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DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

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September 1986

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Report of Investigations 86-23

MINERAL RESOURCES OF THE NORTHCENTRAL CHUGACH MOUNTAINS, ALASKA

By
Rainer J. Newberry

STATE OF ALASKA
Department of Natural Resources
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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MINERAL RESOURCES OF THE NORTHCENTRAL CHUGACH MOUNTAINS, ALASKA

Rainer J. Newberry[1]

ABSTRACT

Maps and petrographic and analytical data were compiled for 44 mineral prospects located in the northcentral Chugach Mountains, a rugged area about 60 mi east of Anchorage, Alaska. These prospects include mineralized plutonic, volcanic, and metamorphic rocks affiliated with the Peninsular terrane and deposit types that range from magmatic oxide and sulfide to hydrothermal and metamorphic sulfide. Analysis of the data presented indicates that these prospects are too small, low grade, or structurally disrupted to possess economic potential under current economic conditions and that the likelihood of large, metal-rich prospects in the area is small. This conclusion is derived from the extreme structural disruption observed, low assay values, lack of geologic continuity of metalliferous hosts, and lack of suitable hosts for porphyry or massive sulfide deposits.

INTRODUCTION

The northcentral Chugach Mountains have been historically considered to possess minor mineral resources. Berg and Cobb's (1967) compilation of lode prospects of Alaska, for example, lists only four prospects, with no production in this area. Exploration, however, has been hindered by the steep, inaccessible topography. Panning and stream-sediment sampling (conventional reconnaissance-exploration techniques) are less useful than in other areas of the state due to extremely active slope erosion. However, large areas (up to 5 mi^2) of surficial iron-staining produced by active weathering of sulfide minerals are present and suggest the existence of metalliferous prospects. The relatively recent discoveries of chromite (Wolverine Complex, Clark, 1972) and lead-zinc-silver prospects (Nelchina lode; Henning and Pessel, 1980) by the U.S. Geological Survey (USGS) and Alaska Division of Geological and Geophysical Surveys (DGGS) and the lack of geologic maps in most parts of the study region suggest that the northern Chugach Mountains have not been adequately evaluated for their mineral resources.

Regional metal-resource studies (MacKevett and others, 1978) based on sparse geologic data suggest the possibility of ultramafic-related chromium-platinum deposits, copper-molybdenum-gold porphyry deposits, and precious-metal vein deposits in the area. Lithologies present in the northern Chugach Mountains are geologically suitable for such types of deposits, but available geologic and mineral-deposit data are inadequate for a realistic resource appraisal. To provide additional data to evaluate the mineral potential of the region, DGGS inaugurated a program of geologic mapping and mineral-deposit studies in 1979. This report is a summary evaluation of the mineral potential of the study area based on regional geologic mapping by G.H. Pessel,

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L.E. Burns, T.A. Little, J.E. Decker, and me of the Anchorage C-1, 2, 3, 4, 5 and D-1, 2, 3, 4, 5 Quadrangles and of selected areas of the Anchorage and Valdez Quadrangles. The studies were conducted between 1979 and 1983 and were supplemented by detailed geologic and mineral-prospect mapping, bedrock geochemistry, and petrographic studies in 1982. Figures 1 and 2 show the location of the study area and major mineral prospects. In this report, the term prospect refers to an area that contains metallic minerals and does not signify that an area has been claimed or previously investigated. The term deposit is reserved for prospects with economic mineral production.

GENERAL GEOLOGIC SETTING

Mineral prospects in the northern Chugach Mountains occur in or near four major units: 1) Mesozoic or Paleozoic amphibolite, schist, and minor marble; 2) Jurassic ultramafic- to intermediate-composition plutonic rocks; 3) Jurassic intermediate- to felsic-composition volcanic rocks of the Talkeetna Formation; and 4) Tertiary hypabyssal felsite dikes and plugs. For geologic maps, cross-sections, and detailed lithologic descriptions, refer to Grantz (1961), Pessel and others (1981), Burns and others (1983), McMillin (1984) and Little and others (1986).

Generally, the first three units form east-west-trending fault-bounded belts. From south to north, these belts comprise pre-Jurassic amphibolite and schist and Jurassic plutonic and volcanic rocks (Burns and others, 1983). Tertiary felsic dikes and plugs occur throughout the region, commonly along or roughly parallel to east-west-striking faults. All four major map units are complexly deformed and metamorphosed; inter- and intra-unit contacts are dominated by Tertiary to Holocene high-angle faults. The first three units were regionally metamorphosed to zeolite, greenschist, and amphibolite facies.

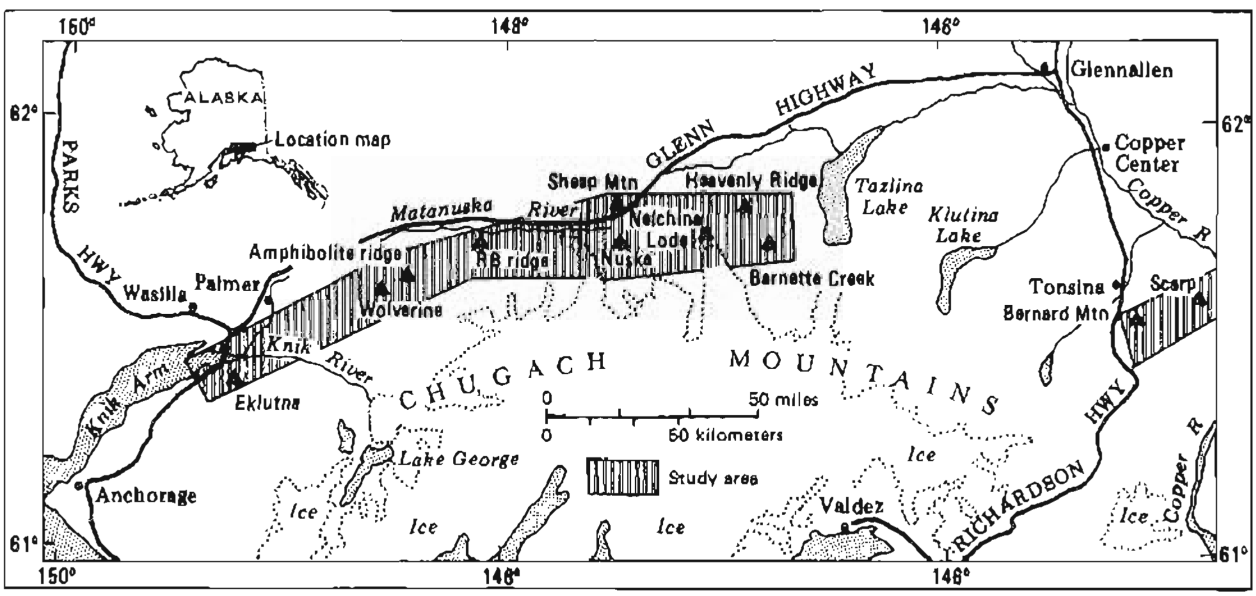

Figure 1. Map of study area showing location of major prospects examined.

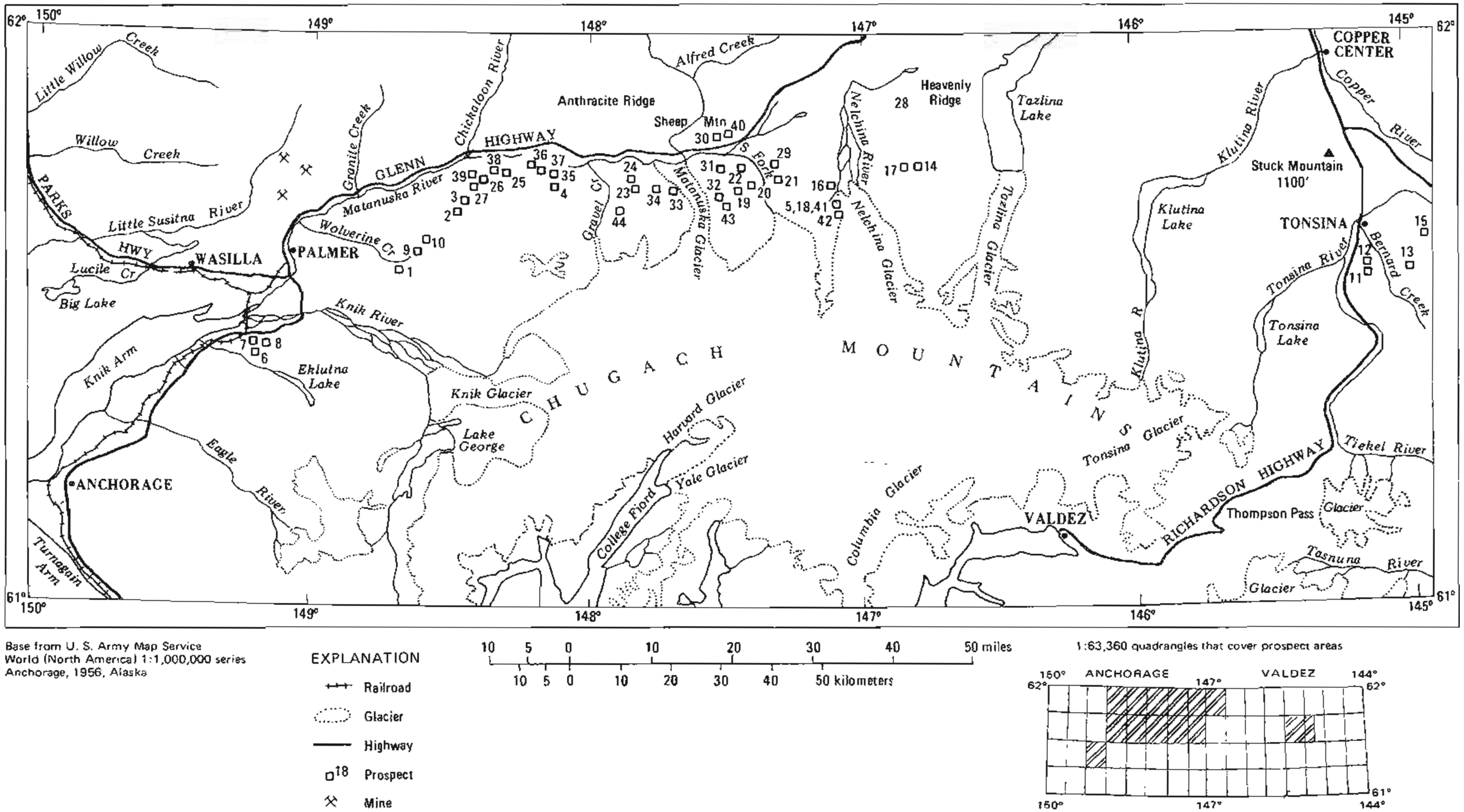

Figure 2. Map showing prospect locations in the study area. See tables 1 and 2 for assay results and prospect characteristics.

Burns (1983) interpreted the geology of the region as a Jurassic island-arc sequence in high-angle fault contact on the south with a Cretaceous subduction complex and accretionary wedge (McHugh Complex and Valdez Group). The Jurassic rocks and amphibolite-schist unit were tilted to the north, and all units, including the McHugh Complex and Valdez Group, were intruded by Tertiary mafic and felsic dikes.

The following descriptions of mineral prospects in the study area are grouped according to the major unit in which they occur. The locations of the prospects are shown on figures 1 and 2; assay results are given in table 1.

PROSPECTS IN AMPHIBOLITE-SCHIST UNIT

Hornblende amphibolite, biotite-garnet schist, and minor marble occur discontinuously along the southern border of the study area, commonly in fault contact with greenstone and schist of the McHugh Complex or Valdez Group to the south and with plutonic rocks to the north. The amphibolite-schist unit resembles the Strelna and Skolai Groups of upper Paleozoic age in the Valdez Quadrangle (Winkler and others, 1981), implying a possible correlation. Sulfide-bearing mafic sills (Herreid, 1970) in these Paleozoic units may be analogous to some metamorphic-hosted mineral occurrences in the Chugach Mountains.

Prospects in the amphibolite-schist unit (prospects 1 through 5, fig. 2; table 1) are of three varieties: 1) 'stratiform' disseminated sulfides; 2) 'strata-bound' veinlet-controlled sulfides; and 3) sulfide-bearing skarns. Evidence presented below suggests that the veinlet sulfide bodies are retrograded and altered stratiform bodies; whereas the sulfides that locally occur in skarns are largely due to intrusive-related alteration. Disseminated stratiform and veinlet strata-bound horizons are best exposed in the 'Amphibolite ridge' area of the western Anchorage C-4 Quadrangle (prospects 3 and 3A, fig. 2). Geologic mapping (fig. 3) indicates complexly folded amphibolite, gneiss, and schist with minor marble and calc-silicate lenses intruded by gabbro, diorite, quartz diorite, and diabase. Variable concentrations (2 to 10 percent) of foliated, deformed stratiform sulfides (chiefly pyrrhotite, lesser chalcopyrite, and minor supergene chalcocite) occur mainly in and adjacent to hornblende-epidote amphibolite. These foliated rocks contain medium-grained aggregates of hornblende, quartz, epidote, and plagioclase with minor amounts of secondary chlorite and white mica. Sulfide-bearing units cannot be traced along strike for distances greater than 100 ft, presumably because of the complex deformation and original lenticular stratigraphy. Veinlets of trondhjemite are common in the amphibolites and indicate some elemental mobilization during high-temperature metamorphism.

The 'Red reef' (prospect 3A, fig. 3) represents the strata-bound type of sulfide prospect in the amphibolite. This prospect covers a 0.02-mi^2 area that is characterized by pyritic veinlets and disseminations in quartz-chlorite-muscovite rock (altered amphibolite, as shown by pseudomorphic textures in thin section). Remnant pyrrhotite masses in porphyroblastic pyrite grains indicate retrograde alteration of pyrrhotite to pyrite that probably

Table 1. Assay results for mineral prospects located in the study area.

Prospect	Sample	Location	Rock type	Assay (ppm)						Others	Lat/long	Comments
				Cu	Pb	Zn	Au	Ag	Co			
1	82Ny217	Anchorage C-5 Quadrangle near Wolverine Cr.	Garnet-pyroxene skarn	156	15	6	0.1	0.3	- -	W (2 ppm)	61°35'27" N. 148°41'46" W.	Along contact between marble and schist
1	82Ny223	Anchorage C-5 Quadrangle near Wolverine Cr.	Trondhjemite dike	120	1	36	0.1	0.1	- -	- -	61°35'27" N. 148°41'46" W.	Near skarn
2	82Ny227	Far eastern Anchorage C-5 Quadrangle	Amphibolite	140	4	20	0.1	0.1	- -	- -	61°41'44" N. 148°29'25" W.	Pyrrhotite-rich zone, 5-ft-thick
2	82Ny231	Far eastern Anchorage C-5 Quadrangle	Garnet-epidote skarn	1	7	1	0.1	0.2	- -	W (2 ppm)	61°41'44" N. 148°29'25" W.	Adjacent to diorite contact
3	82Ny104A	'Amphibolite ridge,' W. Anchorage C-4 Quadrangle	hbl-gar-plag-qtz[a] amphibolite	171	1	60	0.1	0.1	13	- -	61°42'25" N. 148°28'07" W.	1-3% foliated pyrrhotite
3	82Ny104B	'Amphibolite ridge,' W. Anchorage C-4 Quadrangle	qtz-hbl-plag amphibolite	80	1	49	0.1	0.2	10	- -	61°42'25" N. 148°28'07" W.	Well foliated 2-5% pyrrhotite in 10-ft-wide zone
3	82Ny108A	'Amphibolite ridge,' W. Anchorage C-4 Quadrangle	gar-pyx-woll[b] skarn	429	45	45	0.1	0.2	10	- -	61°42'25" N. 148°28'07" W.	Pyritic zone with qtz diorite and diabase dikes
3	82Ny108B	'Amphibolite ridge,' W. Anchorage C-4 Quadrangle	Garnet skarn	8	<1	21	<0.1	<0.1	10	W (2 ppm)	61°42'25" N. 148°28'07" W.	Garnet skarn next to quartz diorite dike
3	82NY110	'Amphibolite ridge,' W. Anchorage C-4 Quadrangle	hbl-qtz-plag amphibolite	194	<1	66	<0.1	<0.1	40	- -	61°42'25" N. 148°28'07" W.	Fine grained with 2-5% pyrrhotite
3	82Ny111	'Amphibolite ridge,' W. Anchorage C-4 Quadrangle	hbl-qtz-plag amphibolite	95	<1	63	<0.1	0.1	20	- -	61°42'25" N. 148°28'07" W.	Fine grained with 2-5% pyrrhotite
3A	82Ny115B	'Red reef,' W. Anchorage C-4 Quadrangle	musc-qtz[c] hbl 'schist'	85	<1	92	<0.1	<0.1	- -	- -	61°42'20" N. 148°27'41" W.	3-8% disseminated and vein pyrite
4	82Ny269A	Ridge west of Monument Cr. W. Anchorage C-3 Quadrangle	Sheared gar-hbl-qtz amphibolite	65	4	18	<0.1	<0.1	- -	- -	61°43'33" N. 148°06'02" W.	2% pyrite as discontinuous veinlets
5	82Ny20	Nelchina Glacier	gar-epidote skarn	39	3	204	<0.1	<0.1	<10	Cr (85 ppm)	61°42'40" N. 147°5'22" W.	5-8% pyrite

Prospects 6-13 on table 2.

[a]hbl = hornblende; gar = garnet; plag = plagioclase; qtz = quartz
[b]pyx = pyroxene; woll = wollastonite
[c]musc = muscovite
- - Not found in sample.

Table 1 (con.)

Prospect	Sample	Location	Rock type	Assay (ppm) Cu	Pb	Zn	Au	Ag	Co	Others	Lat/long	Comments
7	82Ny17	Eklutna - Old Glenn Highway	Clino-pyroxenite	<1	8	17	<0.1	<0.1	56	Pt (<50 ppm) Pd (20 ppm) Ni (592 ppm)	61°28'46" W. 149°09'56" W.	1-3% interstitial pyrrhotite
14	82Ny148	Barnett Cr., W. Valdez Quadrangle	Gabbro-norite	2140	<0.1	13	<0.1	0.2	90	Pt (<50 ppm) Pd (20 ppm) Ni (237 ppm)	61°45'36" N. 146°47'8" W.	4-in.-thick band with 5% interstitial sulfide
15	82Ny312	'Scarp' Tonsina complex	Metagabbro-norite + clinopyroxenite	- -	- -	- -	- -	- -	- -	Pt (50 ppm) Pd (20 ppm)	61°38'20" N. 144°53'37" W.	2-6% sulfide
16	82Ny16a	Nelchina Glacier	Mafic gabbro-norite	86	<1	112	<0.1	<0.1	29	V (604 ppm)	61°43'59" N. 147°05'25" W.	Continuous chip sample, 15-ft interval
16	82Ny16b	Nelchina Glacier	Mafic gabbro-norite	188	7	131	<0.1	<0.1	51	V (599 ppm)	61°43'59" N. 147°05'25" W.	Continuous chip sample, 15-ft interval
16	82Ny16c	Nelchina Glacier	Mafic gabbro-norite	249	<1	117	<0.1	<0.1	34	V (777 ppm)	61°43'59" N. 147°05'25" W.	Continuous chip sample, 15-ft interval
16	82Ny16d	Nelchina Glacier	Mafic gabbro-norite	312	1	103	<0.1	<0.1	33	V (896 ppm)	61°43'59" N. 147°05'25" W.	Continuous chip sample, 15-ft interval
16	82Ny17a	Nelchina Glacier	Mafic gabbro-norite	169	<1	65	<0.1	<0.1	33	V (677 ppm)	61°43'59" N. 147°05'25" W.	Continuous chip sample, 16-ft interval
16	82Ny17b	Nelchina Glacier	Mafic gabbro-norite	154	<1	85	<0.1	<0.1	40	V (676 ppm)	61°43'59" N. 147°05'25" W.	Continuous chip sample, 16-ft interval
17	82Ny145	Barnett Cr. Valdez Quadrangle	Serpentinized gabbro	99	<1	33	<0.1	<0.1	134	Ni (834 ppm)	61°46'01" N. 146°49'56" W.	5-10% disseminated magnetite, minor pyrite
18	82Ny19	Nelchina Glacier	Chlorite-pyrite-rich gabbronorite	88	1	125	<0.1	<0.1	26	Cr (110 ppm)	61°42'51" N. 147°05'26" W.	
19	82Ny129	Anchorage C-2 Quadrangle, S. of Base Camp Cr.	Sheared micro-gabbro	249	<1	- -	<0.1	<0.1	18	Ni (16 ppm)	61°43'14" N. 147°27'02" W.	2-5% pyrite
19	82Ny131	Anchorage C-2 Quadrangle, S. of Base Camp Cr.	Sheared gabbro-norite and microgabbro	124	<1	62	<0.1	<0.1	12	- -	61°43'14" N. 147°27'02" W.	Chloritized, 5-10% pyrite
19	82Ny131A	Anchorage C-2 Quadrangle, S. of Base Camp Cr.	Sheared hornblende pegmatite	3	<1	26	<0.1	<0.1	24	- -	61°43'14" N. 147°27'02" W.	Pink, piedmontite-bearing?
19	82Ny132	Anchorage C-2 Quadrangle, S. of Base Camp Cr.	Sheared gabbro-norite	221	<1	26	<0.1	<0.1	- -	- -	61°43'14" N. 147°27'02" W.	Near trondhjemite dike
20	82Ny161	Anchorage C-2 Quadrangle, ridge W. of S. Fork River	Sheared gabbro-norite	- -	<1	<0.1	<0.1	- -	- -	- -	61°43'51" N. 147°24'16" W.	2-4% pyrite
21	82Ny236	Chug Ridge, W. Anchorage D-1 Quadrangle	Quartz diorite	- -	<1	- -	<0.1	<0.1	- -	- -	61°44'52" N. 147°18'02" W.	Pyritic shears near mafic dikes

Table 1 (con.)

Prospect	Sample	Location	Rock type	Assay (ppm) Cu	Pb	Zn	Au	Ag	Co	Others	Lat/long	Comments
21	82Ny237	Chug Ridge, W. Anchorage D-1 Quadrangle	Quartz diorite/ diorite	142	2	66	<0.1	<0.1	- -	- -	61°44'52" N. 147°18'02" W.	Adjacent to fault contact with basaltic andesite
22	82Ny50	Base Camp Cr., Anchorage D-2 Quadrangle	Sheared quartz diorite	5	3	23	<0.1	<0.1	<10	Cr (136 ppm)	61°45'45" N. 147°26'22" W.	Chloritized with 3-5% pyrite
23	82Ny64	Anchorage C-3 Quadrangle, W. of Glacier Cr.	Sheared quartz diorite	33	6	85	<0.1	<0.1	<10	- -	61°43'54" N. 147°50'03" W.	Chloritized, 1% pyrite
24	82Ny70	Anchorage C-3 Quadrangle W. of Glacier Cr.	Sheared quartz diorite	10	2	64	<0.1	<0.1	10	- -	61°44'09" N. 147°50'38" W.	At fault contact with andesite
25	82LE130	Anchorage D-4 Quadrangle near Riley Cr.	Sheared quartz diorite	7	- -	<0.1	<0.1	- -	- -	As (211 ppm)	61°45'25" N. 148°19'15" W.	
26	82Ny260	Ridge W. of Coal Cr., Anchorage C-4 Quadrangle	Sheared quartz diorite and diorite	5	5	90	<0.1	<0.1	- -	Sb (12 ppm) As (531 ppm)	61°44'46" N. 148°24'25" W.	
27	82Ny262	E-W-trending Creek W. of Coal Cr., Anchorage C-4 Quadrangle	Sheared quartz diorite and diorite	34	<1	43	<0.1	<0.1	<10	- -	61°44'08" N. 148°25'12" W.	Pyritic shears along mafic dikes
27	82Ny264	E-W-trending Creek W. of Coal Cr., Anchorage C-4 Quadrangle	Sheared quartz diorite and diorite	73	3	26	<0.1	<0.1	10	- -	61°44'08" N. 148°25'12" W.	Zone 30 ft wide, 1-5% pyrite near andesite dikes
28	82Ny101A	Heavenly Ridge, Valdez D-8 Quadrangle	Andesite tuff	38	10	32	<0.1	<0.1	- -	- -	61°52'44" N. 146°53'54" W.	
28	82Ny101B	Heavenly Ridge, Valdez D-8 Quadrangle	Silicified andesite	25	4	47	<0.1	0.1	- -	- -	61°52'44" N. 146°53'54" W.	5-15% disseminated pyrite
28	82Ny101C	Heavenly Ridge, Valdez D-8 Quadrangle	Silicified dacite tuff	59	9	37	<0.1	0.2	- -	- -	61°52'44" N. 146°53'54" W.	10-20% pyrite, disseminated + veinlets
28	82Ny101D	Heavenly Ridge, Valdez D-8 Quadrangle	Silicified dacite	77	5	76	<0.1	0.2	- -	As (43 ppm)	61°52'44" N. 146°53'54" W.	3-5% very fine grained pyrite
28	82Ny101E	Heavenly Ridge, Valdez D-8 Quadrangle	Silicified andesite	38	9	40	<0.1	0.2	- -	Ba (1,250 ppm)	61°52'44" N. 146°53'54" W.	5-10% disseminated pyrite, barite veinlets
28	82Ny101F	Heavenly Ridge, Valdez D-8 Quadrangle	Carbonate-altered andesite	26	2	137	<0.1	0.1	- -	- -	61°52'44" N. 146°53'54" W.	
29	82Ny121	W. Chug Ridge, Anchorage D-1 Quadrangle	Pyrite-veined andesite	31	2	50	<0.1	<0.1	10	- -	61°46'10" N. 147°19'38" W.	8-15% pyrite

Table 1 (con.)

Prospect	Sample	Location	Rock type	Assay (ppm)							Lat/long	Comments
				Cu	Pb	Zn	Au	Ag	Co	Others		
30	82Ny143	Sheep Mtn., Anchorage D-2 Quadrangle	Pyritic andesite	76	3	94	<0.1	<0.1	- -	- -	61°49'23" N. 147°31" W.	5% pyrite, some gypsum
30	82Mn43	Sheep Mtn., Anchorage D-2 Quadrangle	Pyritic dacite	50	<1	134	<0.1	0.1	14	As (<10 ppm) Sb (<1 ppm)	61°49'23" N. 147°31" W.	
30	82Mn152	Sheep Mtn., Anchorage D-2 Quadrangle	Pyritic andesite tuff	66	<1	68	<0.1	<0.1	- -	As (<10 ppm) Sb (<1 ppm)	61°49'23" W. 147°31" W.	Grab samples of pyritic volcanic rocks
30	82Mn123	Sheep Mtn., Anchorage D-2 Quadrangle	Pyritic silicified tuff	- -	357	- -	<0.1	0.2	- -	As (<10 ppm) Sb (<1 ppm)	61°49'23" W. 147°31" W.	
30	82Mn254	Sheep Mtn., Anchorage D-2 Quadrangle	Pyritic, sheared andesite(?)	- -	4	- -	0.1	0.9	- -	As (<10 ppm) Sb (<1 ppm)	61°49'20" N. 147°30'59" W.	
31	82Ny154B	Benchmark, Nuska ridge, Anchorage D-2 Quadrangle	Crystal-lithic andesite tuff	18	2	46	0.1	0.1	- -	- -	61°45'39" N. 147°30'55" W.	1-2% pyrite, largely in shears
31	82Ny157	Benchmark, 'Nuska' Anchorage D-2 Quadrangle	Silicified dacite	12	8	53	<0.1	0.4	- -	As (45 ppm)	61°45'39" N. 147°30'55" W.	Strongly brecciated, about 50% secondary quartz
31	82Ny158	Benchmark, 'Nuska' Anchorage D-2 Quadrangle	Silicified andesite tuff	12	3	45	0.1	1.1	- -	As (268 ppm)	61°45'39" W. 147°30'55" W.	Sheared, pyrite-veined, about 10% pyrite
31	82Ny159	Benchmark, 'Nuska' Anchorage D-2 Quadrangle	Brecciated andesite	12	3	51	<0.1	0.4	- -	As (38 ppm)	61°45'39" W. 147°30'55" W.	Pyrite-veined, 30-ft-wide shear zone
32	82Ny72	Spoon High Camp ridge, Anchorage C-2 Quadrangle	Silicified andesite	51	2	67	<0.1	<0.1	10	- -	61°42'38" N. 147°30'55" W.	30-ft chip sample across exposure
32	82Ny74	Spoon High Camp ridge, Anchorage C-2 Quadrangle	Dacitic crystal tuff	9	5	18	<0.1	<0.1	<10	- -	61°42'38" N. 147°30'55" W.	2-5% pyrite
32	82Ny77	Spoon High Camp ridge, Anchorage C-2 Quadrangle	Andesitic tuff	6	6	35	<0.1	<0.1	<10	As (<10 ppm) Sb (<1 ppm)	61°42'38" N. 147°30'55" W.	5-10% disseminated pyrite
32	82Ny81	Spoon High Camp ridge, Anchorage C-2 Quadrangle	Silicified andesite	32	2	33	<0.1	<0.1	<10	- -	61°42'38" N. 147°30'55" W.	2% pyrite
33	82Ny40	Mt. Wickersham, E. Anchorage C-2 Quadrangle	Silicified andesite tuff	31	73	168	<0.1	0.2	- -	As (<10 ppm) Sb (<1 ppm)	61°43'24" N. 147°40'59" W.	Abundant secondary quartz

Table 1 (con.)

Prospect	Sample	Location	Rock type	Cu	Pb	Zn	Assay (ppm) Au	Ag	Co	Others	Lat/long	Comments
34	82Ny94	Mt. Wickersham, W. Anchorage C-2 Quadrangle	Dacitic lithic tuff	56	3	76	<0.1	0.1	- -	As (<10 ppm)	61°42'10" N. 147°44'44" W.	Chip sample taken across 30-ft-wide pyritic bed
34	82Mn54	Mt. Wickersham, W. Anchorage C-2 Quadrangle	Pyritic rhyolite	- -	10	- -	<0.1	<0.1	- -	As (<10 ppm Sb (<1 ppm)	61°42'10" N. 147°44'44" W.	Chip sample taken 15-ft across unit
35	82Ny254	Lower Chickaloon ridge, NE. Anchorage Quadrangle	Silicified dacite and andesite	3	2	12	<0.1	0.1	- -	- -	61°45'04" N. 148°08'09" W.	2-5% pyrite grab sample from 400-ft² area
36	82Ny181	'RB Ridge,' E. of Ninemile Cr., Anchorage D-4 Quadrangle	Sheared rhyo-dacite tuff	36	2	93	<0.1	<0.1	11	- -	61°45'22" N. 148°10'15" W.	0.5-2% pyrite
36	82NY182A	'RB Ridge,' E. of Ninemile Cr., Anchorage D-4 Quadrangle	Pyritic dacite	61	<1	85	<0.1	<0.1	- -	- -	61°45'22" N. 148°10'15" W.	10% disseminated pyrite, 5-ft-thick bed, continuous chip sample
36	82Ny184	'RB Ridge,' E. of Ninemile Cr., Anchorage D-4 Quadrangle	Pyritic dacite	7	1	136	<0.1	0.1	- -	- -	61°45'22" N. 148°10'15" W.	
36	82Ny185	'RB Ridge,' E. of Ninemile Cr., Anchorage D-4 Quadrangle	Silicified andesite tuff	2	<1	27	0.1	0.1	- -	- -	61°45'22" N. 148°10'15" W.	Sheared, pyritic zone 30-ft wide
36	82Ny243	'RB Ridge,' E. of Ninemile Cr., Anchorage D-4 Quadrangle	Silicified pyritic dacite	30	4	90	<0.1	0.1	- -	- -	61°45'22" N. 148°10'15" W.	5-15% pyrite, chip sample over 100-ft interval
36	82Ny245	'RB ridge,' E. of Ninemile Cr., Anchorage D-4 Quadrangle	Sheared andesite	1	1	137	<0.1	<0.1	- -	- -	61°45'22" N. 148°10'15" W.	1-2% disseminated pyrite
36	82Ny247	'RB ridge,' E. of Ninemile Cr., Anchorage D-4 Quadrangle	Pyritic andesite and dacite	17	8	55	<0.1	<0.1	- -	- -	61°45'22" N. 148°10'15" W.	2-5% pyritic chip sample taken over 150-ft interval
37	82Ny248	Ridge W. of Ninemile Cr., Anchorage D-4 Quadrangle	Andesite tuff	7	3	90	<0.1	<0.1	- -	- -	61°46'09" N. 148°13'10" W.	1-2% pyrite grab sample
38	82Ny301	Ridge E. of Coal Cr., Anchorage D-4 Quadrangle	Andesite tuff	- -	4	- -	<0.1	<0.1	- -	As (15 ppm)	61°45'29" N. 148°21'23" W.	Chip sample taken over 20-ft interval
39	82Ny282	Ridge between Carbon and Coal Cr., Anchorage D-4 Quadrangle	Dacite	6	3	5	<0.1	<0.1	- -	- -	61°44'46" N. 148°25'47" W.	2-5% pyrite

Table 1 (con.)

Prospect	Sample	Location	Rock type	Assay (ppm) Cu	Pb	Zn	Au	Ag	Co	Others	Lat/long	Comments
39	82Ny284	Ridge between Carbon and Coal Cr., Anchorage D-4 Quadrangle	Andesite	20	5	23	<0.1	<0.1	10	- -	61°44'46" N. 148°25'47" W.	Pyritic, next to shear zone
40	82Mn	Sheep Mtn.	Quartz-epidote chalcocite vein	51,600	7	266	0.8	45.8	- -	As (<10 ppm) Sb (<1 ppm)	61°49'35" N. 147°29'27" W.	Short veinlets in tuff near basaltic tuff
41	82Ny21	Nelchina 1 lode, Nelchina Glacier	Felsic-dike breccia with sulfides	317	93,000	13,400	35.9	- -	- -	As (389 ppm) Sb (<1 ppm)	61°42'46" N. 147°5'22" W.	Continuous channel sample across breccia body, 4-ft-long
41	82Ny22	Nelchina 2 lode, Nelchina Glacier	Calcite-sulfide-cemented felsic breccia	69	200	6,500	0.2	0.8	- -	As (1,279 ppm)	61°42'46" N. 147°5'22" W.	Grab samples from 7- by 15-ft area
42	82Ny26C	S. end, Nelchina Glacier exposure	Bleached, silicified gabbronorite	5	5	90	<0.1	<0.1	57	Ni (806 ppm) Cr (832 ppm)	61°41'49" N. 147°5'3" W.	Next to 1-mi² felsic body
42	82Ny30	S. end, Nelchina Glacier exposure	Chloritized gabbronorite	225	1	115	<0.1	<0.1	30	Cr (85 ppm)	61°41'49" N. 147°5'3" W.	1% disseminated pyrite near felsic dike
43	82Ny78	Spoon High Camp ridge, Anchorage C-2 Quadrangle	Felsic-porphyry dike	2	1	12	<0.1	<0.1	<10	- -	61°42'15" N. 147°29'23" W.	Grab sample, minor pyrite present
43	82Ny84	Spoon High Camp, Anchorage C-2 Quadrangle	Felsic-breccia dike	209	1	103	<0.1	<0.1	21	- -	61°42'15" N. 147°29'23" W.	1-10% pyrite, 20-ft chip sample across dike
44	82Ny15	Central Anchorage C-3 Quadrangle, between Glacier and Gravel Cr.	Calcite-quartz-pyrite vein material	36	1	47	<0.1	<0.1	<10	- -	61°41'18" N. 147°53'08" W.	In schist (McHugh Complex) next to brecciated felsic dike
44	82Ny152	Central Anchorage C-3 Quadrangle, between Glacier and Gravel Cr.	Brecciated felsic dike	46	2	50	<0.1	<0.1	18	- -	61°41'18" N. 147°53'08" W.	10-ft chip sample across dike; no obvious pyrite
44	82Ny153	Central Anchorage C-3 Quadrangle between Glacier and Gravel Cr.	Sheared Tertiary conglomerate with siderite-qtz	39	2	59	<0.1	0.1	18	- -	61°41'18" N. 47°53'08" W.	Near contact with felsic dike

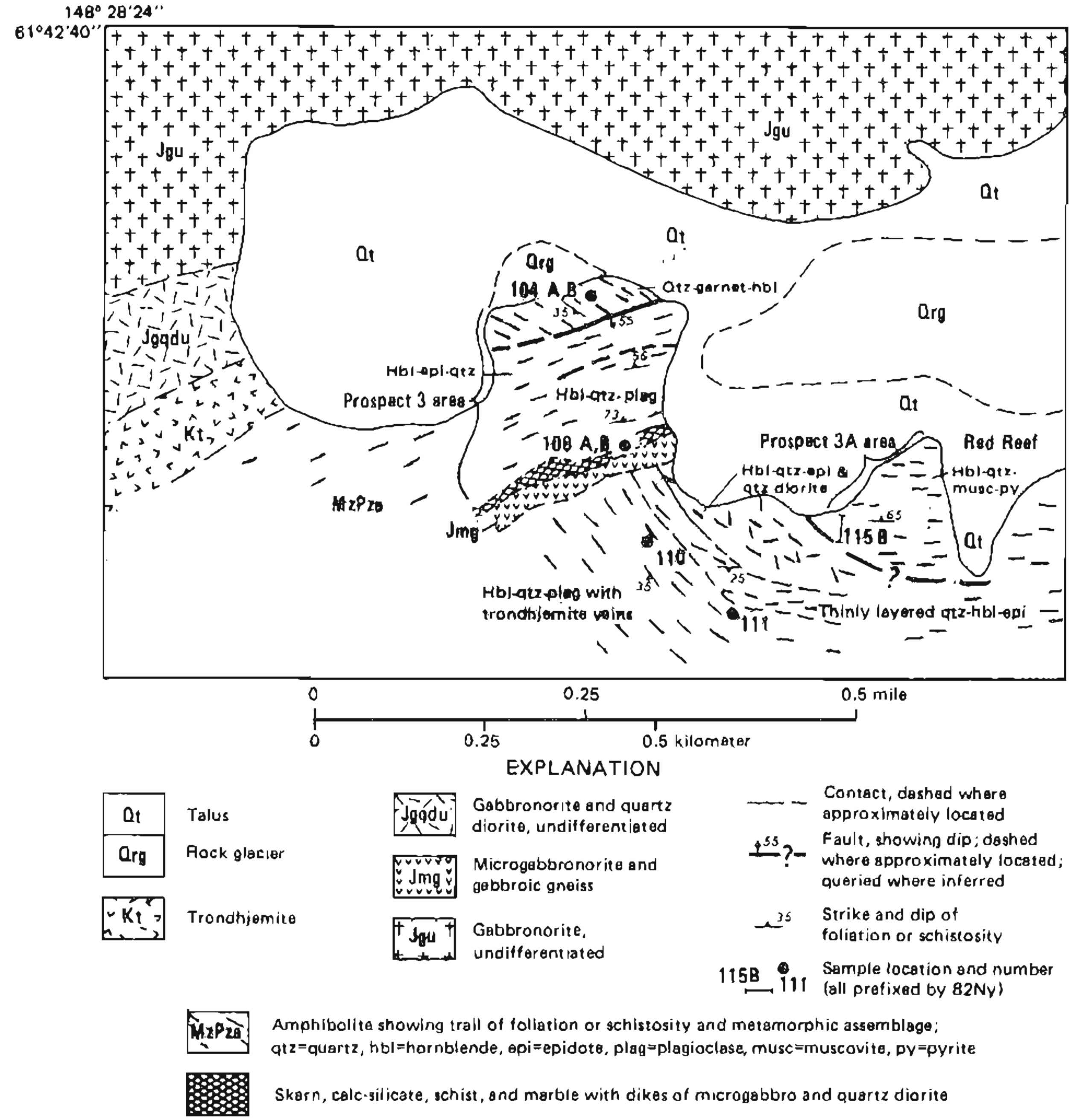

Figure 3. Geology of the 'Amphibolite ridge' area, western Anchorage C-3 Quadrangle. Geology by R.J. Newberry, L.E. Burns, and G.H. Pessel, July 1982.

accompanied retrograde alteration of amphibole, biotite, and plagioclase to chlorite and muscovite. Thus, the cross-cutting and pyritic nature of the body is presumably due to introduction of retrograde fluids along structural conduits rather than epigenetic, post-metamorphic introduction of exotic sulfides.

Assays of grab samples (table 1) from the 'Amphibolite ridge' area indicate slightly anomalous values for copper, silver, and cobalt. These values reflect the occasional grains of chalcopyrite and supergene covellite observed in polished sections from the prospect. Assays also indicate no significant differences in metal values between stratiform pyrrhotite- and veinlet-controlled pyrite-bearing samples, which suggests a common origin for the two types.

Sulfide-bearing amphibolite and schist similar to that in the 'Amphibolite ridge' area occur at prospects 2 and 4 (fig. 2, table 1). They have weakly anomalous metal values. Stratiform pyrrhotitic lenses and discordant pyritic veinlets occur at these prospects and indicate a premetamorphic age for some sulfides. However, only small amounts of sulfide are exposed at these prospects.

Because the presence of foliated pyrrhotite- and pyrite-rich sulfide lenses in these metamorphic rocks shows no consistent relationship to igneous bodies, a premetamorphic age for the original mineralization is indicated. The typical mode of sulfide occurrence as disseminations in amphibolite suggests that the deposits are metamorphosed sulfide-bearing mafic sills or flows in a sedimentary-volcanic sequence. The sparse distribution, low metal grades, and complex deformational histories, however, indicate that these sulfide-bearing rocks have little economic potential in the northern Chugach area. Similar rocks in areas of less complex deformation and lower grade metamorphism may contain ore.

Calc-silicate bodies (skarns) that are 1 to 6 in. thick occur in marble in the amphibolite-schist unit at prospects 1, 2, 3, and 5 (figs. 2, 3, and 4). These skarns are near diorite at prospect 2, near gabbronorite at prospects 3 and 5, and near trondhjemite at prospect 1. X-ray diffraction studies of garnet indicate iron-rich and iron-poor compositions that in turn indicate a metamorphic and a metasomatic origin, respectively, for the calc-silicates (Einaudi and others, 1981). Sparse pyrite that occurs in some of these calc-silicate skarns is mostly associated with epidote-actinolite-calcite-quartz retrograde alteration of garnet and pyroxene. Assays of grab samples from the skarns have slightly anomalous values of copper, silver, cobalt, but no detectable tungsten. These characteristics are similar to associated mafic-pluton skarns seen elsewhere in Alaska (Newberry, 1984). The absence of thick skarn zones in marble adjacent or subjacent to various plutonic rocks (gabbronorite, diorite, quartz diorite, or trondhjemite) and the absence of significant albitic alteration in the intrusions indicate that these intrusions were not major sources of hydrothermal metasomatism (Newberry, 1984). These characteristics, along with the low metal grades in the skarns and the general scarcity of marble in the amphibolite-schist unit, indicate that skarns in this region are probably not of economic interest.

PROSPECTS IN PLUTONIC ROCKS

The plutonic rocks of the northern Chugach Mountains crop out in broad east-west-trending belts, with ultramafic rocks to the south and gabbroic and intermediate-composition plutonic rocks to the north. Most contacts are faulted, but field relations show some gradational intrusive relations among the three belts (Burns and others, 1983; Little and others, 1986). These

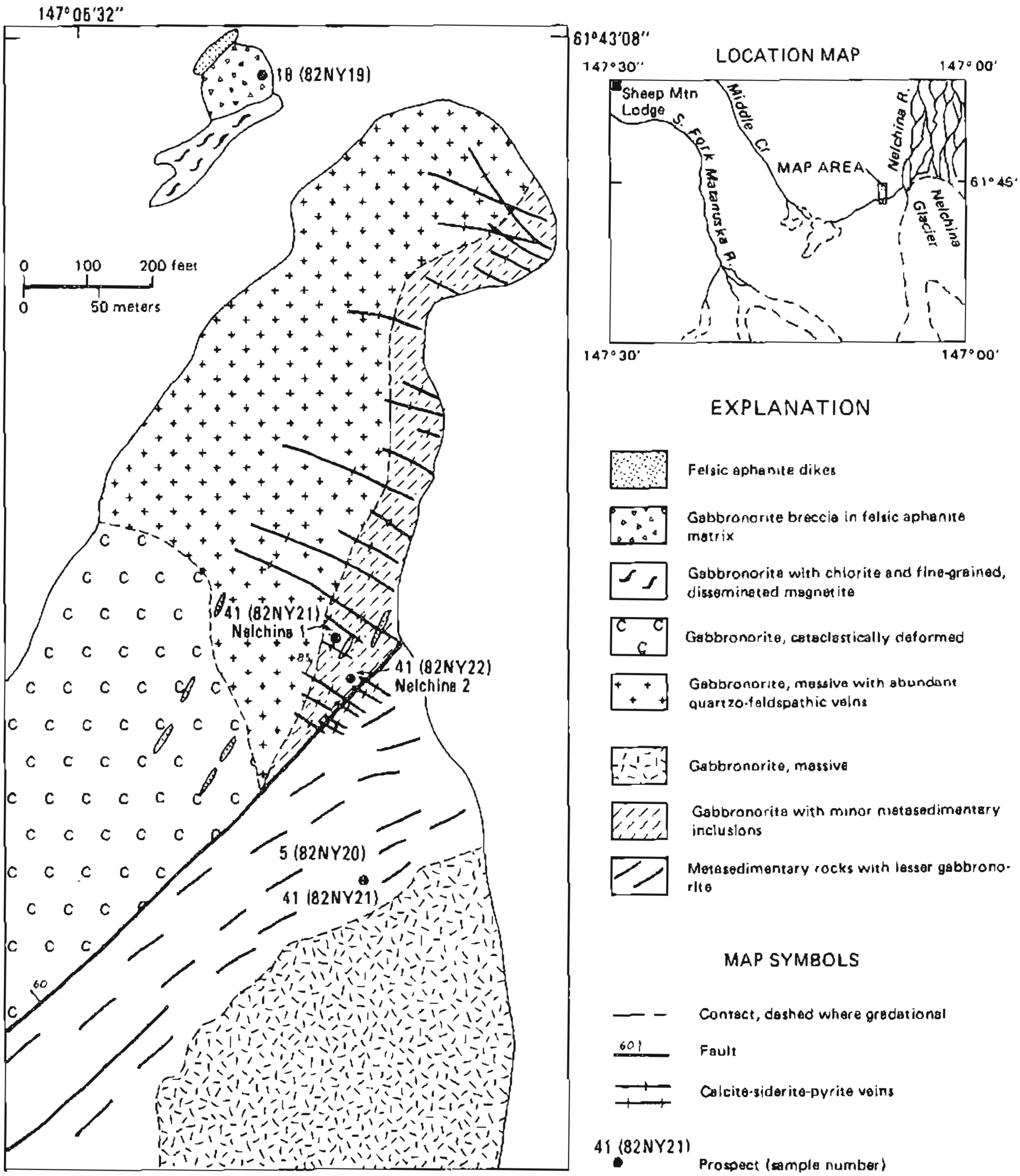

Figure 4. Generalized geologic map of the Nelchina lode area. Geology modified from Burns (1983).

discontinuous plutonic belts are mineralized in contrasting patterns. Generally, the ultramafic rocks host chromite prospects, the gabbroic rocks contain magmatic copper-sulfides and pyritic shear zones, and the intermediate-composition plutonic rocks have pyritic shear zones.

Ultramafic-hosted Prospects

Significant masses of ultramafic rocks that contain minor chromite accumulations occur in the Eklutna, Wolverine Creek (Anchorage Quadrangle), and Tonsina (Valdez Quadrangle) areas (prospects 6 through 13, fig. 2). Similarities in mode of occurrence, mineral composition, mineralogy, and petrology among these prospects indicate that they possess a common origin, despite their geographic separation (Newberry and Burns, 1984; Burns, 1985). Other very small (100 to 1,000 ft^2), fault-bounded, thoroughly serpentinized, low-chromite ultramafic bodies occur adjacent to major faults in the southern portion of the study area and are of no economic interest. The major chromite prospects are described individually below. Because they are similar in morphology and grade, their economic potential is considered for the entire belt. Data of economic importance, including chromite compositions, likely tonnages, and grades, are listed in table 2.

Eklutna complex

The Eklutna ultramafic body (previously studied by Rose, 1966) consists of dunite, wehrlite, clinopyroxenite, and gabbronorite (fig. 5). The 1- to 2 mi-wide body is in fault contact with rocks of the McHugh Complex to the southeast and with intrusive, volcanic, and sedimentary rocks to the northwest. Outcrops are generally poor and occur along the few road and stream cuts and on some ridges. The body is generally characterized by an igneous stratigraphy that consists (from southeast to northwest) of cumulate dunite and chromitite that grade up to wehrlite, clinopyroxenite, and gabbronorite (fig. 5). Chromitite layers (Rose, 1966) are limited to cumulate dunite host rock. Irregular changes in the strike and dip of igneous laminations and abundant shearing indicate some postcrystallization internal faulting. The dominantly east- to southeast-dipping layers indicate overturning from tectonic deformation or original nonhorizontal layering in a complexly shaped magma chamber. Several chromite-bearing areas were studied in the Eklutna Complex, including the largest on 'Twin Peaks Ridge' (a ridge 2 mi west of Twin Peaks) and several small prospects.

The 'Twin Peaks Ridge' prospect (prospect 6, figs. 2, 6, and 7; table 2) is a 200-ft-long by 200-ft-wide chromite-bearing zone exposed along the southwest side of Twin Peaks, approximately 1,000 ft northwest of the fault contact with greenstone of the McHugh Complex. Southeast of the prospect, the ultramafic rocks are poorly exposed and appear to consist largely of cumulate dunite and lesser wehrlite. Alternating 10- to 100-ft-thick layers of dunite with minor clinopyroxenite and wehrlite and very minor chromite occur northwest of the prospect.

Detailed mapping of the prospect 6 area (fig. 6) indicates two discontinuous zones of chromitite (an ultramafic rock that contains more than 20 percent chromite) outcrop (an east zone and a west zone) and a small zone

Table 2. Characteristics of chromite prospects, northcentral Chugach Mountains.

Prospect	Lat/long	Area of chromitite outcrop	Chromitite descriptions	Average chromite composition and range[a]	Estimated chromite tonnage/grade	Cr:Fe	Other metals
Eklutna-- Twin Peaks ridge (6)	61°26'43" N. 149°12"03" W.	5,000 ft^2	Two major zones, 20-50 ft wide; highly discontinuous 1- to 4-ft-wide chromitite bands that average 15-20% chromite	Cr_2O_3 = 51%; 40-57% FeO $\cong$ 24%; 27-21% Al_2O_3 = 14%; 8-20%	50,000 to 100,000 tons/8% Cr_2O_3	2.1	- -
Eklutna-- Highway (7)	61°28'46" N. 149°09'56" W.	500 ft^2	Minor disseminated chromite	Not analyzed		- -	Ni (600 ppm) in pyrrhotite-rich pyroxenite
Eklutna-- Pioneer Creek (8)	61°28'8" N. 149°07'40" W.	400 ft^2	Minor disseminated chromite in creek bed; minor concentrations reported by Rose (1966)	Not analyzed	None	- -	
Wolverine west (9)	61°37'31" N. 148°37'06" W.	0.03 mi^2	One 1- to 20-ft-wide zone, discontinuously traceable for more than 1/2 mi; averages 10-20% chromite	Cr_2O_3 = 46%; 42-50% FeO $\cong$ 26.5%; 23-30% Al_2O_3 = 14%; 12-16%	100,000 to 300,000 tons/8% Cr_2O_3	1.7	- -
Wolverine east (10)	61°37'52" N. 148°36'44" W.	0.01 mi^2	Several discontinuous, partly fault-bound, sheared 1- to 5-ft-wide zones of deformed nodular and lesser layered chromitite	Cr_2O_3 = 57%; 56-60% FeO $\cong$ 26%; 24-30% Al_2O_3 = 7%; 6-8%	20,000 to 40,000 tons/10% Cr_2O_3	2.2	- -
Tonsina-- Bernard Mtn. Harzburgite (11)	61°34'53" N. 195°07'21" W.	0.08 mi^2	Small, highly irregular pods of high-grade chromitite in large dunite masses surrounded by harzburgite	Cr_2O_3 $\approx$ 53%; 48-60% FeO $\cong$ 21%; 16-25% Al_2O_3 = 11%; 16-15.5%	5,000 to 15,000 tons/5% Cr_2O_3	2.5	- -
Tonsina-- Bernard Mtn. Cumulate (12)	61°35'08" N. 145°08'14" W.	0.02 mi^2	Eight irregular 1- to 5-ft-thick chromitite bands that average 20% chromite; each band separated by 20-250 ft of dunite and wehrlite	Cr_2O_3 = 56%; 54-59% FeO $\cong$ 19%; 16-23% Al_2O_3 = 10%; 9-12%	100,000 to 200,000 tons/11% Cr_2O_3	3.0	- -
Tonsina-- Dust Mtn. (13)	61°34'55" N. 144°59'30" W.	0.01 mi^2	Two irregular zones in cumulate peridotite that average 15-20% chromite; approximately 1/2 mi apart	Cr_2O_3 = 40%; 15-45% FeO $\cong$ 34%; 27-37% Al_2O_3 = 11%; 8.5-38%	3,000 to 10,000 tons/7% Cr_2O_3	1.2	- -

[a]Electron-microprobe analyses of 3 to 8 spots on each of 4 to 15 grains per prospect; analyses performed at University of California, Berkeley, using an 8-channel wavelength-dispersive Applied Research Laboratories microprobe and a well-characterized Stillwater chromite standard.

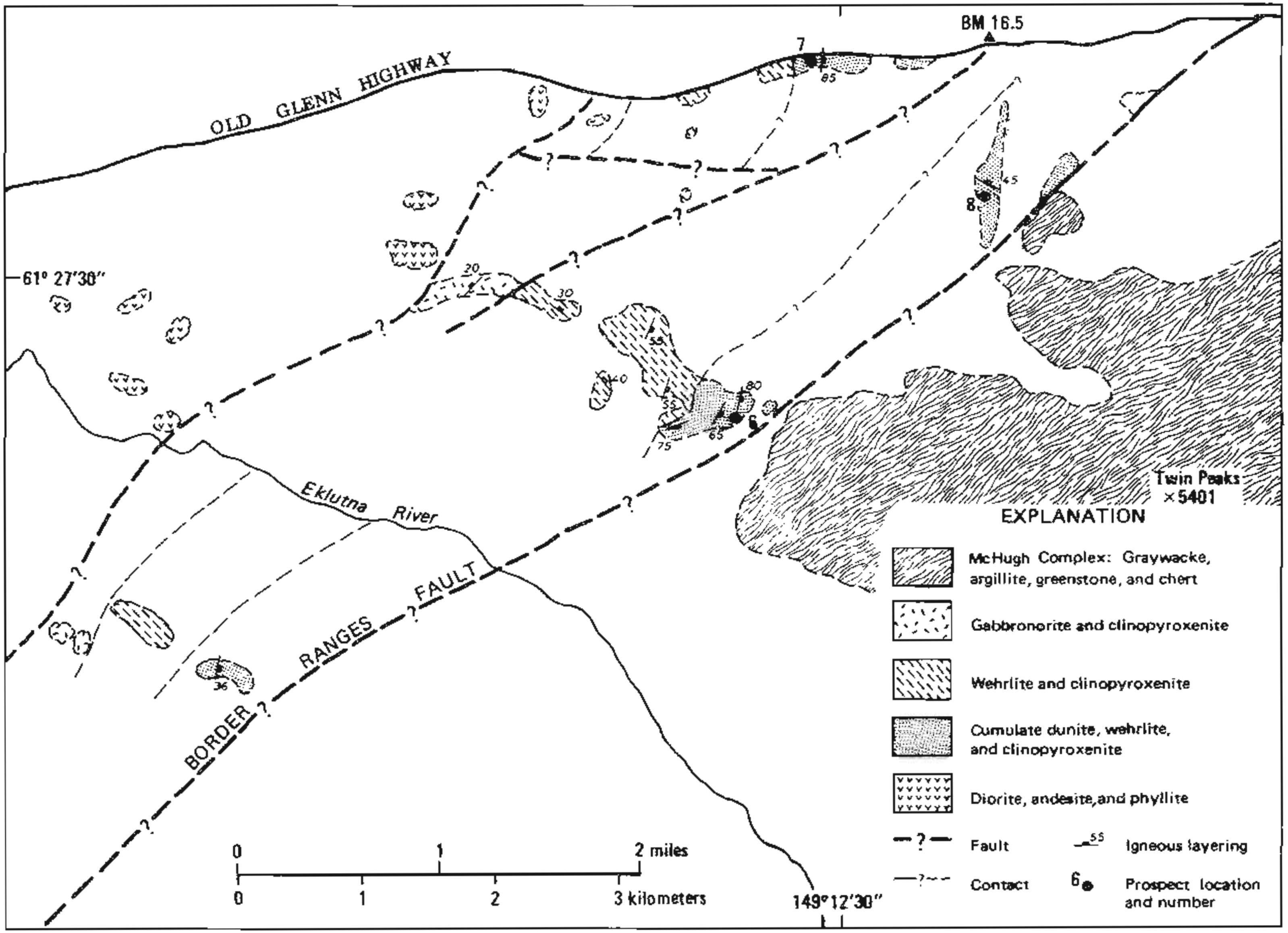

Figure 5. Bedrock geology of the Eklutna ultramafic/mafic complex, Anchorage B-6 Quadrangle. Geology modified from Rose (1966) by Burns and Newberry.

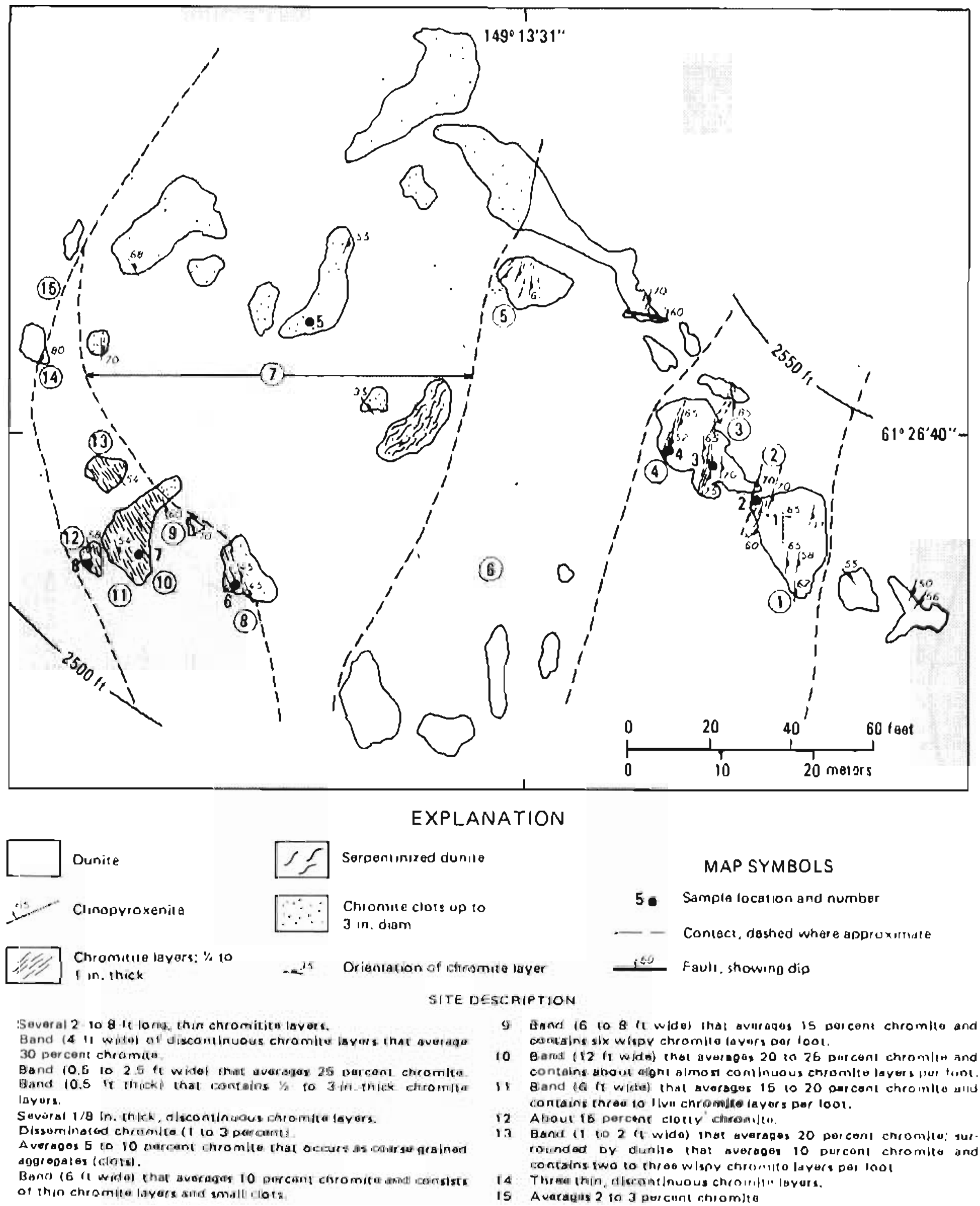

Figure 6. Outcrop map of the 'Twin Peaks Ridge' chromite prospect (prospect 6, fig. 2), Anchorage B-6 Quadrangle, based on compass and tape survey by Burns and Newberry, June 30, 1982.

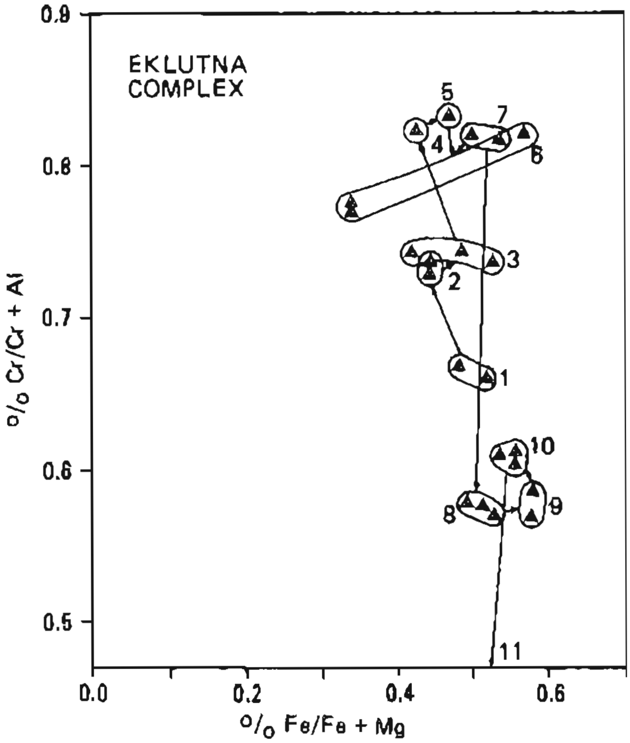

Figure 7. Compositional trends for chromite from the Eklutna complex. Analytical data from microprobe analyses (table 2) on samples shown on figure 6. Arrows show changes in samples located progressively up section.

of massive chromitite subcrop (the north zone). The east zone contains five 0.5- to 4-ft-wide lenticular bands of high-chromite rocks that average 20 to 40 percent chromite separated by barren dunite that is 5 to 20 ft thick. Each band is composed of two to 30 highly anastomosing, ¼- to 1 ¼-in.-thick massive chromite layers intercalated with 1 to 6 in. of barren dunite. The zone averages about 7 percent chromite. Individual chromite layers are continuous for less than 2 ft; the bands (groups of layers) visibly pinch and swell over a 30-ft strike length. The thickest band observed varied from 1 to 4 ft thick along a 20-ft strike length; 0.5- to 1-ft-thick bands visibly terminate in the outcrop.

The western chromitite zone is separated from the eastern zone by 50 to 150 ft of low-chromite dunite, in which 3 to 5 percent of the chromite occurs as medium- to coarse-grained 'clots' and occasional wispy layers less than 1 ft long. The western zone is a maximum of 40 ft wide and 100 ft long. At its maximum width, the western zone consists of irregular chromite-bearing bands that are 2 to 12 ft thick. Each band is composed of many discontinuous, anastomosing chromite layers that are ¼ to 1 ½ in. thick and 2 to 5 ft long. Individual chromite-rich layers that are highly irregular in form and continuity are separated by 1 to 6 in. of dunite; bands (groups of layers) are separated by 1 to 8 ft of barren dunite. Generally, three to eight chromitite layers occur per foot with an average chromite concentration for the zone of about 15 percent.

The irregularities in size and grade of the chromitites indicate that although the zones as a whole may have some strike and dip continuity, individual chromitite horizons lack such continuity. The lack of deformation textures (for example, chromite 'pull-aparts' and kink banding in olivine and clinopyroxene) suggests that the distribution of the bands and layers is controlled by magmatic or late-magmatic processes, not by subsequent deformation. On the basis of these features, extrapolation of chromitite bands for more than 100 ft in depth or strike seems unwarranted.

The subcrop of massive chromitite (the north zone; fig. 6) is projected approximately 300 ft north of the main prospect area, roughly halfway between projections of the eastern and western chromite zones. The outcrop pattern suggests a fold in a single chromite horizon with subsequent concentration of chromite in the nose of the fold. If this is the case, chromite compositional patterns of the west zone should mirror those of the east zone. To test this hypothesis and to accurately assess chromite compositional variations, chromite samples from the prospect and surrounding area were analyzed by electron-microprobe techniques. Analyses indicate (table 2) high chromium and relatively low iron and aluminum contents, with an average chromium to iron ratio of 2.1. On a Cr/(Cr + Al) vs. Fe/(Fe + Mg) diagram (fig. 7) analyses plotted with sample numbers (indicative of stratigraphic heights) show that the west zone does not mirror the east zone; rather the bulk of chromite from the west zone is significantly more chromium-rich than the chromite from the east zone. Most of the west-zone chromite contrasts significantly with the east- and north-zone chromite. The three zones are, in fact, different. Further, the sharp decline in chromium content of chromite northwest of prospect 6 indicates that the quality and quantity of chromite is unsatisfactory to the northwest; thus, the area of abundant high-chromium chromitite is quite limited.

Previous workers (Rose, 1966; Bjerklund and Wright, 1948) noted two other chromite-bearing zones in the Eklutna ultramafic body: along the Old Glenn Highway (prospect 7, fig. 5) and Pioneer Creek (prospect 8, fig. 5). Only traces of chromite were found in these areas during this investigation. Clinopyroxenite from prospect 7, however, contained locally significant amounts of disseminated sulfide. Examination of a polished section showed pyrrhotite with minor pentlandite interstitial to clinopyroxene. Significant amounts of alteration or veining were not observed, which indicates that the sulfides are of magmatic origin. Assay of this material (prospect 7, table 1) indicates high nickel values and low platinum and palladium values. The highly discontinuous nature of this sulfide and the low content of platinum-group elements (PGE) indicate poor economic potential for this zone.

Wolverine Complex

The Wolverine Complex (prospects 9 and 10, figs. 1 and 7) is located 25 mi northeast of the Eklutna complex and occurs in a similar structural setting. Previous work (Clark, 1972) indicates the presence of ultramafic and gabbroic rocks, faulted contacts, and local chromite concentrations over a 10-mi^2 area. Mapping (fig. 8) indicates that the Wolverine Complex is highly deformed and consists of northeast-southwest-trending, fault-bounded blocks (200 to 2,000 ft wide) that are composed of dunite-werhlite-harzburgite, gabbro-clinopyroxenite, and amphibolite-metachert. Ultramafic rocks are generally more abundant to the southeast and gabbroic rocks to the northwest. Layering in these rocks commonly dips to the southeast, but is disrupted by faulting. Chromite layers are particularly disrupted by shearing into

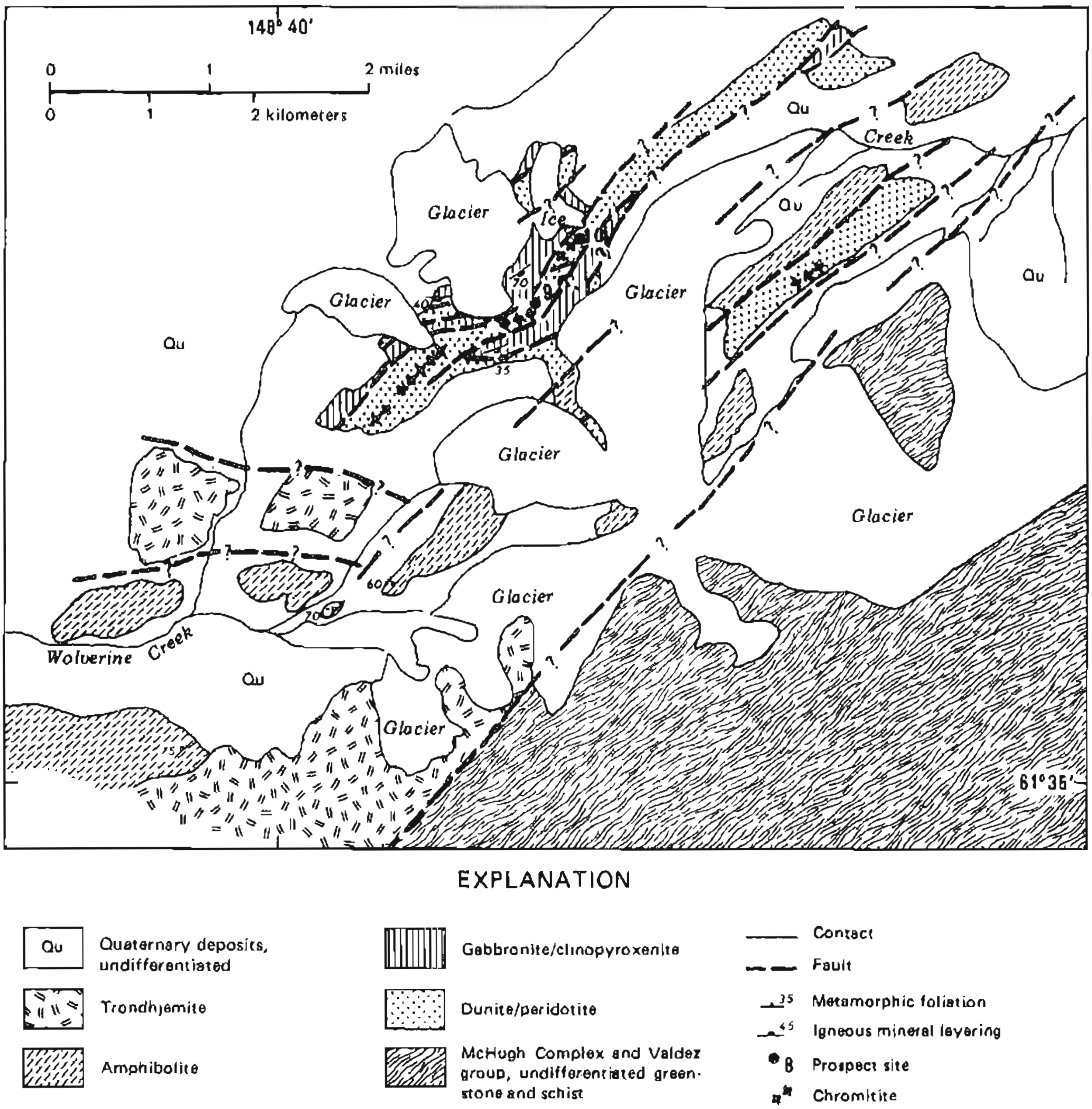

Figure 8. General geology of the Wolverine area, Anchorage C-5 Quadrangle.

elongate bodies near faults. Mapping (fig. 8) shows two major chromite zones, the west and east prospects (table 2), associated with cumulate dunite and with sheared dunite and harzburgite, respectively.

The Wolverine west prospect (prospect 9, fig. 8) consists of a main zone continuous for approximately 500 ft along strike and several discontinuous strike extensions. The main west zone is 5 to 30 ft wide and contains individual ¼- to 3 in.-wide massive chromitite layers separated by ½ to 2 in. of dunite and minor wehrlite. Although individual chromitite layers are only continuous up to 8 to 10 ft along strike, the zone has a roughly constant grade of 10 to 20 percent chromite. The zone gradually pinches out to the west and is cut off to the east by a faulted contact with gabbronorite.

Chromite bands are isoclinally folded in part, with thickening in noses of folds and thinning along limbs (fig. 9). Lack of deformation textures in olivine (as observed in thin section) suggests that this deformation occurred at relatively high temperatures (late- to post-magmatic) and not during Tertiary faulting.

A subsidiary chromite-bearing zone that is located approximately 200 ft along strike west of the west end of the main zone possibly represents a continuation of the main horizon. This zone is discontinuously traceable in subcrop for approximately 500 ft, varies from 1 to 5 ft wide, and averages about 7 percent chromite. The zone is composed of discontinuous layers similar to the main west zone, but the layers are thinner and less abundant. Discontinuous exposures in subcrop beyond this second zone show that bedrock may contain minor amounts of chromite for another 2,000 to 5,000 ft. However, a major thickness and high chromite content are not likely.

The Wolverine east zone is a series of chromitite lenses and deformed nodules interlayered with harzburgite and dunite, approximately 500 ft northeast of the west zone (prospect 9, fig. 8). Layering trends approximately east-west and generally dips to the south in this area. Cumulate dunite-clinopyroxenite and rare harzburgite bands occur above and below the chromite-rich zone. These mineral layers are discontinuously traceable for approximately 800 ft along strike and are terminated at either end by intrusive contacts with gabbronorite. Mapping of subcrop exposures reveals a chromitite zone about 20 to 30 ft wide that contains discontinuous, folded chromite bands ¼ to 2 in. thick and deformed (stretched) 1- to 3-in. chromitite nodules in less deformed cumulate dunite. This zone has an average

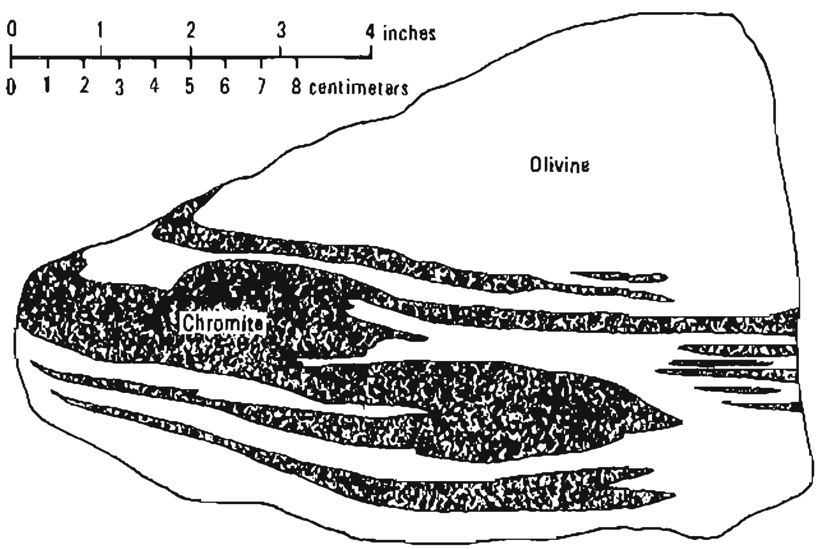

Figure 9. Sketch of a hand specimen (drawn from a photograph) illustrating isoclinal folding of chromite layers. Lack of deformation features in olivine and chromite grains suggest that this represents late-magmatic or early post-magnetic deformation. The specimen is from the Wolverine complex, western prospect.

chromite abundance of 10 to 15 percent and, based on other exposures in the area, is probably a series of chromitite lenses rather than a single continuous band.

Chromite compositions (fig. 10 and table 2) vary systematically between the Wolverine east and west prospects. Chromite from the west prospect area has lower chromium and higher aluminum contents, similar to those from the Eklutna area northwest of prospect 6; chromite from the Wolverine east prospect has higher chrome and lower aluminum contents, similar to that from prospect 6. The west Wolverine prospect, although larger, contains less chromite and less desirable chromite compositions. Furthermore, the considerable variations in chromite composition at the west prospect imply multiple chromitite lenses rather than a continuous chromitite band. If the chrome content of chromite generally decreases upward in the section, as suggested by this and other Eklutna data (L.E. Burns, written commun., 1985) and by Leblanc and Violette (1983), the east prospect is stratigraphically below the west prospect. The presence of harzburgite at the east prospect may also indicate a lower stratigraphic position than the west prospect (Malpas and Strong, 1975). This stratigraphy is contrary to the general south-to-north transition from dunite to gabbronorite observed at Wolverine and may reflect considerable structural or intrusive complexity. Individual fault bounded slivers were apparently rotated and possibly overturned, which makes lithologic continuity unlikely. Effective chromite exploration in an area of such structural complexity would be difficult.

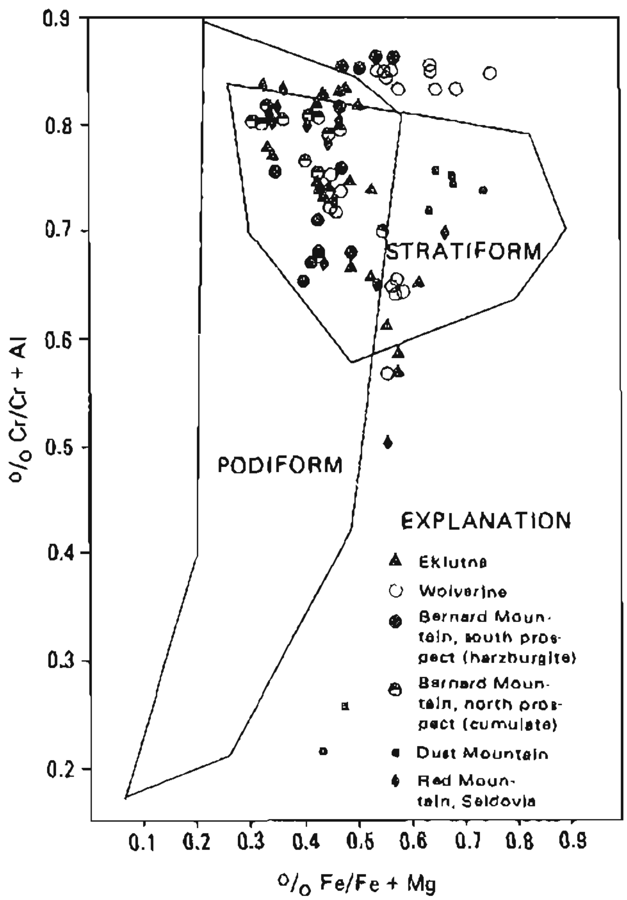

Figure 10. Compositional data for Chugach Mountains chromite prospects. Analyses show a distinctive compositional signature for the group. Analyses from Red Mountain (Seldovia) are shown for contrast. Note the relatively high chromium and iron contents.

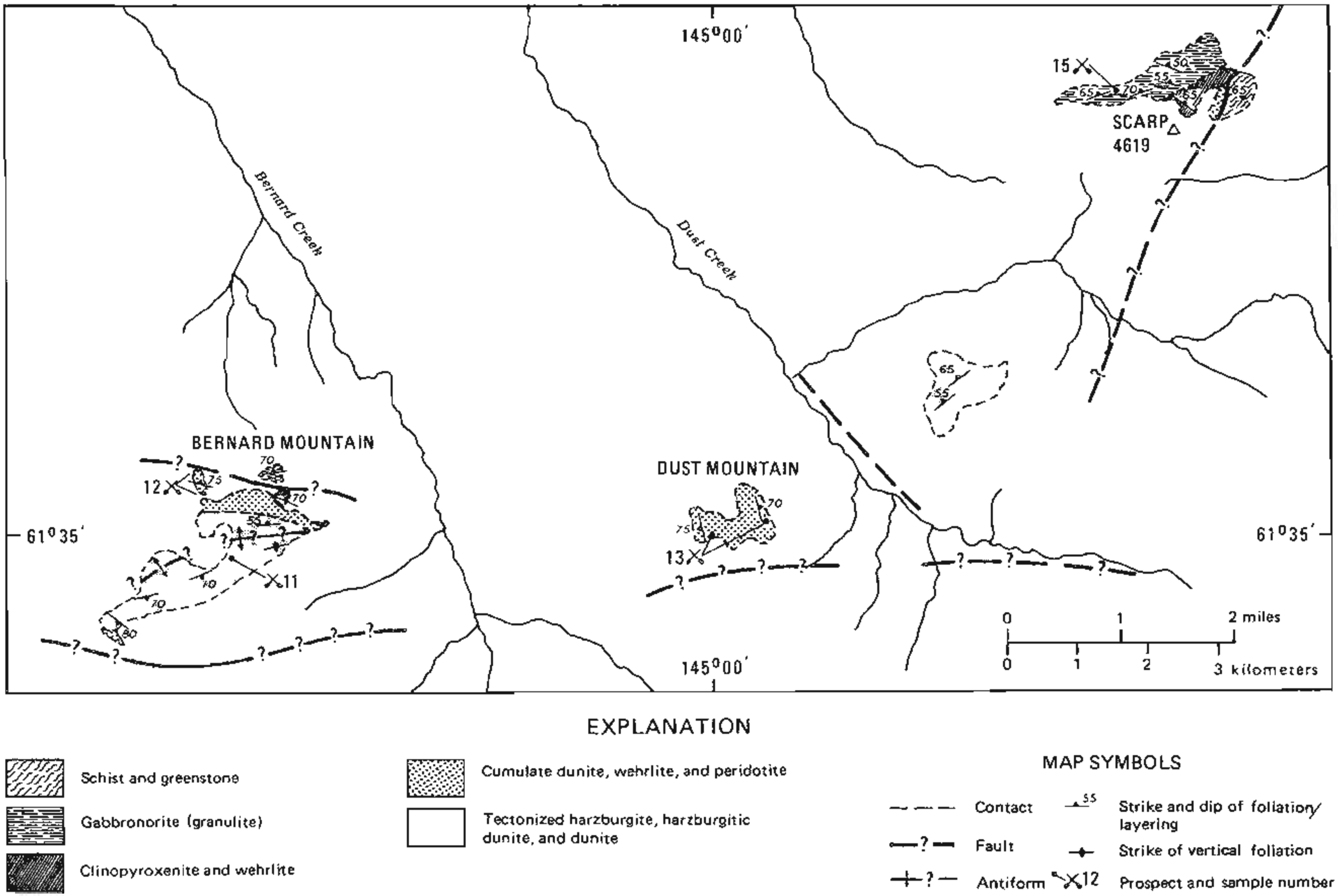

Figure 11. Bedrock geology of the Tonsina ultramafic/mafic complex, Valdez C-3 and C-4 Quadrangles. Geology by R.J. Newberry, L.E. Burns, G.H. Pessel and T.A. Little.

Tonsina complex

The Tonsina ultramafic complex (prospects 11 through 13, figs. 1, 2, and 11) is approximately 120 mi east of the Wolverine Complex, but displays many similarities in structural and lithologic setting to the Wolverine and Eklutna complexes. Aeromagnetic data (Case and others, 1985) and mapping (fig. 11) show a 60-mi^2 area of ultramafic and mafic plutonic rocks, but exposures are limited to isolated topographic highs. Complex foliation patterns, abundant shear zones, and inconsistent igneous stratigraphy (for example, tectonized harzburgite located between gabbronorite and cumulate peridotite) indicate that the area is highly deformed. The Tonsina complex is in fault contact with schists and metavolcanic rocks of the Strelna(?) Formation to the east and south and is covered by thick alluvium and glacial sediments to the north (Hoffman, 1974). A general south-to-north variation in magmatic stratigraphy is indicated by the presence of harzburgite and dunite to the south and clinopyroxenite and metagabbronorite to the north. Chromite prospects are limited to harzburgite and dunite hosts at Bernard Mountain and Dust Mountain.

Bernard Mountain (fig. 12) is composed of tectonized and cumulate ultramafic rock and minor metagabbronorite. Two different types of chromite prospects are present: 1) pods of dunite with chromitite in tectonized harzburgite (central area); and 2) cumulate chromitite with cumulate dunite and clinopyroxenite (north area). These prospects differ in size, localization, structural continuity, and chromite grade.

The central Bernard Mountain area (prospect 11) consists of tectonized harzburgite with pods and masses of chromite-bearing dunite. S_1 foliation in the harzburgite is defined by elongated, stretched (3:1 to 5:1) orthopyroxene and chromite crystals in a matrix of strained, kink-banded olivine. In many cases, S_1 foliation is apparently nearly parallel to S_o igneous lamination, but foliation of thin, discontinuous chromitite layers is occasionally at a substantial angle to the igneous lamination. Sparse outcrops limit the obtainable structural data, but there is a suggestion of a large antiformal structure (fig. 12) in the tectonized harzburgite. The metamorphic fabric, which is indicative of high-temperature deformation, and the highly forsteritic olivine compositions (Hoffman, 1974) suggest that the harzburgites are of mantle derivation (Coleman, 1977).

Significant chromite in the central prospect area is largely restricted to orthopyroxene-poor dunite masses that exhibit deformed textures and are generally elongated in the direction of foliation of the enclosing harzburgite. These masses may, in part, represent intrusions into the harzburgite, as noted in other dunitic harzburgite terranes (for example, New Caledonia; Cassard and others, 1981). Chromitite occurs in the dunite as sporadic, ½- to 6-in.-thick, 6- to 30-in.-long, discontinuous lenses and contorted masses. Within a typical dunite body of the Tonsina complex, concentrations of chromite masses are occasionally large enough to reach average chromite concentrations of 5 to 10 percent over a 200- by 30-ft area. Two main areas of chromite concentration were observed in the central Bernard Mountain area; neither possesses significant length or, presumably, depth.

The second type of chromite prospect on Bernard Mountain occurs in cumulate dunite and clinopyroxenite that crop out on its north side (fig. 12). The contact between tectonized harzburgite and largely undeformed cumulate dunite and clinopyroxenite is characterized by a poorly exposed 800-ft-wide zone of pyroxene-free dunite that may represent the base of the cumulate section. The northern chromite-prospect area (prospect 12, table 2) is located approximately 1,200 ft north of the northern contact of harzburgite (fig. 12).

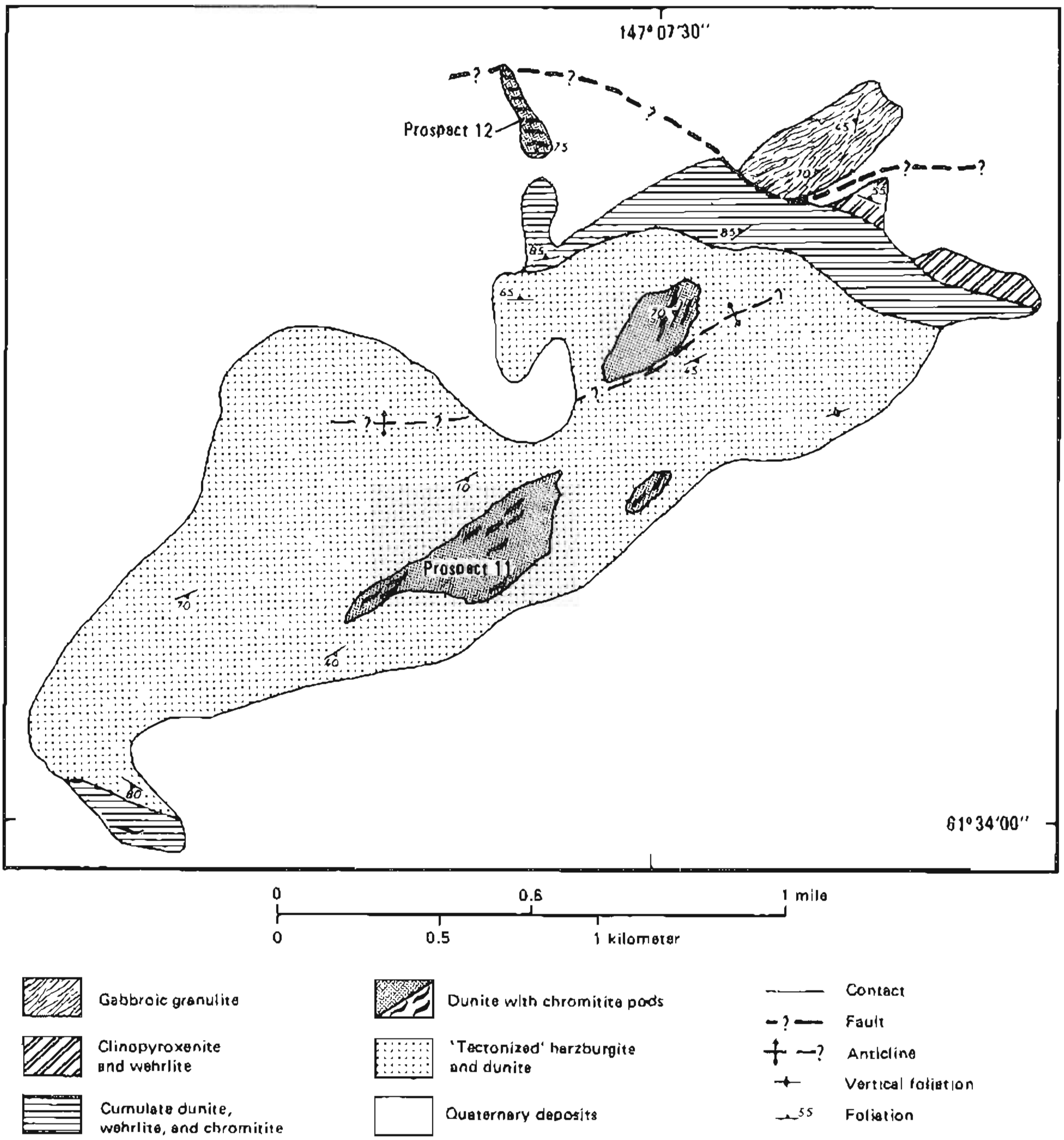

Figure 12. Bedrock geology of Bernard Mountain, Valdez C-4 Quadrangle (see fig. 11 for location). Geology by Hoffman (1974) and Newberry, Burns, and Pessel.

The northern prospect is a 1,000-ft-wide zone that consists of eight steeply dipping, east-west-striking, chromitite-rich bands. Because the exposures are limited to a stream cut and adjacent banks, the strike continuity of the bands could only be observed for 30 to 100 ft. Terminations of the bands were not observed, but based on characteristics of the Eklutna and Wolverine complexes, strike lengths of less than 200 ft and dip extensions of less than 50 ft are likely. Chromitite-rich bands, 1 to 5 ft thick, are separated by 20 to 250 ft of dunite and wehrlite that contain 3- to 5-ft-thick clinopyroxenite layers. The chromite bands consist of five to 30 discontinuous chromite layers, each ¼ to 1 in. thick. Individual layers are traceable for 2 to 5 ft. The bands contain 10 to 20 percent chromite; grades are roughly uniform along observed strike lengths. Folding and shearing were not observed in the chromitites, which suggests that the discontinuous nature of the layers and bands represent fluctuations in magmatic crystallization rather than tectonic deformation. Chromite-bearing bands continue to the north end of the exposure and could continue in the subsurface beyond that point. However, if a fault to the east (fig. 12) extends through the covered area, the chromite-bearing unit is cut off shortly past the end of exposed outcrop.

Two poorly exposed chromite-bearing zones (prospect 13, fig. 11) occur at Dust Mountain, approximately 4 mi east of Bernard Mountain. These zones are in a cumulate olivine-rich rock with subequal amounts of clinopyroxene and orthopyroxene. The chromitites occur on opposite sides of Dust Mountain, separated by approximately 3,000 ft of barren cumulate peridotite. High-temperature subsolidus deformation textures do not occur in the chromitites or surrounding peridotite. The chromite-bearing zones are 2 to 5 ft wide and traceable for approximately 50 to 75 ft along strike. The zones appear to pinch out along strike, probably from magmatic causes, because no shearing or faulting is evident. The zones are similar to those at Eklutna, western Wolverine, and northern Bernard Mountain and are composed of individual, discontinuous chromitite layers bounded by cumulate peridotite layers.

Mafic and ultramafic rocks are exposed on hills east of Dust Mountain (tectonized harzburgite) and northeast of Dust Mountain (clinopyroxenite and metagabbronorite). Both areas contain traces of disseminated chromite. The typical ultramafic stratigraphy suggests that the metagabbronorite-clinopyroxenite is too far upsection to contain significant chromite. The absence of significant chromite in the tectonized harzburgite east of Dust Mountain suggests poor overall potential for harzburgite in the Tonsina area.

Compositions of chromite from the Tonsina complex are (except for Dust Mountain) similar to other Chugach prospects examined and distinctive from the classic 'podiform' field compositional signatures (table 2 and fig. 10). Chromite from the cumulate portion of Bernard Mountain spans a range of compositions similar to those shown by Eklutna chromite. Tonsina chromitites exhibit an irregular variation in chrome content with stratigraphic position. Of the cumulate chromitites, those farthest upsection are lowest in chrome (similar to Eklutna). Chromite from central Bernard Mountain (podiform prospect 11; fig. 12) has a slightly lower average chrome content than northern Bernard Mountain (prospect 12, fig. 12). However, both Bernard Mountain prospects possess chromite with high chromium-iron ratios (3.0 and 2.5, respectively). Chromite from the Dust Mountain cumulate rocks is very high in iron with only moderate chrome contents. The chromium-iron ratio from Dust Mountain is the lowest (1.2) for any prospect studied in the Chugach area and is of low economic interest.

Summary of Chugach chromite prospects

The large number of chromite prospects with high chromium-iron ratios and the relatively large amounts of ultramafic rock (75 mi^2) indicate that the northcentral Chugach area has chromite resource potential. Table 2 indicates, however, that the tonnages estimated at exposures of chromite-bearing rocks are low. The potential for high tonnages of chromitite at these prospects thus depends on the likelihood of lateral continuity of the chromite horizons. Detailed mapping of several prospects indicates limited continuity of chromitites due to magmatic or early postmagmatic processes. Further structural complications were imposed on the 'lenslike' stratigraphy; that is, the ultramafic complexes were disrupted (Tonsina), rotated (Eklutna), and possibly inverted (Wolverine).

An important further limitation to the resource potential is that most chromite in the study area does not occur as chromite-rich bodies in tectonized harzburgite as do most chromite ores in alpine-type ultramafic settings (Thayer, 1964; Dickey, 1975). Worldwide, cumulate ultramafic rocks that comprise the vast bulk of ultramafic rocks in the study area rarely contain significant chromite. Comparison with other chromite districts (for example, Acote, Phillipines; Hawkins and Evans, 1983) suggests that the Tonsina area has the strongest chromite potential due to its abundance of tectonized harzburgite. Although this comparison suggests that the Tonsina complex may have potential for high-tonnage chromite deposits, the limited exposures of tectonized harzburgite, obvious structural complexity, and most importantly, thick overburden over most of the complex (Winkler and others, 1981) would make exploration exceedingly difficult.

The Wolverine Complex appears to contain chromite lenses with the greatest stratigraphic continuity. For this reason, further mapping is warranted to obtain a true picture of chromite localization and continuity. However, the chromite resources in this part of the Chugach Mountains appear to be small and irregular and are generally in an unfavorable lithologic setting.

Gabbroic Rocks

Gabbroic rocks outside of southcentral Alaska have been successfully exploited for iron-titanium-vanadium, cobalt-nickel, copper, gold, and platinum-palladium deposits (Mitchell and Garson, 1981). The possibility that such resources could occur in gabbroic rocks of the Chugach Mountains was investigated by detailed sampling and mapping at several sites: two possible magmatic-sulfide prospects (Barnette Creek, prospect 14, and Scarp, prospect 15; figs. 1 and 2), a magmatic iron-titanium oxide prospect (Nelchina Glacier, prospect 16, fig. 2), and several hydrothermal sulfide and oxide prospects (Barnette Creek, prospect 17, Nelchina Glacier, prospect 18, and other prospects; figs. 1 and 2). Investigations indicate that the potential is poor for commercial deposits of any of these types of prospects.

Investigations of layered gabbroic rocks in the Barnette Creek area (prospect 14, figs. 1 and 2) indicate magmatic copper sulfides in layered spinel gabbronorite. This prospect consists of a 4-in.-thick band of sulfide-rich rock that is traceable for approximately 10 ft along strike. Gabbronorite near the prospect exhibits a consistent layering which strikes N. 20° to N. 50° E. and dips moderately west. The sulfides occur as intersilicate disseminations and irregular masses that are crudely parallel to the layering. Petrographic examination showed 2 to 7 percent interstitial, undeformed sulfide with pyrrhotite subequal to chalcopyrite and minor pentlandite. The sulfides are surrounded by equant, unaltered plagioclase and pyroxene grains. These features imply a magmatic rather than a hydrothermal origin for the sulfides.

Assays of sulfide-rich material showed anomalous copper (2 percent) and nickel (240 ppm) values, but insignificant gold, platinum, and palladium. Magmatic sulfides act as 'collectors' of gold, platinum, and palladium from silicate magmas (Naldrett and Duke, 1980); thus, higher values of these elements could be expected. Magmatic sulfides in gabbroic intrusions generally contain higher (and in some cases economic) concentrations of these elements. Low values indicate a low initial content of platinum and palladium in the magmas that gave rise to the Barnette Creek gabbroic rocks (depleted source material) or the possibility of unexposed, stratigraphically lower sulfide-bearing horizons that concentrated most of the gold and platinum-group elements in the magma. In either event, the presence of magmatic sulfide, although not in itself commercially significant, suggests the possibility of other larger, richer sulfide horizons in the 5-mi-wide body. More extensive geologic mapping in this area is warranted.

A possibly similar prospect that consists of pyrite-bearing metagabbronorite and garnet granulite occurs near benchmark 'Scarp' in the Tonsina complex (prospect 15, fig. 11). A 100- by 30-ft area of layered mafic rock contains 0.5 to 5 percent pyrite associated with secondary chlorite. Pyrite distribution roughly parallels the foliation in the igneous rocks. Polished sections show small amounts of 'birdseye' marcasite, a common supergene alteration product of pyrrhotite, and minor chalcopyrite. The association of pyrite with chlorite in this prospect and the generally strata-bound character suggest low-grade metamorphism and remobilization of a pyrrhotite-rich magmatic sulfide deposit. The lack of shearing and large-scale veining in the gabbronorite also suggest a magmatic origin for the sulfides. Assays of sulfide-rich grab samples (table 1) show low platinum-group-element values.

Economic iron-titanium oxide and vanadium-bearing magnetite ores occasionally occur in gabbroic rocks of mafic complexes (Mitchell and Garson, 1981). The large amount of gabbroic rocks in the Chugach Mountains and their distinctive magnetic signature (Burns, 1982) suggest the possibility of large resources of iron-titanium or vanadium-bearing oxides. To investigate these possibilities, highly magnetic zones in the gabbroic rocks were mapped and sampled.

Burns (1983, 1985) reported high magnetite-ilmenite contents in gabbroic rocks, and a hand magnetometer survey revealed highly magnetic zones near Nelchina Glacier (prospect 16, fig. 2). Detailed mapping and sampling of the most opaque exposure of the Nelchina gabbroic body showed 30- to 60-ft-wide zones of opaque gabbronorite cut by 20- to 30-ft-wide, slightly opaque leucocratic gabbronorite dikes. Examination of polished sections from this area indicated a maximum 8 to 20 percent medium-grained magnetite and 'ilmenite,' and 1 to 4 percent disseminated pyrite. These magnetite contents are far too low to be considered as potential iron ore. Semiquantitative microprobe scans of the magnetite showed low vanadium content, a result confirmed by bulk-rock assays.

Microprobe analyses of 'ilmenite' from the prospect area (table 3) showed that these grains are instead 'arizonite,' a very fine-grained mixture of rutile, anatase, sphene, hematite, and minor ilmenite pseudomorphous after ilmenite. This mineraloid presumably formed during retrograde alteration of the gabbronorite, possibly during pyrite crystallization, as suggested by occasional intergrowths of 'ilmenite' and pyrite. Previous workers (for example, Flinter, 1959) discovered that 'arizonite' is not magnetic and therefore cannot be recovered from the silicate gangue by normal extractive methods, which renders the titanium value of this rock nil.

Table 3. Representative analyses of 'ilmenite' from the Nelchina gabbronorite (%) and calculated 'modal' mineralogy (mole %).

	Low Ca	High Ca	Low Fe	High Fe
	Sample 147	Sample BC16	Sample BC16	Sample 221
SiO_2	1.11	3.74	0.37	1.70
TiO_2	53.50	56.76	67.91	53.89
Al_2O_3	1.12	0.19	0.58	0.64
Cr_2O_3	0.13	0.09	0.18	0.01
MgO	0.18	0.10	0.08	0.41
FeO[a]	33.69	30.68	25.12	37.88
MnO	4.34	5.72	1.18	2.85
CaO	1.46	3.25	0.91	0.93
		Calculated 'modal' mineralogy		
sphene	3	8	1	1
ulvospinel	77	71	43	85
rutile	18	21	55	14
hemite	2	- -	1	- -

[a]Analyses by electron microprobe as described in table 2.

No other major magnetite-rich areas were found in the gabbroic rocks of the Chugach Mountains. Other aeromagnetic highs (for example, near Barnette Creek, prospect 17, figs. 1 and 2) are apparently due to strong serpentinization of gabbroic and ultramafic rocks adjacent to major faults and melange zones. Polished-section examination of typical serpentinized material revealed moderate amounts (15 to 20 percent) of very fine grained magnetite, but very little ilmenite. Microprobe analyses indicate that this magnetite is characteristically low in titanium and vanadium. A single grab sample taken from a 700-ft^2 serpentinized zone (prospect 17, table 1) was slightly, but not significantly, anomalous in nickel and cobalt and contained very little titanium.

Cobalt and gold occur locally in significant amounts in hydrothermally altered gabbroic rocks from other mafic complexes (for example, at the Bou and Azzer deposits in Morocco; Leblanc and Billaud, 1982). Assays of the altered Chugach gabbroic rocks, however, show no significant cobalt or gold values despite locally high pyrite content. Chip samples across pyritic gabbronorite exposed near the Nelchina Glacier (for example, prospect 16, table 1) indicate low cobalt values and no detectable gold. A 300-ft^2 zone of chloritized gabbronorite with 3 to 8 percent disseminated pyrite (prospect 18, fig. 4) in the southern Nelchina Glacier area also yielded low metal values.

Sheared, pyritic gabbronorite was noted on ridges west of the South Fork Matanuska River (prospects 19 and 20, fig. 2). Prospect 19 (fig. 13) constitutes ½ mi^2 of complexly interdigitated, coarse-grained, generally layered gabbronorite and fine-grained gabbronorite-diorite. The mafic rocks are intruded by irregular trondhjemite dikes and hypabyssal plugs and by sparse 1- to 30-ft-wide, steeply dipping felsic dikes. The most iron-stained area is approximately 1,000 ft wide and ½ mi long; the zone trends northeast and dips moderately northwest. This zone is composed of eight to 10 pyritic, chloritized shears (20 to 30 ft wide) separated by 50 to 250 ft of relatively unaltered, fine- and coarse-grained gabbronorite. The altered gabbronorite contains abundant chlorite and lesser actinolite and 1 to 7 percent poikilitic pyrite grains. Assays of chip samples across pyritic zones (table 1) indicate slightly anomalous copper concentrations, negligible cobalt and gold, and one barely anomalous silver value (0.1 ppm).

A similar zone of sheared, pyrite-chlorite-actinolite-bearing gabbronorite (prospect 20, fig. 2) is located 1.5 mi northeast of prospect 19 (fig. 2). This zone is approximately 50 ft wide, trends northeast, and dips moderately northwest. Assay of a single grab sample shows low metal values.

Pyritic zones in gabbronorite bear no direct relation to felsite dikes or masses (figs. 3 and 13) and no consistent relation to trondhjemite masses. They most often occur as widespread disseminated zones (as near the Nelchina Glacier) or as well-defined shear zones whose orientation indicates that they are older than the Tertiary and recent east-west-trending, strike-slip faulting (Burns and others, 1983). The presence of poikilitic pyrite and association with chlorite and actinolite suggest that the pyritic zones were caused by late-metamorphic fluids with little ore-carrying capabilities. Despite their large size and high sulfide contents, these zones do not contain appreciable metals.

In general, mapping and sampling of gabbroic rocks in the central Chugach Mountains indicate a poor likelihood of valuable metalliferous deposits. Metallic minerals occur in low abundance, and elements of economic interest

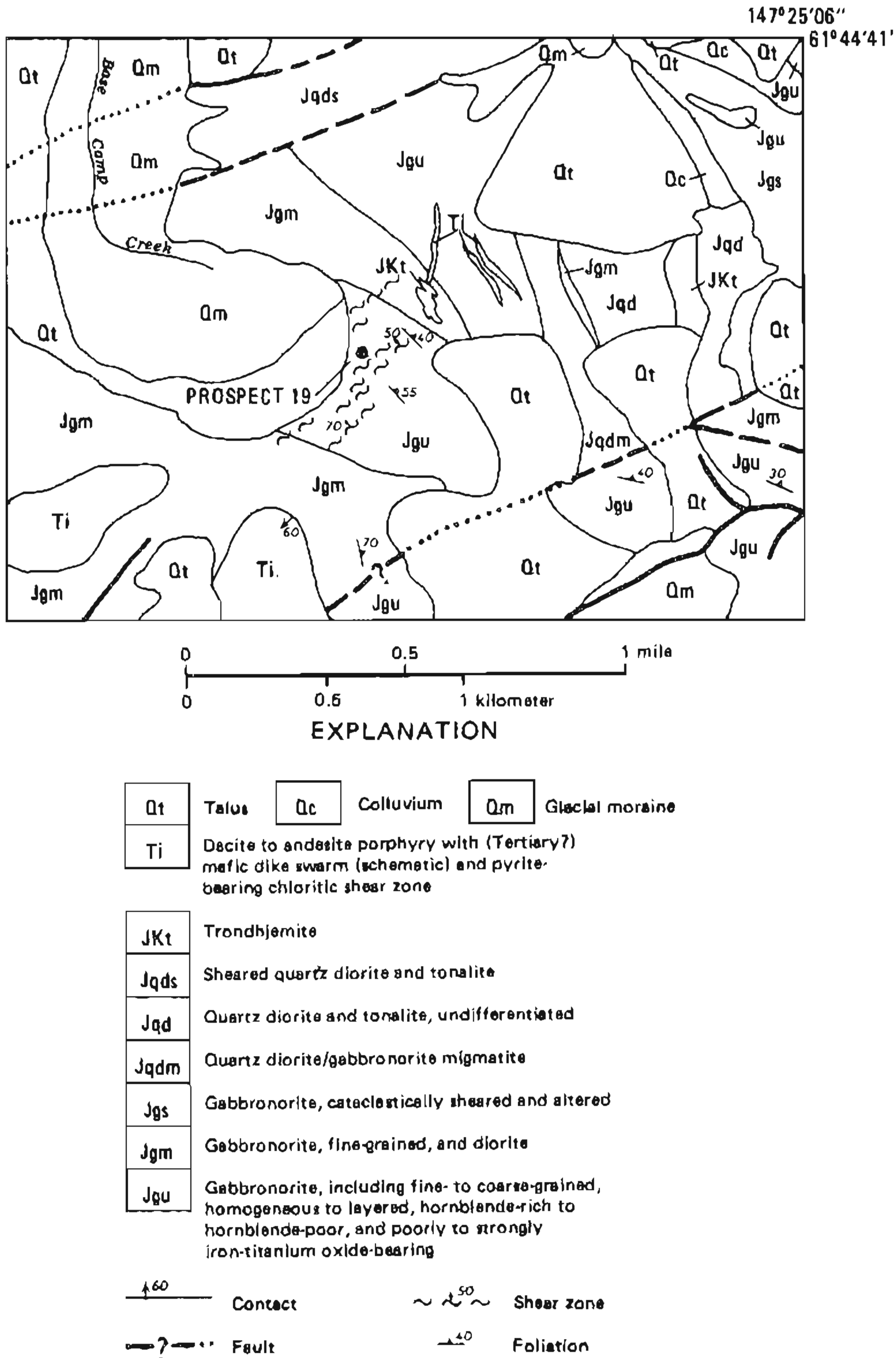

Figure 13. Geology of the upper 'Base Camp Creek' (prospect 19) gabbroic prospect, Anchorage C-2 Quadrangle. Geology modified from Burns and others (1983).

occur in very low concentrations. Prospect 14 (fig. 2) contains a small amount of magmatic-derived sulfide near Barnette Creek warrants further mapping, but is not in itself mineable under current economic conditions.

Prospects in Quartz Diorite

Intermediate-composition plutonic rocks (diorite, quartz diorite, tonalite, and local granodiorite) crop out near the northern edge of the Chugach Mountains. Locally, these rocks show minor copper staining and contain minor pyritic zones. Comparison with porphyry copper-gold deposits elsewhere (for example, Hollister, 1978) suggests that the plutons may have potential for such deposits, but Flynn and Pessel's (1984) investigations of the geology, petrography, and rock geochemistry show that such potential is unlikely.

Pyrite-bearing quartz diorite and diorite occur at several places in the northcentral Chugach area (prospects 21 through 27, fig. 2). Although the detailed settings of the prospects vary, all are in slightly pyritic shear zones, have local minor copper-staining, and are associated with chloritic alteration of the host rock. Shear zones are typically 2 to 20 ft wide and generally are adjacent to mafic-dike contacts (prospect 21 and 22, fig. 2) or along fault contacts with other igneous rock types (prospect 26 and 27, fig. 2). The absence of sulfide-bearing quartz veins; secondary biotite, potassium feldspar, or muscovite; and copper sulfides indicates the absence of major hydrothermal systems; the low assay values for the pyritic shear zones indicate a lack of metal deposition. More shallow exposures of these plutons could be of economic interest, but the intermediate-composition plutonic rocks in the northcentral Chugach Mountains appear to lack appreciable metal concentrations.

PROSPECTS IN VOLCANIC ROCKS

Two types of prospects occur in volcanic rocks of the Jurassic Talkeetna Formation: 1) abundant stratiform to strata-bound, slightly argentiferous, pyrite-rich zones; and 2) rare copper-sulfide - quartz veinlets. Mapping during this investigation suggests that these prospects were not formed by intrusive-related hydrothermal metasomatism as indicated by the absence of spatial associations between altered volcanic rocks and plutonic rocks. Formation of most prospects was probably by contemporaneous to postvolcanic hydrothermal metamorphism (circulating seawater) because they resemble modern-day geothermal systems (for example, Brown and Ellis, 1970) Low assay values for the large pyritic zones and the small size and extent of the copper veins indicate poor economic potential for these prospects.

The Talkeetna Formation in the northern Chugach area (Burns and others, 1983) consists dominantly of andesitic rocks with subordinate basaltic andesite, dacite, and minor basalt and rhyolite. Approximately 75 percent of the rocks are volcanic flows and ignimbrite; the remainder are waterlain tuffs and volcaniclastic-derived sediments. The volcanic members are typically overlain by sedimentary members, but complex deformation makes it difficult to trace the stratigraphy (Burns and others, 1983). The unit is regionally metamorphosed to greenschist facies, and alteration (epidote, chlorite, muscovite, or rare pyrophyllite) appears even more extensive in areas of high pyrite abundance.

Pyritic Zones

The largest and most obvious zones of iron staining and abundant pyrite in the northern Chugach Mountains are in the volcanic and volcaniclastic rocks of the Talkeetna Formation. Iron-stained zones (prospects 28 through 31, fig. 2) vary from several hundred square feet to several square miles in extent (for example, prospect 30, Sheep Mountain, fig. 2). The occasional presence of fluviatile sediments (Arkose Ridge and Chickaloon Formations) that uncomfortably overlie the iron-stained Talkeetna Formation (Little and others, 1986) may indicate that much of the spectacular iron-staining is due to deep paleoweathering in a warm, humid environment, rather than to high sulfide abundances. The common localization of pyritic zones at or near contacts with quartz diorite has prompted several workers (for example, MacKevett and others, 1978) to conclude that the pyritic alteration results from plutonic-related hydrothermal activity and that these areas represent the fringes of porphyry-type deposits. This investigation, however, shows that the pyritic Talkeetna Formation has no consistent relationship with the plutonic rocks. For example, pyritic rocks occur near fault contacts with quartz diorite (prospects 36, 37, and 29; fig. 2); near fault contacts with gabbronorite (prospect 32, fig. 2); near intrusive contacts with quartz diorite at Mount Wickersham (prospects 33 and 34, fig. 2); and do not occur near any exposed intrusive contacts at prospects 28, 30, 31, 35 (fig. 2). Consequently much, if not all, of the pyrite in the Talkeetna Formation does not appear to be derived from plutonic sources. On the other hand, pyrite is most common in silicic volcanic rocks (rhyolite, dacite, and andesite) and in silicified parts of the volcanic rocks, which implies at least some stratigraphic control.

At least 11 occurrences of the pyritic Talkeetna Formation are known in the northern Chugach Mountains (fig. 1). The occurrences differ mainly in size and degree of structural control of mineralization, but otherwise are similar. The pyritic zones can be described by two end members: 1) 'stratiform' bodies that show alteration in the form of sulfide disseminations and minor veinlets; and 2) discordant veins. Most prospects show both types of mineralization. The two types show no significant difference in metal grades, which suggests that the two are genetically related. The discordant veins might record metamorphic remobilization of original stratiform minerals or might represent feeders for the stratiform mineralization. Prospects described below include Heavenly Ridge (prospect 28, fig. 14), Nuska (prospect 31, fig. 2), and Sheep Mountain (prospect 30, fig. 15), the stratiform, discordant, and intermediate types, respectively.

At Heavenly Ridge (prospect 28, figs. 1 and 2; fig. 14), a thick sequence of pyritic, altered volcanic rocks is exposed in a 0.1-mi^2 area that surrounds a stream cut. The stratigraphically lowest unit is a slightly pyritic andesite that has slightly anomalous silver values (table 1); the mafic minerals were altered to epidote-chlorite-calcite-pyrite-sphene. Forty to 50 ft of silicified andesite and dacite that contain 5 to 20 percent secondary quartz overlie the lowest unit. These rocks contain relatively abundant, but variable amounts of pyrite (3 to 15 percent), anomalous silver (0.2 ppm), and locally anomalous barium (1,250 ppm). These rocks were pervasively altered; original mafic minerals and some plagioclase were replaced by muscovite or chlorite or by epidote, pyrite, and rutile. The silicified rocks are capped by a less-altered, nonpyritic andesite tuff. All the pyrite appears to be of a replacement origin; there are no cherty pyritic rocks or other signs of chemical sedimentation.

No pyritic veins occur at this site, and pyrite is not particularly concentrated along unit contacts. Alteration appears to be stratigraphically controlled, possibly by permiability contrasts in the volcanic rocks. The sharp break between altered volcanic rocks and overlying unaltered tuffs is consistent with a broadly contemporaneous volcanic age for the pyritic alteration.

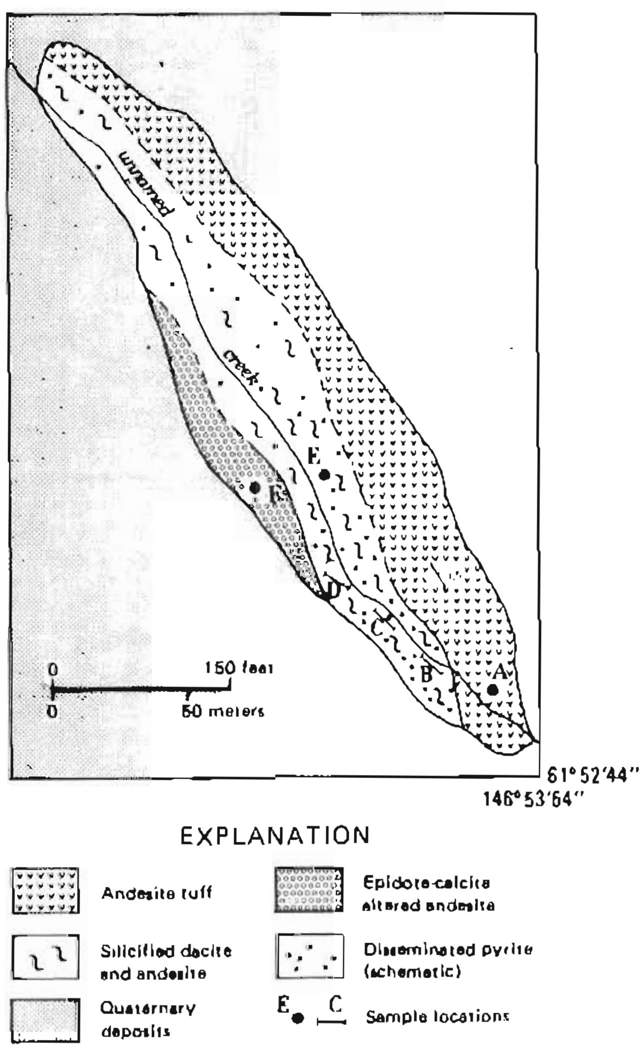

Figure 14. Bedrock sketch map of the Heavenly Ridge Prospect (28), Valdez D-8 Quadrangle. All samples have a prefix of 82Ny101.

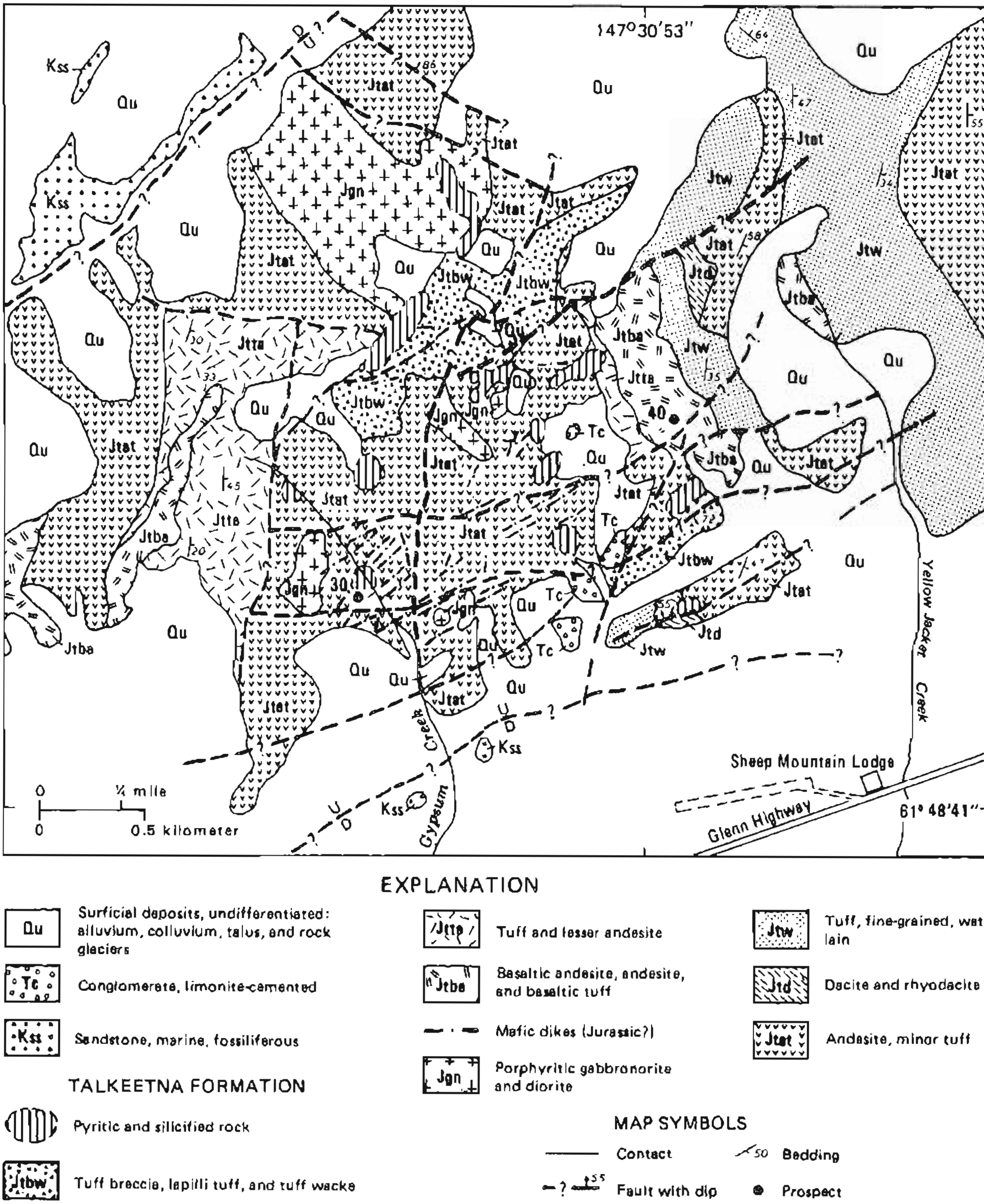

Figure 15. Geology of the Sheep Mountain pyritic zone, Anchorage D-2 Quadrangle. Modified from McMillin (1984) and Grantz (1961).

Discordant, strata-bound, pyritic alteration in volcanic rocks of the Talkeetna Formation at Nuska (prospect 31, figs. 1 and 2), south of Sheep Mountain, appears to be controlled by faults, although the altered zones are limited to andesite-dacite tuffs and flows. Regional mapping (Burns and others, 1983) shows that the Nuska altered zone is in a sequence of dominantly north-south-striking, east-dipping volcanic rocks. Volcanic and nonvolcanic sedimentary rocks crop out stratigraphically above the pyritic zone, whereas basaltic andesite and andesite crop out below the zone. East-west-trending, quartz- and pyrite-rich zones (20 to 80 ft wide and 100 to 1,500 ft long) crosscut the strata and are the major hosts for precious-metal mineralization. Pyrite contents vary from less than 1 to more than 15 percent, and the rocks are variably silicified. The metal-rich rocks (up to 0.1 ppm gold, 1.1 ppm silver, 280 ppm arsenic) are strongly silicified, and brecciated andesite and andesite tuff contain up to 60 percent quartz. Original mafic minerals are completely altered to epidote-chlorite-pyrite. Epidote-chlorite alteration is pervasive in the 0.5-mi^2 surrounding area, but is mostly concentrated along faults. Pyrite and silicification are limited to the immediate vicinity of faults and shears.

The stratigraphically localized silicification and sulfide minerals in the silicic-intermediate volcanic rocks of the Nuska area suggest a contemporaneous volcanic age for original mineralization. The discordant veins may record a difference in structural preparation of the host rocks (relative to other Talkeetna Formation hosted prospects) or a later period of metamorphic remobilization.

The largest altered zone known in the Chugach Mountains is located at Sheep Mountain (prospects 30 and 40, figs. 1 and 2; fig. 15) and has characteristics intermediate between the stratiform and discordant types of mineralization. The area is described more fully by Grantz (1961) and McMillin (1984); only the general features are described below.

Mapping of the Anchorage D-2 Quadrangle (Grantz, 1961) shows a zone of several square miles of pyritic volcanic rocks on Sheep Mountain. Grantz and Eberlein (written commun., 1982) found locally abundant pyrophyllite, muscovite, and gypsum and anomalous gold and silver values in grab samples of pyritic material. They concluded that the outcrops represented distal expressions of a porphyry copper deposit. Evidence presented here, however, suggests that these altered zones are not part of a major intrusive-related metasomatic hydrothermal system and have no copper potential.

A generalized map of Sheep Mountain (fig. 15) shows mainly east-dipping volcanic and volcaniclastic rocks cut by east-west-striking normal faults and intruded by diorite plugs and andesite dikes. Zones of pyrite-bearing rocks are limited to andesite, dacite, and andesite tuff members of the volcanic sequences. Pyrite is concentrated in quartz-rich rocks (variably silicified andesites and dacites), particularly those adjacent to dike contacts and faults, but also occurs in irregular masses not obviously related to structures. Gypsum crystals are forming in soils below major-sulfide outcrops. Thus, large gypsiferous pods may indicate Holocene or Tertiary supergene alteration of sulfides in a calcium-rich (andesite) host rock.

The altered volcanic rocks are characterized by the replacement of original mafic and opaque minerals by pyrite accompanied by variable amounts of rutile, sphene, chlorite, epidote, and muscovite. Quartz-pyrophyllite-pyrite rocks occur locally, as do carbonate-veined rocks. Relationships of crosscutting veins indicate that silicification and quartz veining preceded chlorite-epidote-muscovite-pyrite alteration and veining, which in turn was followed by calcite + chlorite veining. No consistent sense of zoning was observed during this investigation; variable replacement of mafic minerals by muscovite, epidote, or chlorite occurs without a clear paragenetic order or spatial distribution. Textural relations show that at least two-thirds of the pyrite can be accounted for by direct replacement of original opaque and mafic minerals. Although sulfur was clearly introduced into these rocks, most iron was originally present and merely 'fixed' as pyrite during alteration.

Metal values for pyrite-rich and silicified rocks are quite low; precious metals are the only elements present in anomalous amounts, with a maximum of 0.1 ppm gold and 1 ppm silver. Precious-metal values appear to be highest in strongly silicified rocks and are not related to pyrite abundance. Most samples contain less than 0.1 ppm silver and less than 0.1 ppm gold. Samples contain low copper-lead-zinc and generally low arsenic-antimony contents and show no correlation between gold-silver and other elements. In general, precious-metal values are much lower and more erratic than in currently mined precious-metal deposits.

Stratigraphic control of sulfide minerals, modified by variable degrees of structural localization, appears to be a feature common to pyritic prospects in volcanic rocks of the Talkeetna Formation. The abundance of quartz and potassium-feldspar phenocrysts and eutaxitic textures in altered rocks at most prospects indicates original silicic volcanic (dacite and subordinate rhyolite) composition (for example, West Wickersham, prospect 34, fig. 2). At some prospects, only silicified andesite and andesite tuff were identified in thin section. Even in complex stratigraphic settings, the prospects are restricted to intermediate to silicic volcanic flows and ignimbrite; they do not occur in the mafic volcanic rocks, water-lain tuffs, or sedimentary rocks.

In summary, a very large area of pyritic volcanic rock is exposed in the northern Chugach Mountains. Detailed mapping shows that these areas are not related to plutonic-derived porphyry systems, but probably represent contemporaneous to late volcanic alteration events. Detailed petrography indicates that much of the pyrite is simply derived by alteration of original opaque and mafic minerals in the volcanic rocks and that alteration assemblages show no consistent paragenetic or spatial pattern. The low but measurable precious-metal values, pervasive chlorite-epidote-muscovite-quartz alteration, and generally spotty, often structurally controlled alteration-mineralization suggest paleogeothermal systems with occasional siliceous sinters, similar to geothermal systems in the Taupo volcanic zone of New Zealand (Browne, 1971; Browne and Ellis, 1970). The confinement of alteration to volcanic members below volcanic sediments may be the result of contemporaneous volcanic alteration that preceded sediment deposition. The alteration mineral assemblages, widespread disseminated pyrite, and general absence of hydrothermal veins also imply contemporaneous volcanic alteration rather than alteration associated with intrusion or metamorphism. This investigation also indicates that metal values are too low to constitute ore and that high tonnages with higher grades are not likely.

Copper-rich Veins

Numerous small, erratically distributed but high-grade, copper-bearing veins occur in volcanic rocks of the Talkeetna Formation at Sheep mountain (prospect 40, fig. 15). These veins occur in andesitic tuffs interbedded with thick basaltic tuff (McMillin, 1984). The veins contain bornite, chalcopyrite, quartz, epidote, and supergene chalcocite and covellite, with local very high assay values of copper, silver, and gold (table 1). Three veinlets are exposed, each 1 to 4 in. wide and 1 to 5 ft long, that trend approximately perpendicular to the bedding in the volcanic rocks. The restriction of the veins to the volcanic sequence suggests that the veins formed by remobilization of copper and other metals from the basaltic volcanic rocks during deposition, late volcanic alteration, or metamorphism. These veins are similar in mineralogy and geologic setting to deposits within and stratigraphically above the Nikolai Greenstone and equivalents in southcentral Alaska and western British Columbia (for example, Lincoln, 1981). Regional mapping (Burns and others, 1983) shows that Sheep Mountain is the only outcrop area of basaltic-andesitic tuff of the Talkeetna Formation known in the northcentral Chugach Mountains, which implies that the occurrence of such copper-rich veinlets is not very widespread.

PROSPECTS ASSOCIATED WITH FELSITE DIKES

Quartz and feldspar porphyry dikes and plugs of presumably Eocene-Paleocene age (Winkler and others, 1981) crop out in an east-west-trending belt through the plutonic sequence in the northern Chugach Mountains (Burns and others, 1983). Sheared calcite-siderite veins with some accessory sulfides are commonly associated with brecciated felsite dikes. Most dikes (prospects 42 through 44, fig. 2) contain little or no mineralization; however, one major dike system (the Nelchina lode, prospect 41, figs. 1 and 2) is associated with locally significant lead, zinc, and silver.

The Nelchina lode (figs. 1, 2, 4, and 16), briefly described by Henning and Pessel (1980), is associated with a series of dominantly northeast-trending felsite porphyry dikes that cut gabbronorite and metamorphic rocks near Nelchina Glacier (fig. 4). This investigation indicates that the two prospects called Nelchina 1 and Nelchina 2 are separated by about 200 ft of barren gabbronorite.

Detailed mapping of the well-exposed Nelchina 1 lode (fig. 16) indicates an irregular northeast-trending felsic aphanite-matrix breccia body cut by northwest-trending calcite-siderite + pyrite veins that are slightly offset by northeast-trending faults. Several breccia bodies occur near the lode, but only one contains appreciable amounts of sphalerite and galena. This breccia body contains 1- to 4-in.-wide, parallel to anastomosing felsic aphanite and siderite-calcite-sulfide veins that cut the felsic aphinite-matrix breccia. Sulfides accompany the carbonate, not the felsic aphanite. The felsic aphanite and immediately adjacent gabbronorite are strongly altered to calcite

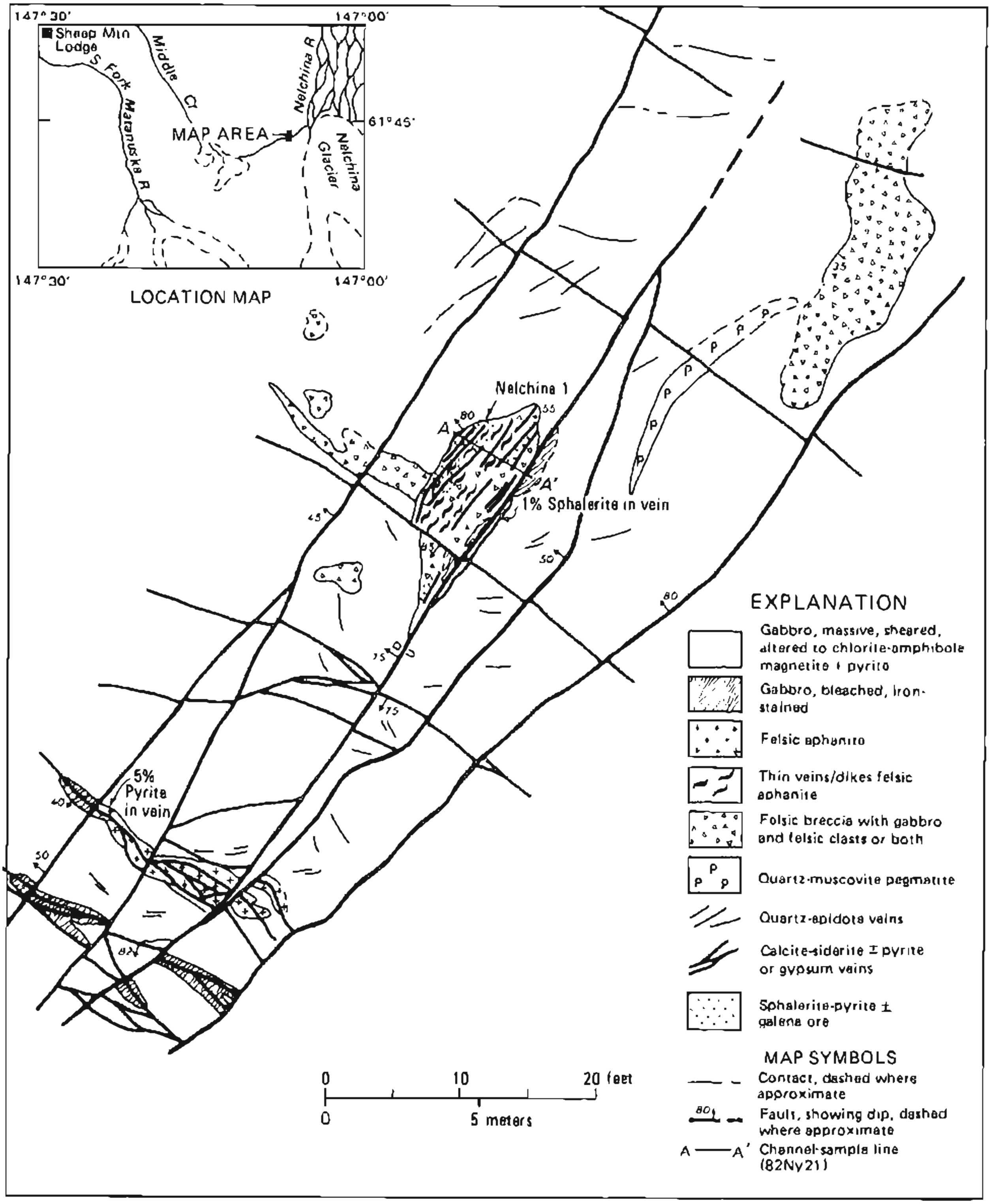

Figure 16. Geologic map of the Nelchina 1 lode area (prospect 41). Geology by R.J. Newberry, June 13, 1982.

+ very fine grained white mica; as much as 75 percent of the rock is secondary calcite. Assays of a continuous channel sample across the widest portion of the dike (table 1) indicate high lead, zinc, and silver values and slightly anomalous copper and arsenic. Galena, pyrite, and low-iron sphalerite were the only minerals identified in polished section.

The Nelchina 2 lode (fig. 4) is a poorly exposed, apparently fault-bounded, 15-ft-long by 7-ft-wide zone of carbonate-veined felsic aphanite. The sulfide-bearing zone is surrounded by carbonate-altered gabbronorite. The morphology of the body is probably similar to the Nelchina 1 lode (fig. 16), as suggested by sharp limits to the sulfide-rich float. Assays of representative grab samples (table 1) show lower base- and precious-metal values than at the Nelchina 1 prospect.

Overall, I estimate that the Nelchina lode contains less than 500 tons of rock that averages about ½ oz of silver per ton and several percent of lead + zinc. Detailed examination of the surrounding area failed to reveal additional galena-sphalerite, although felsic dikes and carbonate veins are extremely abundant (Burns, 1983). The source of the metals is not known. Amphibolite could be a potential source (Henning and Pessel, 1980), but the low lead and zinc contents of amphibolite elsewhere in the study area (prospect 2 through 4, fig. 2) and the lack of significant mineralization in felsic dikes that cut the amphibolite do not support this interpretation. Instead, I suggest a magmatic source related to explosive release of volatiles from underlying felsic plugs.

Other prospects associated with felsic dikes (prospects 42 through 44, fig. 2) locally contain anomalous copper values, but this investigation revealed no sulfide minerals or significant base-metal concentrations. Most felsic intrusive bodies that were examined in the northcentral Chugach Mountains showed no hydrothermal brecciation, alteration, or signs of mineralization. The very low and erratic metal values indicate that none of the prospects associated with felsic dikes are mineable under current conditions except possibly on a very small scale.

CONCLUSIONS

Mineral deposits in the northcentral Chugach Mountains that occur in many lithologic types and represent a variety of geologic ages and processes were mapped, sampled, and studied by petrographic and microprobe techniques and by assay. Although there are many oxide- and sulfide-rich occurrences, none are rich or large enough to mine under current conditions. In the ultramafic plutons, chromite deposits are probably too discontinuous and structurally disrupted to contain adequate tonnage. In the mafic plutons, magnetite deposits are too small and low grade and magmatic sulfide deposits are too small and contain insufficient platinum-group-element concentrations. In the metamorphic and volcanic rocks, hydrothermal sulfide deposits are far too small or low grade. Little evidence exists for magmatic-related hydrothermal metasomatism in most hydrothermal sulfide deposits. Instead, most sulfides were probably deposited during contemporaneous or late volcanic alteration and subsequent metamorphism. Most rocks and mineral deposits in the study area also show at least some regional metamorphism, whose waning stages probably were accompanied by fluid circulation that produced widespread retrograde alteration. Sulfides associated with felsic dikes are probably of igneous hydrothermal origin, but the deposits are very small and of erratic grade.

Because this area probably constitutes the base of a Jurassic island arc (Burns, 1985), the apparent absence of arc-related hydrothermal or magmatic mineral deposits may be the result of erosion to depths below such deposits. If so, shallower and possibly ore-bearing exposures of the same Jurassic arc complex may occur to the north, in the Talkeetna Mountains.

ACKNOWLEDGMENTS

Field support, assays, thin and polished sections, and funds for microprobe analyses were provided by DGGS. Field assistance and data were ably provided by S.L. McMillin and L.D. Flynn. Discussions and field mapping with L.E. Burns, G.H. Pessel, and T.A. Little provided inspiration and geologic insight; their assistance is gratefully acknowledged. Reviews by H.C. Berg, L.E. Burns, G.H. Pessel, and M.R. Robinson improved the presentation of this report. However, conclusions and interpretations are my responsibility.

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