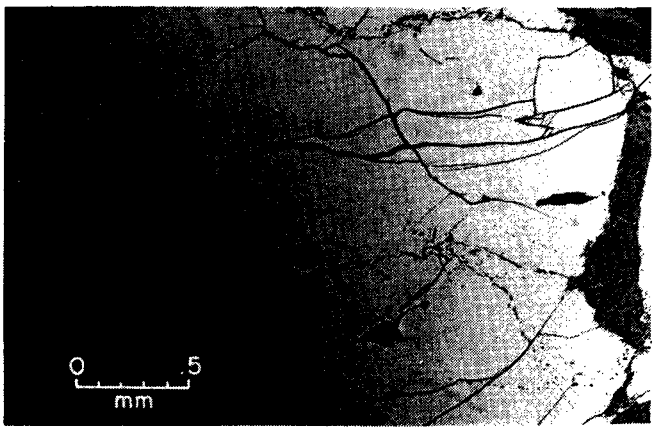


FIGURE 19. - Photomicrograph of polished section from Caribou Mountain showing fractures in massive chromite. These fractures are filled by serpentine and fine blebs of magnetite.

[8]All samples identified by capital letters are those later beneficiated at ALRC. The eight-digit alphanumeric designation is the sample field number.

Upper Kanuti River Complex

Numerous concentrations of disseminated chromite in dunite were seen in the upper Kanuti River ultramafic body, but these were relatively small in area. Results of analyses for rock samples collected on the upper Kanuti River complex are listed in table B-2.

Lower Kanuti River Complex

The chromite occurrences within the lower Kanuti River ultramafic body are labeled 11 through 24 on figure 18. Sample PB 12700R (95, fig. 12) was collected at occurrence 11 and represented a small (approximately 25-sq-ft) pod of disseminated and coalescent chromite in dunite at the north end of the ridge on which occurrences 12 through 14 are situated. Analyses for this and other samples collected in the lower Kanuti River ultramafic body are listed in table B-3.

Sample D (PT 16636R) was collected at occurrence 12 for beneficiation tests. Occurrence 12 provides the best exposure of chromite in dunite in the area. Figure 20 depicts the site where sample PB 15672R (98, fig. 12) was collected and shows the layered morphology of the chromitite in the dunite. Figure 21 is a photomicrograph of a polished section showing disseminated anhedral chromite in serpentinized dunite from occurrence 12.

This outcrop is exposed for a strike length of 80 ft and consists of a 5-ft-thick interval composed of layers of disseminated to coalescent chromite up to 4 in thick. These chromite-bearing layers alternate with barren intervals of dunite having the same thickness. This outcrop is covered by tundra at both ends and is remarkably well layered compared with the typical, irregular-shaped pods of chromite seen throughout the area investigated. Six samples (PB 15618R through PB 15623R) (97, fig. 12) were collected across this same mineralized interval at different points along the outcrop.

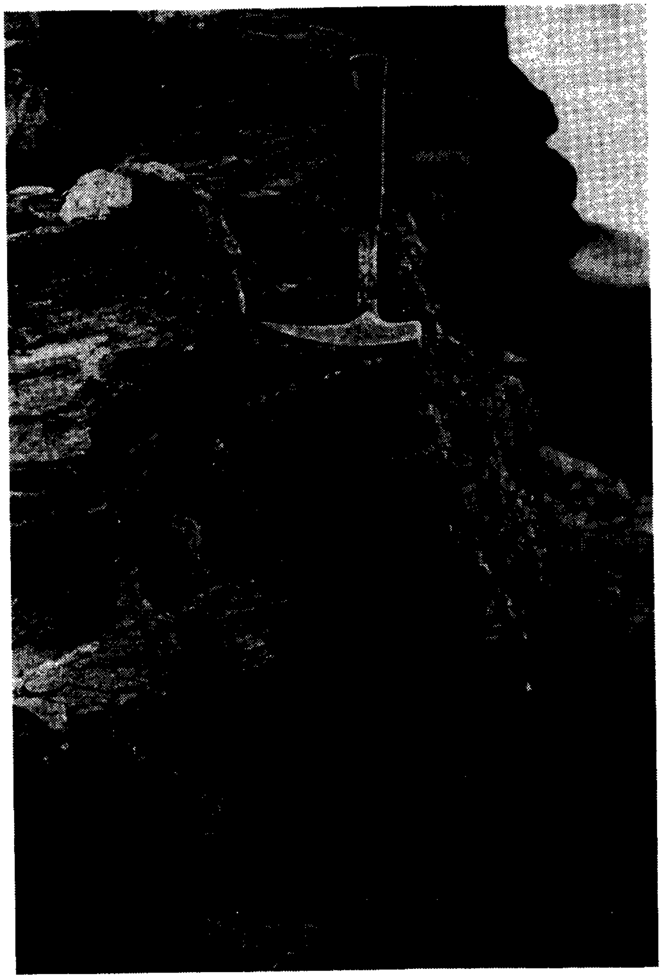


FIGURE 20. - Photograph of outcrop at chromite occurrence 12 showing alternating layers of chromite and dunite.

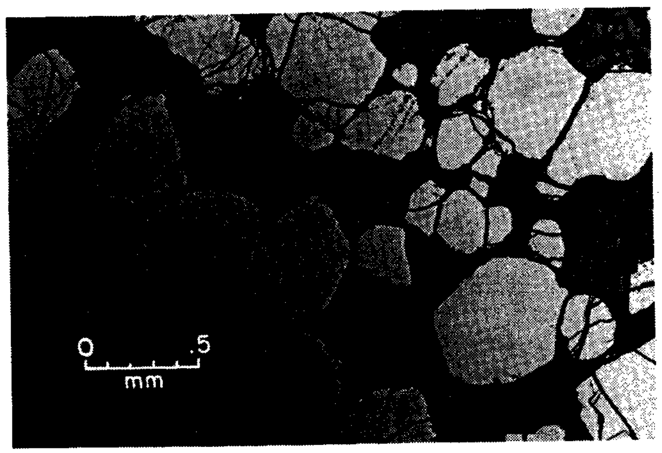


FIGURE 21. - Photomicrograph of disseminated, anhedral chromite grains in serpentinized dunite from chromite occurrence 12.

Occurrence 13 is poorly exposed and is located to the south of occurrence 12 on the same ridge. It is representative of the more typical mode of occurrence. Occurrence 14 is a narrow-banded or layered occurrence and is shown in figure 22. The exposed strike length of this occurrence is approximately 33 ft.

Occurrences 15, 16, and 17 are on the hill to the southwest of occurrences 12-14 (approximately 1.8 mi). Occurrences 15 and 16 are no more than local concentrations of wispy, disseminated chromite in serpentinized dunite. Occurrence 17, however, consists of a pod of massive chromitite exposed in a pit within the claims located by Oil Development Co. of Texas in 1975. Sample E (PT 15535R) was collected from this pit for beneficiation tests.

Occurrences 18 through 22 are on the hill to the west of the previous locations. A pod of chromite at occurrence 18 is intensely deformed and remobilized along a high-angle shear zone that strikes northwesterly. Nodular chalcedony and drusy quartz constitute fracture fillings in chromite and dunite at this location, and magnestite encrusts the surfaces of both. Occurrence 19 consists of disseminated to coalescent chromite in dunite and is conformable to the northwest-dipping layers of dunite and pyroxene-peridotite. Samples F (PB 16517R) and G (PB 16518R) were collected from occurrences 18 and 19, respectively. Photomicrographs of these two samples are shown in figures 23 and 24.

Chromite occurrence 20 is poorly exposed, but sample H (PT 16639R) was collected there from abundant massive and coalescent chromite rubble. This chromitite rubble is intermixed with dunite, and the mixed rubble is confined to a steep gulley on the east side of the hill. Sample H was collected exclusively at the top of this gully, closer to the bedrock source.

Occurrence 21 consists of disseminated and massive chromite in dunite rubble at the ridge crest adjacent to occurrences 18-20. Samples I and J (PT 16638A and B) were collected at this location for beneficiation tests.

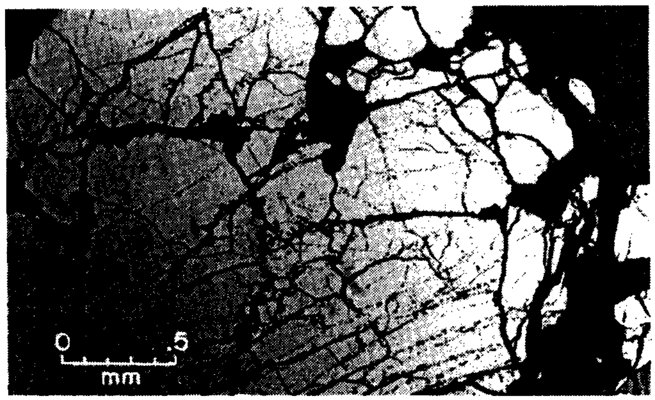


FIGURE 23. - Photomicrograph of polished section (sample F) showing fractures in massive chromite.

FIGURE 22. - Photograph of well-layered chromite in lower Kanuti River ultramafic body showing disseminated to massive chrome spinel in serpentinized, dunite gangue.

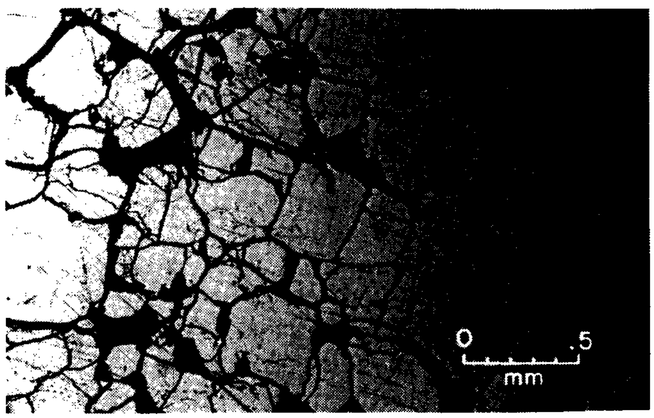


FIGURE 24. - Photomicrograph of polished section (sample G) showing coalescent habit among chromite anhedra.

Occurrence 22 is located on the west side of the same ridge and consists of discontinuous lenses of disseminated chromite in dunite up to 4 in thick. Sample K (PT 16640R) was collected at this location for beneficiation.

Occurrences 23 and 24 are located 2.5 mi southwest of the previous occurrences and consist of discontinuous layers of disseminated and massive chromite in serpentinized dunite. Samples PB 10317R through PB 10325R (100 and 114-121, fig. 12) were collected at these locations.

CONCLUSIONS

Podiform chromite deposits were found in central Alaska in the Caribou Mountain and lower Kanuti River ultramafic complexes, which are part of the Caribou Mountain-Melozitna ultramafic belt. Similar occurrences of small extent were found in the upper Kanuti River ultramafic complex. A brief visit to the Kilolitna ultramafic complex revealed another similar occurrence in dunite rubble. These chromite occurrences are discontinuous in form and small in outcrop size. The chromite occurs as disseminated and massive concentrations in dunite gangue. These deposits are similar in form, mineralogy, and texture to podiform chromite deposits found in other alpine peridotite complexes. It is possible that larger, buried deposits exist.

RECOMMENDATIONS

It is recommended that a low-cost means of subsurface exploration be employed to establish the extent of chromite occurrences discovered during the course of this investigation. This could be done with a track-mounted auger, and the results would aid in determining if resources worthy of trenching or drilling exist.

Additional reconnaissance is recommended within the Holonada ultramafic complex at the southwestern end of the Caribou Mountain-Melozitna ultramafic belt. This complex has not been investigated for chromium resources and may contain additional deposits of chromite.

REFERENCES

1. Goles, G. G. Trace Elements in Ultramafic Rocks. Ch. in Ultramafic and Related Rocks, ed. by P. J. Wyllie. John Wiley & Sons, Inc., New York, 1967, pp. 352-362.

2. Herreid, G. Geology and Geochemistry of the Sithylemenkat Lake Area, Bettles Quadrangle, Alaska. Alaska Div. Mines and Geol., Geol. Rept. 35, 1969, 22 pp.

3. Levinson, A. A. Introduction to Exploration Geochemistry. Applied Publishing Ltd., Maywood, Ill., 1973, pp. 43-44.

4. Patton, W. W., Jr., and T. P. Miller. Analyses of Stream Sediment Samples From the Bettles and the Southern Part of Wiseman Quadrangles, Alaska. U.S. Geol. Survey Misc. Field Studies Map MF-492, 1:250,000, 1973.

5. _____. Bedrock Geologic Map of Bettles and Southern Part of Wiseman Quadrangles, Alaska. U.S. Geol. Survey Misc. Field Studies Map MF-492, 1:250,000, 1973.

6. _____. Preliminary Geologic Investigations in the Kanuti River Region, Alaska. U.S. Geol. Survey Bull. 1312-J, 1970, pp. J1-J7.

7. Patton, W. W., Jr., T. P. Miller, M. A. Lanphere, and W. P. Brosge. Kanuti Ultramafic Belt. Paper in Geological Survey Research 1976. U.S. Geol. Survey Prof. Paper 1000, 1976, 53 pp.

8. Patton, W. W., Jr., I. L. Tailleur, W. P. Brosge, and M. A. Lanphere. Preliminary Report on the Ophiolites of Northern and Western Alaska. Pres. at Sudbury Ultramafic Conf., North American Meeting of Internat. Working Group on Ophiolites of Continents and Comparable Oceanic Rocks, Sudbury, Ontario, 1979; available from U.S. Geol. Survey, Menlo Park, Calif. Also in Oreg. Dept. Geol. and Miner. Ind. (Portland, Oreg.), Bull. 95, 1977, pp. 51-57.

9. Robinson, M. S., and P. A. Metz. Evaluation of the Mineral Resources of the Pipeline Corridor (contract G0166180, Mineral Industry Research Laboratory). Unpublished rept. submitted to Bureau of Mines, 1979, 264 pp.; available on loan from Alaska Field Operations Center, Fairbanks and Juneau, Alaska.

10. U.S. Department of Energy. Report of Analyses From Mineral Resource Investigations in Central and Eastern Alaska (prepared by Bendix Field Engineering Corp., Grand Junction, Colo., and Bureau of Mines, Alaska Field Operations Center, Fairbanks, Alaska). Rept. GJBX-178 (81), 1981, 148 pp.

11. Wahrhaftig, C. Physiographic Divisions of Alaska. U.S. Geol. Survey Prof. Paper 482, 1965, 52 pp.

APPENDIX A.--PETROGRAPHIC DESCRIPTIONS OF ROCK SAMPLES

TABLE A-1. - Estimated modal mineralogy (volume-percent) and petrographic descriptions of selected rock samples from Caribou Mountain ultramafic complex

Sample[1]	Field No.[2]	Olivine	Enstatite	Clinopyroxene	Hornblende	Tremolite	Plagioclase	Talc	Serpentine	Quartz	Chlorite	Iddingsite	Carbonate	Chromite	Sericite	Petrographic description
1	KA 9755	60	0	10	0	0	0	0	25	0	0	0	2	2	0	Anhedral clinopyroxene in extensively serpentinized olivine groundmass.
2	76 AMR 245A	60	0	15	5	0	0	0	20	0	0	0	2	0	0	Minor hornblende replacing clinopyroxene in serpentinized wehrlite.
4	KA 12292	0	0	0	0	0	0	0	20	75	0	5	0	0	0	Breccia: serpentinite fragments in microcrystalline and vuggy quartz.
7	PB 15779	0	0	98	0	0	0	0	0	0	0	0	0	A	0	Coarse-grained granular clinopyroxenite.
8	PB 15780	90	0	0	0	0	0	A	5	0	0	0	A	2	0	Fresh olivine in dunite with mesh texture.
9	KA 12288	65	0	30	0	0	0	0	5	0	0	0	0	0	0	Strained and fragmented clinopyroxene in cataclastic, serpentinized olivine groundmass.
12[3]	PB 12912	0	0	0	60	0	35	0	0	0	A	0	0	0	A	Hornblende clasts and broken plagioclase phenocrysts in foliated and granulated hornblende-plagioclase groundmass.
13a[3,4]	76 AMR 238A	0	0	0	80	0	15	0	0	0	A	0	0	A	A	Protoclastic, hypidiomorphic, plagioclase-bearing hornblendite.
13b	76AMR 238C	65	15	0	0	0	0	5	10	0	0	0	0	A	0	Cataclastic and serpentinized harzburgite.
14	PB 12913	90	0	0	0	0	0	A	5	0	0	0	A	2	0	Chromite in serpentinized dunite with mesh texture.
16	PB 12915	45	30	15	0	0	0	A	5	0	0	A	A	A	0	Lherzolite: coarse, strained and broken pyroxene grains in fine-grained granulated serpentinized olivine.
17[5]	76 AMR 239A	80	4	0	0	0	0	0	10	0	0	0	0	3	0	Mesh texture in serpentinized dunite.
19	76 AMR 240A	60	10	5	0	4	0	0	15	0	0	0	4	A	0	Strained, anhedral pyroxene grains in sheared, serpentinized olivine groundmass.
20	KA 12296	40	15	0	0	0	0	0	35	0	0	A	0	5	0	Sheared, serpentinized, and silicified harzburgite.

See footnotes at end of table.

TABLE A-1. - Estimated modal mineralogy (volume-percent) and petrographic descriptions of selected rock samples from Caribou Mountain ultramafic complex--Continued

Sample[1]	Field No.[2]	Olivine	Enstatite	Clinopyroxene	Hornblende	Tremolite	Plagioclase	Talc	Serpentine	Quartz	Chlorite	Iddingsite	Carbonate	Chromite	Sericite	Petrographic description
21a[4]	KA 12285	0	0	20	40	0	35	0	0	0	0	0	0	A	3	Hornblende replacing clinopyroxene in subophitic gabbro.
21b	KA 12286	0	0	0	0	0	0	5	80	0	0	5	5	5	0	Extensively sheared and altered peridotite.
21c	KA 12290A	80	0	0	0	0	0	5	5	0	0	A	5	A	0	Mesh texture in serpentinized dunite.
21d	KA 12290B	10	0	0	0	0	0	0	30	55	0	5	0	0	0	Breccia: serpentinite fragments in microcrystalline and vuggy quartz.
22[3, 4]	KA 12289	0	0	5	55	0	35	0	0	0	A	0	0	2	A	Clinopyroxene replaced by hornblende in ophitic gabbro.
24	PB 12918	70	0	0	0	0	0	A	5	0	0	A	A	20	0	Disseminated chromite in sheared and serpentinized dunite.
25a	76 AMR 241A	60	10	5	0	3	0	0	20	0	0	0	0	2	0	Strained, anhedral pyroxene grains in sheared, serpentinized olivine groundmass.
25b	PB 12920	40	15	25	0	0	0	5	10	0	0	0	3	A	0	Lherzolite: strained and broken pyroxene grains in fine-grained granulated serpentinized olivine.
27a	KA 12295	10	0	0	0	0	0	0	40	0	0	0	0	50	0	Disseminated chromite with pull-apart structure in serpentinized dunite.
28[4]	KA 12299	10	A	65	20	0	0	0	A	0	A	0	0	0	0	Hornblende replacing clinopyroxene in olivine clinopyroxenite.
29[3]	PB 15790	0	0	55	0	0	30	0	0	0	10	0	0	2	A	Altered gabbro with coarse-grained anhedral, chloritized pyroxene and subhedral, altered plagioclase.
30	76 AMR 243A	8	0	90	0	0	0	0	2	0	0	0	0	A	0	Strained clinopyroxene grains in groundmass of anhedral clinopyroxene and olivine.
31[4]	KA 12302	65	0	0	0	0	0	5	20	0	0	A	5	2	0	Serpentinized dunite.

A Mineral present in accessory amount.

[1]Numbers refer to locations on figure 10 in the main text.

[2]Samples with the designation AMR were collected by Mark Robinson, Mineral Industries Research Laboratory (now with Alaska State Div. Geol. and Geophys. Survey).

[3]Contains accessory amount of epidote.

[4]Contains accessory amount of apatite.

[5]Contains accessory amount of spinel.

TABLE A-2. - Estimated modal mineralogy (volume-percent) and petrographic descriptions of selected rock samples from upper Kanuti River ultramafic complex

Sample[1]	Field No.	Olivine	Clinopyroxene	Hornblende	Plagioclase	Talc	Serpentine	Quartz	Chlorite	Iddingsite	Carbonate	Chromite	Sericite	Petrographic description
39	PB 15679	85	0	0	0	0	10	0	0	A	A	4	0	Disseminated chromite in sheared and serpentinized dunite.
40	PB 15678	75	0	0	0	0	20	0	0	A	A	3	0	Do.
41[2]	PB 15677	0	0	45	45	0	A	0	5	A	0	A	2	Altered hornblende and plagioclase clasts in protoclastic hornblende-plagioclase groundmass.
42a	PB 15676	10	5	0	0	A	50	30	0	A	A	A	0	Silicified, serpentinized periodotite.
44a	PB 15627A	2	95	0	0	A	A	0	0	A	A	A	0	Coarse, deformed clinopyroxene grains in granulated groundmass of clinopyroxene and minor olivine.
44b	PB 15627B	80	0	0	0	A	10	A	A	5	A	3	0	Disseminated chromite in serpentinized dunite with mesh texture.

A Mineral present in accessory amount.
[1]Numbers refer to locations on figure 10 in the main text.
[2]Contains accessory amount of apatite.

TABLE A-3. - Estimated modal mineralogy (volume-percent) and petrographic descriptions of selected rock samples from lower Kanuti River ultramafic complex

Sample[1]	Field No.	Olivine	Enstatite	Clinopyroxene	Talc	Serpentine	Chlorite	Iddingsite	Carbonate	Chromite	Petrographic description
96	PB 15673	70	0	0	5	10	0	3	4	8	Disseminated chromite in serpentinized dunite with mesh texture.
97a	PB 15615	30	0	15	0	A	A	A	0	50	Clinopyroxenite veinlet in dunite with disseminated chromite.
97b	PB 15617A	60	A	35	0	A	0	0	0	A	Serpentinized wehrlite.
97c	PB 15617B	40	0	50	0	5	0	3	0	A	Coarse clots of strained and broken clinopyroxene in granulated groundmass of serpentinized olivine.
97j	PB 15624	20	0	0	0	5	0	0	0	75	Disseminated and coalescent chromite with pull-apart structure in serpentinized dunite.
98a	PB 15667	65	0	0	0	10	0	0	0	25	Disseminated chromite with pull-apart structure in serpentinized olivine.
99	PB 15671	90	0	0	0	5	0	0	0	5	Disseminated chromite in serpentinized dunite with mesh texture.
101	PB 15670	65	8	10	0	5	0	10	0	A	Coarse, strained pyroxene grains in serpentinized olivine groundmass.
104	PB 15665	65	30	0	0	A	0	0	0	A	Harzburgite with coarse, strained and broken enstatite grains in serpentinized olivine.
106	PB 15663	80	10	0	0	6	0	0	0	A	Do.
108	PB 15613	65	20	0	A	10	A	0	2	A	Do.
110a	PB 16517A	10	0	0	0	2	0	3	0	85	Coalescent to massive chromite with pull-apart structure in serpentinized dunite.
110b	PB 16517B	70	0	0	0	20	0	8	0	A	Extensively serpentinized dunite-host for PB 15617A.
110c	PT 16518A	25	0	0	0	12	0	3	0	60	Coalescent and massive chromite with pull-apart structure in serpentinized dunite.
110d	PT 16518B	0	0	0	0	0	0	5	0	95	Massive chromite cut by veinlets of chalcedony and iddingsite.

A Mineral present in accessory amount.

[1]Numbers refer to locations on figure 12 in the main text.

APPENDIX B.--ANALYSES OF ROCK SAMPLES

TABLE B-1. - Analyses[1] (parts per million) and descriptions of rock samples from Caribou Mountain ultramafic complex

Sample[2]	Field No.	Cr		Cu		Co		Ni		Description
		1	2	1	2	1	2	1	2	
3	PB 15786	6,556	6,900	16	<50	126.3	<100	1,835	2,300	Serpentine stringers and chromite in dunite.
5	PB 15777	64,490	58,000	35	<50	161.2	<100	2,292	2,400	High-grade disseminated chromite in dunite.
6	PB 15778	10,340	11,000	25	<50	132.9	<100	2,806	2,800	Representative sample from same location as PB 15777.
10a	PB 15782	99,998	200,000	56	<50	189.1	<100	2,355	2,200	High-grade sample of chromite in dunite.
10b	PB 15783	96,140	75,000	38	<50	139.6	<100	3,413	3,100	Representative sample of chromitite layers in dunite.
11	PB 15781	7,112	7,900	20	<50	115.1	<100	2,404	2,800	Dunite with traces of chromite.
15	PB 12914	4,653	4,500	17	<50	129.3	<100	2,559	2,700	Chip sample across 250 ft of dunite and hobnail peridotite.
16	PB 12915	3,908	3,900	<10	<50	129.0	<100	2,341	2,800	Chip sample from hobnail peridotite layer.
18	PB 12916	4,387	5,100	18	<50	128.5	<100	2,486	2,900	Chromite in dunite and hobnail peridotite.
23	PB 12917	36,960	38,000	41	<50	138.9	<100	2,812	2,900	Chip sample across wispy chromite stringers in dunite.
24	PB 12918	4,306	4,900	26	<50	123.6	<100	957	1,200	Chromite in hobnail peridotite.
26a	PB 12921	59,160	61,000	30	<50	133.6	<100	3,308	3,000	Chip sample of dunite with abundant chromite.
26b	PB 15788	10,360	NA	31	NA	121.2	NA	3,239	NA	Representative sample of chromite-bearing dunite.
27b	PB 15789	13,000	13,000	28	<50	139.9	<100	2,770	3,100	Do.
32	PB 12933	66,930	NA	28	NA	142.8	NA	1,976	NA	Abundant disseminated chromite in serpentinized dunite.
45	PB 15803	15,860	12,000	15	2,000	110.4	<300	2,498	1,900	Channel sample in dunite colluvium; line A.
46	PB 15804	NA	13,000	NA	4,100	NA	<300	NA	2,300	Do.
47	PB 15805	NA	8,500	NA	4,900	NA	<300	NA	2,200	Do.
48	PB 15806	16,140	16,000	<10	3,700	116.6	<300	2,735	2,200	Do.
49	PB 15807	16,900	13,000	22	1,800	113.9	<300	2,757	2,100	Do.
50	PB 15808	NA	17,600	NA	4,700	NA	<100	NA	2,900	Do.
51	PB 15809	NA	11,700	NA	1,100	NA	<100	NA	3,100	Do.
52	PB 15810	NA	12,000	NA	1,500	NA	<100	NA	3,100	Do.

See footnotes at end of table.

TABLE B-1. - Analyses[1] (parts per million) and descriptions of rock samples from Caribou Mountain ultramafic complex--Continued

Sample[2]	Field No.	Cr		Cu		Co		Ni		Description
		1	2	1	2	1	2	1	2	
53	PB 15811	NA	22,200	NA	100	NA	<100	NA	3,000	Channel sample in dunite colluvium; line A.
54	PB 15812	9,281	9,400	<10	200	115.9	<100	2,524	2,900	Do.
55	PB 15813	NA	7,900	NA	300	NA	<100	NA	2,800	Do.
56	PB 15814	15,690	15,700	10	100	127.9	<100	2,886	3,000	Do.
57	PB 15815	11,020	13,000	21	230	119.7	<100	2,810	3,000	Do.
58	PB 15816	24,140	26,000	23	80	127.8	<100	2,849	2,800	Do.
59	PB 15817	15,680	16,000	<10	80	137.3	<100	2,473	2,500	Do.
60	PB 15818	12,200	13,000	15	50	128.7	<100	2,566	2,600	Do.
61	PB 15819	14,320	16,000	14	540	146.1	<100	2,298	2,000	Do.
62	PB 15820	11,150	12,000	18	60	138.3	<100	2,011	2,000	Do.
63	PB 15821	5,457	6,000	22	80	135.7	<100	1,399	1,500	Do.
64	PB 15822	3,865	4,500	<10	200	141.7	<100	1,141	1,300	Do.
65	PB 15823	25,760	26,000	18	180	126.6	<100	3,315	3,100	Channel sample in dunite colluvium; line B.
66	PB 15824	13,340	13,000	15	105	121.8	<100	3,188	3,200	Do.
67	PB 15825	11,580	11,000	11	170	117.0	<100	3,245	3,200	Do.
68	PB 15826	10,340	10,000	<10	150	128.6	<100	3,048	3,200	Do.
69	PB 15827	14,160	15,000	30	60	118.6	<100	2,863	3,100	Do.
70	PB 15828	9,603	7,700	36	<100	119.7	<100	2,943	2,500	Do.
71	PB 15829	9,258	7,300	34	<100	122.9	<100	3,055	2,500	Do.
72	PB 15830	9,619	7,600	10	330	123.5	<100	3,218	2,500	Do.
73	PB 15831	9,413	7,700	46	<100	127.5	<100	2,336	2,500	Do.
74	PB 15832	10,470	9,700	40	<160	121.5	<100	3,125	2,500	Do.
75	PB 15833	10,880	8,800	54	<100	127.1	<100	3,056	2,500	Do.
76	PB 15834	7,284	5,500	44	300	116.8	<100	2,871	2,500	Do.
77	PB 15835	6,684	5,100	25	270	126.8	<100	3,021	2,400	Channel sample in dunite colluvium; line C.
78	PB 15836	6,606	3,400	15	<100	122.6	<100	3,124	2,500	Do.
79	PB 15837	8,108	4,900	18	<100	119.8	<100	3,101	2,200	Do.
80	PB 15838	6,506	4,700	29	370	115.1	<100	3,456	2,500	Do.
81	PB 15839	8,744	6,300	16	<100	118.7	<100	3,378	2,500	Do.
82	PB 15840	9,432	7,800	12	<100	125.9	<100	3,272	2,500	Do.
83	PB 15841	9,578	10,000	<10	100	124.5	<100	2,801	3,500	Do.
84	PB 15842	9,655	9,700	<10	<50	133.0	<100	3,013	3,300	Do.
85	PB 15843	NA	NA	NA	NA	NA	NA	NA	NA	Do.
86	PB 15844	9,411	13,000	<10	<50	125.6	<100	2,897	3,500	Do.
87	PB 15845	10,600	11,000	<10	<50	130.9	<100	2,743	3,000	Do.
88	PB 15846	7,637	7,600	74	<50	127.9	<100	2,820	3,200	Do.
89	PB 15847	7,474	8,700	19	<50	140.0	<100	1,674	1,900	Do.
90	PB 15848	8,520	8,500	<10	<50	144.6	<100	1,653	1,800	Do.
91	PB 15849	9,268	9,400	12	60	151.6	<100	1,724	2,000	Do.
92	PB 15850	5,310	5,400	<10	100	154.4	<300	1,297	1,000	Do.
93	PB 15851	6,226	6,300	<10	100	132.6	<300	1,357	1,000	Do.
94	PB 15852	2,951	2,400	<10	100	134.2	<300	1,011	700	Do.

NA Not analyzed.

[1]Columns headed by the number 1 show analyses by Los Alamos (N. Mex.) Scientific Laboratories. Copper was detected by X-ray fluorescence; chromium, cobalt, and nickel by neutron activation. Columns headed by the number 2 show analyses by the Bureau of Mines Reno (Nev.) Research Center using atomic absorption techniques.

[2]Numbers refer to locations on figures 10 and 11 in the main text.

TABLE B-2. - Analyses[1] (parts per million) and descriptions of rock samples from upper Kanuti River ultramafic complex

Sample[2]	Field No.	Cr		Cu		Co		Ni		Description
		1	2	1	2	1	2	1	2	
33	PB 15685	13,560	15,000	30	<50	150.0	<100	2,860	2,200	Abundant chromite in dunite.
34	PB 15684	5,296	6,000	26	440	127.6	<100	1,768	1,500	Abundant chromite in dunite rubble.
35	PB 15683	10,060	11,000	22	100	134.8	<100	2,314	2,200	Discontinuous seam of chromite in dunite boulder.
36	PB 15682	118	5,900	157	210	54.3	<100	186	245	No description.
37	PB 15681	4,843	5,300	17	70	126.6	<100	1,959	2,000	Minor chromite in dunite.
38	PB 15680	2,337	2,600	33	155	148.9	<100	2,003	1,700	Do.
39	PB 15679	6,367	6,800	11	<150	155.9	<100	2,053	1,800	Disseminated chromite in orange-brown weathering dunite.
40	PB 15678	2,575	2,700	10	<50	159.9	<100	1,587	1,300	Chip sample of orange-brown weathering dunite.
41	PB 15677	NA	5,000	NA	145	NA	<100	NA	13,500	Diabase.
42a	PB 15676	1,296	1,700	103	130	37.5	<100	210	260	Magnesite in serpentinite zone.
42b	PB 15675	6,019	6,400	<10	50	40.1	<100	479	305	Cataclastic, chromite-bearing serpentinite.
42c	PB 15674	2,699	3,000	28	100	159.2	<100	1,470	1,200	Cataclastic and serpentinized chromite-bearing dunite.
43	PB 15625	2,137	2,600	24	<50	61.0	<100	419	380	No description.
44	PB 15627	4,472	4,800	36	<50	148.1	<100	1,967	1,700	Minor chromite in dunite.

NA Not analyzed.

[1]Columns headed by the number 1 show analyses by Los Alamos (N. Mex.) Scientific Laboratories. Copper was detected by X-ray fluorescence. Columns headed by the number 2 show analyses by the Bureau of Mines Reno (Nev.) Research Center, using atomic absorption techniques.

[2]Numbers refer to locations on figure 10 in the main text.

TABLE B-3. - Analyses[1] (parts per million) and descriptions of rock samples from lower Kanuti River ultramafic complex

Sample[2]	Field No.	Cr		Cu		Co		Ni		Description
		1	2	1	2	1	2	1	2	
95	PB 12700	13,020	61,000	32	<50	147.4	<100	2,092	2,900	Chromite pod in dunite boulder.
96	PB 15673	4,460	4,800	<10	100	140.8	<100	3,187	2,800	Chromite-bearing dunite.
97d	PB 15618	78,480	73,000	<10	50	137.7	<300	2,618	2,200	40-lb channel sample across 5-ft mineralized interval.
97e	PB 15619	28,120	23,000	11	20	124.9	100	2,679	2,300	1-ft channel sample.
97f	PB 15620	18,680	18,000	<10	NA	118.0	NA	2,674	NA	Do.
97g	PB 15621	39,640	35,000	<10	NA	129.5	<300	2,721	2,200	Do.
97h	PB 15622	99,998	235,000	<10	NA	151.8	<300	2,517	1,600	Do.
97i	PB 15623	99,998	153,000	<10	260	147.5	<300	3,665	2,200	Do.
98b	PB 15672	36,610	85,000	<10	100	126.3	<300	2,749	1,900	5-ft channel sample.
99	PB 15671	3,072	13,000	24	100	139.6	400	3,072	1,400	Chromite in dunite.
100	PB 10317	2,926	3,500	14	<50	110.0	<100	2,384	2,200	Visible chromite in hobnail peridotite.
101	PB 15670	2,260	2,000	208	100	134.3	<300	1,284	700	Magnetite and chromite in serpentinized peridotite.
102	PB 15669	3,584	3,700	26	100	153.2	<300	1,664	1,400	Chip sample of chromite-bearing peridotite.
103	PB 15668	22,150	20,000	11	100	143.9	<300	2,463	1,200	High-graded chromite in dunite.
105a	PB 15664	2,817	3,400	28	100	116.4	<300	3,030	1,500	Chromite in serpentinized dunite.
105b	PB 15665	2,828	2,900	38	100	108.3	<300	2,779	1,500	Chip sample of chromite-bearing peridotite.
106	PB 15663	2,523	2,500	16	100	117.0	<300	2,680	1,400	Chromite in dunite.

See footnotes at end of table.

TABLE B-3. - Analyses[1] (parts per million) and descriptions of rock samples from lower Kanuti River ultramafic complex--Continued

Sample[2]	Field No.	Cr		Cu		Co		Ni		Description
		1	2	1	2	1	2	1	2	
107a	PB 15610	3,154	3,500	<10	<50	125.8	<100	3,064	2,500	Minor disseminated chromite in dunite.
107b	PB 15612	2,731	3,300	21	<50	113.7	<100	2,790	2,600	Chromite in serpentinized and sheared dunite.
109	PB 15614	2,617	3,200	16	<50	110.4	<100	2,943	2,600	Weathered chip of peridotite.
111	PB 15882	62,970	67,000	172	140	174.9	<100	2,234	2,000	Representative sample from high-grade pod in dunite.
112	PB 15881	2,828	3,900	26	<50	112.5	<50	2,416	2,400	Trace chromite in peridotite.
113	PB 15880	2,725	3,300	49	<50	110.8	<100	2,272	2,300	Do.
114	PB 10318	10,040	11,000	33	250	135.3	<100	2,709	2,600	High-graded chromite in peridotite.
115	PB 10319	2,824	3,700	43	<50	119.2	<100	2,438	2,400	Minor chromite in hobnail peridotite.
116	PB 10320	3,346	3,600	<10	<50	123.9	<100	2,857	2,700	Minor chromite in dunite.
117	PB 10321	56,900	67,000	13	<50	129.0	<100	3,191	2,600	Chromite-rich layers in dunite.
118	PB 10322	9,776	11,000	72	75	121.4	<100	2,887	2,700	Dunite from between layers of pyroxene peridotite.
119	PB 10323	37,080	42,000	14	<50	158.4	<100	2,336	2,000	Disseminated and massive chromite dunite.
120	PB 10325	2,970	4,000	12	150	120.7	<100	2,883	2,600	Minor chromite in dunite.
121	PB 10324	3,389	3,800	12	70	111.2	<100	2,389	2,300	Minor chromite in hobnail peridotite.

NA Not analyzed.

[1]Columns headed by the number 1 show analyses by Los Alamos (N. Mex.) Scientific Laboratories. Copper was detected by X-ray fluorescence; chromium, cobalt, and nickel by neutron activation. Columns headed by the number 2 show analyses by the Bureau of Mines Reno (Nev.) Research Center, using atomic absorption techniques.

[2]Numbers refer to locations on figure 12 in the main text.

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