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**GEOLOGY AND MINERAL RESOURCES OF THE
RUSSIAN MISSION C-1 QUADRANGLE,
SOUTHWEST ALASKA**

By

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CONTENTS

	Page
Abstract.....	1
Introduction and geography.....	2
Acknowledgments.....	3
Geologic units.....	3
Introduction.....	3
Gemuk group.....	4
Kuskokwim group.....	4
Volcanic-plutonic complexes.....	5
Volcanic rocks.....	5
Plutonic rocks.....	6
Dikes and sills.....	9
Petrogenesis and age of volcanic-plutonic complexes, dikes and sills.....	9
Hornfels.....	9
Pliocene-Early Quaternary basalt.....	11
Quaternary deposits.....	11
Deposits of glacial origin.....	11
Colluvial dominated deposits.....	14
Fluvial deposits.....	15
Structure.....	15
Economic geology.....	16
Introduction.....	16
Lode deposits.....	16
Owhat prospect.....	16
Louise prospect.....	17
Headwall prospect.....	18
Mission Creek or 'Konechney' prospect.....	18
Other lode prospects in the Russian Mountains.....	19
Lode deposit paragenesis.....	20
Placer deposits.....	20
Industrial minerals and fuel.....	21
Aggregate.....	21
Riprap.....	21
Bibliography.....	23

TABLES

Table 1. K-Ar analyses of selected rock samples from Russian Mission C-1 Quadrangle, Alaska.....	25
2. Major oxide analyses and CIPW norms of igneous rocks from Russian Mission C-1 Quadrangle, Alaska.....	26
3. Analytical results from prospects and mineral occurrences in the Russian Mission C-1 Quadrangle, Alaska.....	27

FIGURES

Figure 1. Location map showing Russian Mountains and adjacent lowland.....	2
2. Fence diagram of Late Cretaceous volcanic section (on plate 1).....	Pocket
3. Plot of Russian Mountains volcanics on K_2O-SiO_2 compositional diagram after McBirney (1984).....	7
4. Rare-earth element variation diagram showing three basaltic andesite samples from Russian Mountains, Alaska.....	7

5. Rare earth element variation diagram of intrusive rocks from Russian Mission, Alaska.....	8
6. Quartz-K-spar-plagioclase plutonic classification scheme for Cretaceous granitic rocks from Russian Mission C-1 Quadrangle.....	10
7. Normative orthoclase-albite-anorthite plot of plutonic rocks, Russian Mission C-1 Quadrangle.....	11
8. AFM plot of plutonic rocks from Russian Mission C-1 Quadrangle, Alaska.....	12
9. Peacock diagram plot of volcanic and plutonic rocks from Russian Mission C-1 Quadrangle, Alaska.....	13
10. Map showing extent of Quaternary glacial advances in the Russian Mountains massif, modified from Kline and Bundtzen (1986).....	14
11. Grain size distribution of Mission Creek, Fan, Russian Mission C-1 Quadrangle, Alaska.....	22

PLATES

Plate 1. Geologic map of the Russian Mission C-1 Quadrangle, Alaska.....	Pocket
2. Mine maps of gold-arsenic-copper prospects in the Russian Mountains, Russian Mission C-1 Quadrangle, Alaska.....	Pocket

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ABSTRACT

The Russian Mission C-1 Quadrangle is a 522 km² (204 mi²) area near the western edge of the Kuskokwim Mountains, an upland dominated by accordant rounded ridges, isolated glaciated massifs, and broad sediment filled lowlands in southwest Alaska. The study area is sparsely populated with Chauthbaluk (population 185) being the only community with year-round residence. The Kuskokwim River passes through the area from east to west and bifurcates the area into uplands (north) and lowlands (south). The region is dominated by the glacially carved Russian Mountains, which protrude above lower rounded hills to elevations of 1,059 m (3,466 ft).

Bedrock units range in age from Permian or older to Late Tertiary. The Gemuk Group consists of argillite, metabasalt, and sandstone of Permian to Lower Cretaceous age that has undergone lower greenschist facies metamorphism. In fault contact with the Gemuk Group area turbidite dominated deposits of the Kuskokwim Group, which range in age from upper Lower to Upper Cretaceous on the basis of sparse faunal existence. The Kuskokwim Group is estimated to be 2,000 m thick in the study area.

Intruding and overlying the older layered rocks, are a volcanic-plutonic complex composed of meta-aluminous, alkali-calcic, andesite flows, tuff, and granodiorite to granite intrusive rocks all of Late Cretaceous age. Peraluminous felsic and mafic dike and sills also of Late Cretaceous age, intrude the igneous complex and layered rocks throughout the study area. Pliocene to early Quaternary(?) basalt cap both the Gemuk Group and Kuskokwim Group immediately west of Owhat River.

Quaternary deposits include four definable glacial sequences in the Russian Mountains, and eolian, fluvial, and colluvial deposits, all of which cover about 55 percent of the map area.

The Owhat Fault, probably a splay of the Iditarod-Nixon transcurrent fault, bifurcates the area from north to south along the Owhat River and juxtaposes the Gemuk Group against the Kuskokwim Group. Late Pliocene-Quaternary basalt (with one K-Ar radiometric date of 6.16 m.y.) caps the fault and dates its last movement.

The principal mineral deposits consist of mesothermal, intrusive hosted, polymetallic, gold-sulfide-tourmaline greisen veins that intrude a prominent, high angle N. 25-35 trending joint/fracture system in the Russian Mountains. Four deposits contain a minimum inferred reserve of 229,290 metric tons (253,350 short tons) grading 0.13 oz/ton gold, 9.59 percent arsenic, 0.20 percent antimony, 0.014 percent tin, 0.61 percent copper, and anomalous silver, tungsten, cobalt, zinc, and uranium.

Placer occurrences of gold are known in Mission Creek and Cobalt Creek, but no records of mining activity have been found.

Aggregate sites identified in the study area could be utilized for local construction and erosion control projects. A promising riprap quarry site located along the flanks of the Russian Mountains north of Chuatbaluk might be capable of supplying material for erosion control programs for Kuskokwim River communities.

INTRODUCTION AND GEOGRAPHY

During July 23-26, 1985, July 15, 1987, August 11, 1987, and June 12-26, 1988, the authors conducted 1:63,360 scale geological and mineral resource investigations in the Russian Mission C-1 Quadrangle of southwestern Alaska (fig. 1). The study area lies within the Kuskokwim Mountains province (Wahrhaftig, 1965), an 80,000 km², maturely dissected, generally unglaciated upland of accordant rounded ridges averaging about 600 m (2,000 ft) altitude that are interspersed with broad sediment-filled lowlands averaging 90 m (300 ft) altitude. Within the Russian Mission C-1 Quadrangle, elevations range from 18 m (61 ft) in the active channel of Kuskokwim River to 1,057 m (3,466 ft) in the western Russian Mountains. The Russian Mountains in the study area is one of 13 isolated mountain massifs or ridge complexes in the Kuskokwim Mountains that were sufficiently large and high to generate alpine glaciers during Quaternary time.

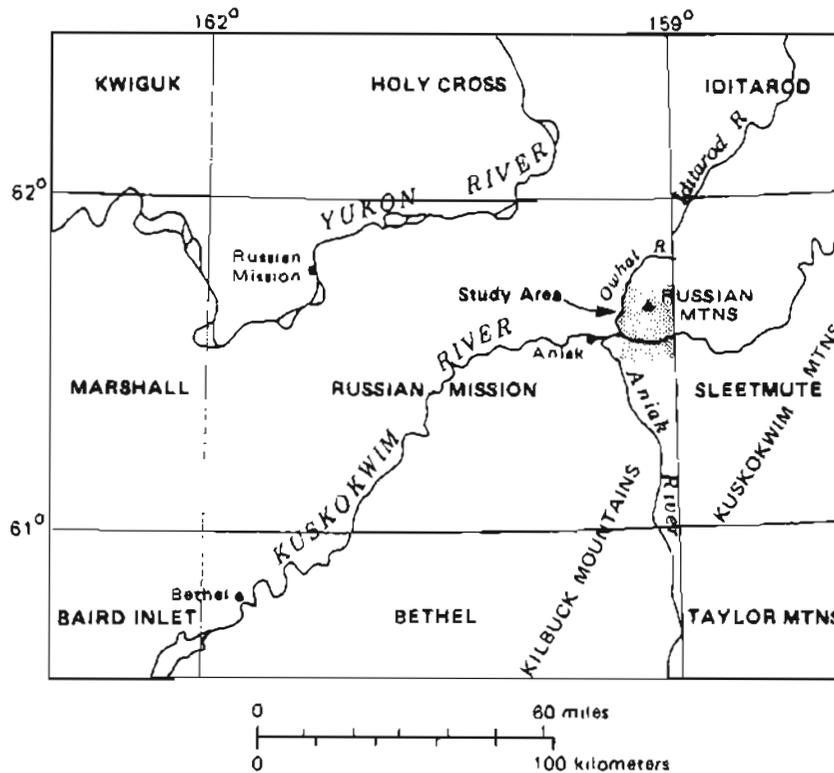


Figure 1. Location map showing Russian Mountains and adjacent lowland.

Main geographic features include the rugged, circular shaped, 140 km² Russian Mountains massif, low rolling hills of the Owhat upland, and near horizontal, vegetation covered flood plains of the Kuskokwim, Aniak, and Owhat Rivers. The Kolmakof River empties into the Kuskokwim River east of the study area and drains most of the eastern slopes of the Russian Mountains. The broad, 10 km wide valley of Owhat River enters the Kuskokwim River in the westcentral part of the study area and drains the western and northern slopes of the Russian Mountains. Mission Creek and other drainages on southerly slopes of the Russian Mountains empty directly into the Kuskokwim River.

No thoroughfare roads exist in the study area but a short, 4 km (2.5 mi) long secondary road links the village of Chauthbaluk (population 185) with a 1,600 m long airport. All terrain vehicle trails (ATV) are abundant and extensively used especially during winter months. Aniak (population 540), about 30 km downstream from Chauthbaluk and west of the map area, serves as a regional logistical center for air transportation, trade, and manufacturing in the middle Kuskokwim River drainage including the Russian Mission C-1 Quadrangle.

Slightly metamorphosed altered sedimentary and volcanic rocks generally underlie the gently rolling hillslopes west of Owhat River and are covered with climax white spruce, birch, and sphagnum moss vegetation. Bedrock control in these lower areas is poor and often confined to river cutbanks. Plutonic (granitic), volcanic and nearby hornfels form the rugged Russian Mountains that average 700 m higher than surrounding vegetated hills. The igneous lithologies and hornfels are well exposed and consists of numerous outcrops and frost riven rubble.

About 55 percent of the study area is covered by Quaternary and Holocene fluvial, colluvial, and eolian deposits.

Land ownership in the study area is shared by the state (31 percent) and federal (35 percent) governments and Native corporations (34 percent). The subsurface and surface estate of the central and southern Russian Mountains is owned by Calista Regional Corporation. Kuskokwim Village Corporation, another Native corporation, manages the surface estate of several Kuskokwim River villages including Chauthbaluk. The western and eastern outlier ridges of the Russian Mountains as well as the Owhat upland is currently owned by the federal government and managed by the U.S. Bureau of Land Management under multiple use principles. The State of Alaska owns most lands south of the Kuskokwim River and the beds of all navigable rivers and also manages its lands for multiple use (Staff, 1986).

ACKNOWLEDGMENTS

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GEOLOGIC UNITS

INTRODUCTION

Fifteen mappable rock units ranging in age from Permian to Late Tertiary are exposed in the study area and depicted with color codes recommended by Van Esigugna (1975) and DGGS standard lithologic schemes. All rock units were studied in the laboratory using standard thin section (transmitted light) petrographic techniques. Multielement and major oxide geochemical analyses, microprobe analyses of ores, and radiometric isotope dating (table 1-3) provide additional data. Fourteen glacial, fluvial, eolian, and colluvial deposits of

Quaternary age were subdivided by field examinations and photogeologic techniques. Abbreviated descriptions of all geologic units are provided on plate 1.

GEMUK GROUP

The oldest known rock unit consists of poorly exposed argillite, altered mafic igneous rocks (mainly metabasalt) and tuffaceous sandstone believed to be part of the Gemuk Group (MzPzvs, pl. 1), originally described and named by Cady and others (1955) after exposures near Cinnabar Creek about 60 km southeast of the study area. Our descriptions are based on brief examination of rubble crop west of Owhat River. Hoare and Coonrad (1959) previously showed this area as being underlain by the Kuskokwim Group. However these workers indicated their work in the Russian Mission C-1 Quadrangle north of the Kuskokwim River was based mainly on photogeologic interpretation.

Thin section analyses (N=3) of lithic sandstone in the MzPzvs unit show grains of subangular to angular quartz (35 percent), angular clasts of chert (25 percent), white mica (5 percent), pumpellyite (2 percent), albitized plagioclase (11 percent), chlorite and epidote (6 percent), rock fragments (17 percent) and undetermined matrix (10 percent). The original sedimentary clasts have been blurred and recrystallized by low grade regional metamorphism. The secondary minerals epidote + pumpellyite + chlorite + albite suggest metamorphic conditions that reached the lower greenschist facies. The sandstones and siltstone show recognizable graded bedding that may have originally been deposited in turbidity currents. Interbedded cherty argillite consists of dark gray, massive, siliceous metasediments composed of approximately 95 percent quartz and undetermined feldspar and 5 percent graphitic material. Some cherty argillite specimens were difficult to differentiate from fine grained igneous rocks. Overall, these metasedimentary lithologies comprise about 80 percent of the MzPzvs unit in the study area.

Altered dark green metabasalt and diorite occur as discontinuous lenses or layers 5 to 50 m thick and traceable along strike for several kilometers. Lack of outcrop control prevented our ascertaining whether these rocks had intrusive or extrusive relationships with enclosing metasediments. Metabasalt contains relict phenocrysts of olivine altered to antigorite, highly corroded clinopyroxene, leucoxene, and albitized plagioclase grains in a groundmass of plagioclase, magnetite(?) and clinopyroxene. One major oxide analyses of altered metabasalt (table 1) shows the sample to be a alkali-olivine basalt similar to those described from oceanic arc settings. About 20 percent of the MzPzvs unit is composed of the metamorphosed mafic igneous rocks.

We found no fossils from metasedimentary rocks and meta-igneous rocks were too altered for radiometric age dating. Hoare and Coonrad (1959) report Permian and Permian(?) fossil localities in Kuskokwim River Group cutbanks of PzMzvs immediately west of the study area. Box (1983, 1985) includes lithologies similar to those in the study area with the Hagameister Terrane, which he regards as an Early Cretaceous oceanic island arc sutured onto North America in Late-Early Cretaceous time.

KUSKOKWIM GROUP

The major stratigraphic units underlying the study area consists of poorly exposed calcareous lithic sandstone and micaceous siltstone (Kls) and undifferentiated, fine to coarse grained, noncalcareous micaceous lithic sandstone and siltstone (Kus), both correlated with the Kuskokwim Group originally described and named by Cady and others (1955). The Kuskokwim Group along the Kuskokwim River is fairly well exposed but outcrops in upland areas are rare and generally collapsed in piles of frost riven rubble.

Coarse lithic sandstone (Kus) west of the Russian Mountains consist of subangular grains of quartz (35 percent), chert (20 percent), volcanoclastic grains (15 percent), white mica (3 percent), and interstitial rock fragments (25 percent). The clasts in the Kus sandstone are less recrystallized than those observed in the older MzPzvs unit, although overall compositions are similar in both units. Secondary prehnite and chlorite replace plagioclase suggesting metamorphic conditions that reached the zeolite facies.

According to Bundtzen and others (1989) river exposures of the Kls unit in the southeast corner of the map area consists of calcareous sandstone and siltstone exposed in rhythmic beds 5-100 cm thick and at volumetrically ratios of 3 (sand) to 1 (silt). In thin section, Kls sandstone was seen to be composed of calcite matrix (30 percent), calcite grains (10 percent), quartz (20 percent), chert (15 percent), slate clasts (15 percent), white mica (2 percent), albite (5 percent), and felsic igneous rocks (3 percent). All of the carbonate consists of either detrital grains or cement and is not believed to be secondary in origin. Prehnite and chlorite partially replace albite and white mica suggesting zeolite metamorphic conditions.

Flutes, Bouma A-C intervals, and rip-up clasts in sand beds suggest that both the Kus and Kls units were deposited by turbidity currents. However, the general lack of contiguous exposures in the study limit detailed structural and stratigraphic studies. Assuming bedding continuity for Kls and Kus units exposed on the Kuskokwim River above Chauthbaluk, we estimate the Kuskokwim Group is at least 2,000 m in the study area. However, Cady and others (1955) estimated a thickness of 12,000 m (40,000 ft) for a section of Kuskokwim Group lithologies exposed from Sleetmute to Crooked Creek upriver from the study area. Bundtzen and Gilbert (1983) and Bundtzen and others (1988) describe stratigraphic thicknesses ranging from 2,200 to 3,500 m to the northeast, similar to that observed in the study area. The Kls and Kus units may be part of the significantly thinner, western edge of a Late Cretaceous, northeasterly oriented, subsiding continental trough dislocated by transcurrent faults (Bundtzen and Gilbert, 1983).

Inoceramus shells of Cenomanian age (Early Late Cretaceous) were reported by Hoare and Coonrad (1959) from seven localities 12-16 km up river from Chauthbaluk (pl. 1). Accumulative fossil evidence suggests that the Kuskokwim Group ranges in age from Albian (Late Early Cretaceous) to Maastrichtian (Late Late Cretaceous) with the most abundant fossil collections yielding Turonian ages (Bundtzen and Laird, 1983; Bundtzen and Gilbert, 1983; Bundtzen and others, 1988; Miller and others, 1989).

VOLCANIC-PLUTONIC COMPLEX

Intruding and overlying the Paleozoic-Mesozoic stratigraphic units previously described are coeval volcanic and plutonic rocks in the Russian Mountains and mafic-to-felsic dikes and sills that crop out throughout upland areas in the quadrangle (pl. 1).

Volcanic Rocks (TKvi, TKva, TKvm, TKvt)

Basaltic andesite flows (TKvm), andesite and dacite flows and tuff (TKvi, TKvt) and agglomerate (TKva) crop out in a circular shaped volcanic blanket on the north flank of the Russian Mountains. These volcanic lithologies form slab shaped, frost-riven, black-lichen-covered rubble averaging 20 cm by 5 cm by 10 cm that contrast with larger (by 3x) blocks of the underlying and flanking plutonic rocks.

Basaltic andesite (TKvm) and andesite (TKvi) display distinctive columnar joints throughout the limits of mapped outcrops suggesting a subaerial depositional environment. Individual flows range from 5 to 20 cm thick and radically change in thickness along strike. In thin section plagioclase phenocrysts (An₃₀₋₄₀) in both basaltic andesite and andesite (TKvm, TKvi) show normal and reverse zoning. Phenocrysts plagioclase average labradorite (An₅₀₋₇₀) in composition but the groundmass plagioclase appears to average andesine (An₃₀₋₅₀); the normative average plagioclase composition (N=4) from four flow rocks (table 2) is in the middle compositional range of andesine (An₄₂). Minor amounts of titanite, uncomon olivine, and rare biotite appear to comprise the mafic constituents. Most basaltic andesite (TKvm) samples exhibit ophitic textures whereas trachytic textures are more common in the andesites and dacites of the TKvi units.

Agglomerate (TKva) contains rounded clasts of andesite and sandstone up to 60 cm in diameter nested in zeolitized clasts dark, greenish gray lappili tuff. The presence of sandstone suggest that underlying marine sedimentary Kuskokwim Group may have been the erosional surface on which the volcanic pile was deposited. Agglomerates in the Russian Mountains bear some resemblance to the lahar and related deposits of the Iditarod volcanics in the De Coursey Mountain area 50 km northeast of the Russian Mountains (McGimsey and Miller, 1988).

Tuff dominated lithologies of the TKvt unit contain abundant, genetically altered microlite-feldspar grains and shards in layers 5-30 cm thick separated by sand layers composed of quartz (25 percent), chert (25 percent), and andesite (50 percent) clasts. A crude grading is evident at outcrop scale with coarsest sand and angular cobble sized fragments near the base and fining upward fragments that culminate in silt sized particles. The graded nature of the alternating sand and microlitic components suggest that much of the TKvt unit was deposited by air-fall processes.

Despite limited outcrop availability of the volcanic units, the Russian Mountains volcanic pile displays a regular stratigraphic arrangement that is graphically illustrated figure 2 on plate 1. Basal basaltic andesite flows are successively overlain by volcanic agglomerate (TKva), andesite and dacite flows (TKvi) and capped by airfall and waterlaid tuffs (TKvt). The succession from more mafic flows near the base of the pile to intermediate flows and airfall dominated deposits at the top is the normal sequence observed in strato-volcanoes worldwide (McBirney, 1984, p. 300-342). The basal basaltic andesite flows are thickest (280 m) in the southwest part of the volcanic pile near VABM 3466 (1,057 m) and thin to the north and northeast (150 m and 80 m respectively). Inversely airfall and waterlaid tuffs are thickest to the north and northeast (280 and 320 m respectively) and thinnest (140 m) above the thick flow section in the southwest corner of the volcanic buildup. Additionally clast size in the TKvt unit is coarsest to the southwest (1-3 cm) and finer to the north (≤ 0.5 cm). We speculate that the southwest flow buildup is most proximal to the volcanic vent and the north and northeasterly airfall dominant zones represent more distal airfall tuff sections down wind and offsite from the volcanic center.

The Russian Mountains mafic volcanic rocks (TKvm) lack iron enrichment typical of tholeiitic magmas but instead show high alumina and normative plagioclase compositions more indicative of calc-alkaline suites. However, three of four samples of basaltic andesite show extreme potassium enrichment and plot in the shoshonite and banakite fields; a fourth plots as a high-K andesite (fig. 3). Rare-earth element trends from three samples of andesite (fig. 4) indicate a relatively low degree of fractionization and exhibit only a modest Eu anomaly. Variation patterns of all three samples are more or less parallel. Overall, the petrography, whole rock chemistry, and REE trends of the Russian Mountains volcanic suite are consistent with those of calc-alkaline to quartz-alkalic volcanic belts within interior regions of continents manifested in back-arc subduction complexes (McBirney, 1984).

Plutonic Rocks (TKsym, TKsy, TKsy, TKmp, TKdm, TKf, TKdi)

The Late Cretaceous volcanic pile and Kuskokwim Group are intruded by a meta-aluminous, multiphase pluton than averages quartz monzonite in composition (TKsym, TKsy, TKmp) and mafic to felsic dikes, the latter of which displays peraluminous chemistry (table 2).

The main intrusion, the Russian Mountain pluton, crops out in a circular shaped 85 km² massif that defines the geographic limits of the Russian Mountains. Intrusive phases show sharp contacts with each other and the entire pluton is in sharp, high angle contact with hornfelsed sedimentary rocks to its western, southern, and southeast limits. Volcanics (often thermally altered) are generally in low angle contact with the larger intrusive mass and several small windows of plutonic rocks are observed beneath the volcanics in the northern Russian Mountains. These contact relationships indicate that the entire mountain range is probably underlain by intrusive rock (pl. 1).

Syeno-monzonite (TKsym) generally exhibits a medium-to-coarse grained, hypidiomorphic-granular texture with glomeroporphyritic clusters up to 1 cm in diameter of altered diopside in a finer grained groundmass of andesine (An₃₅), quartz, fine grained biotite, and zircon. Syeno-monzonite generally forms the outermost rim of the Russian Mountains pluton as well as the higher (or shallowest) level of the presumed magma chamber directly underneath volcanic roof pendants. Because xenoliths of TKsym are found in TKsy and TKmp, it is presumed to be the oldest intrusive phase. REE patterns of selected TKsym samples indicate similar trends to those of the volcanics previously described (figs. 4, 5).

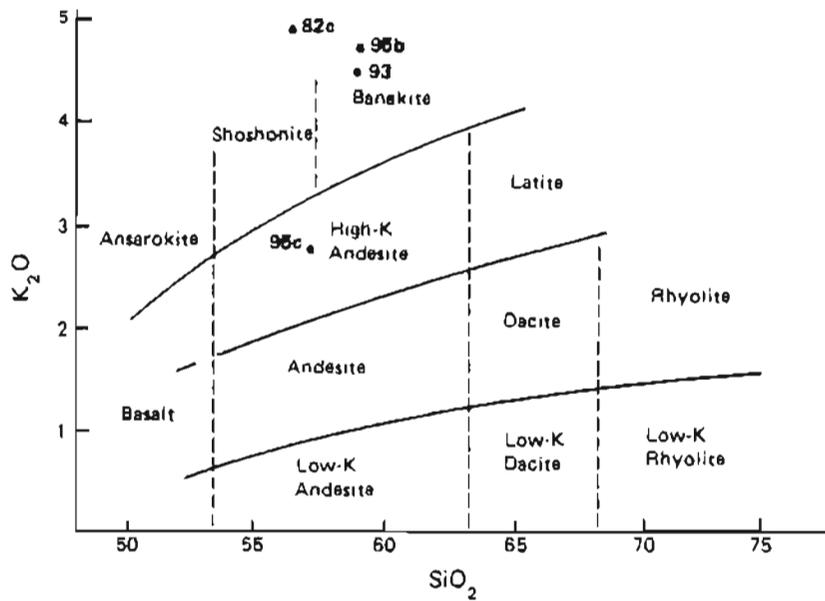


Figure 3. Plot of Russian Mountains volcanics on K_2O - SiO_2 compositional diagram after McBirney (1984).

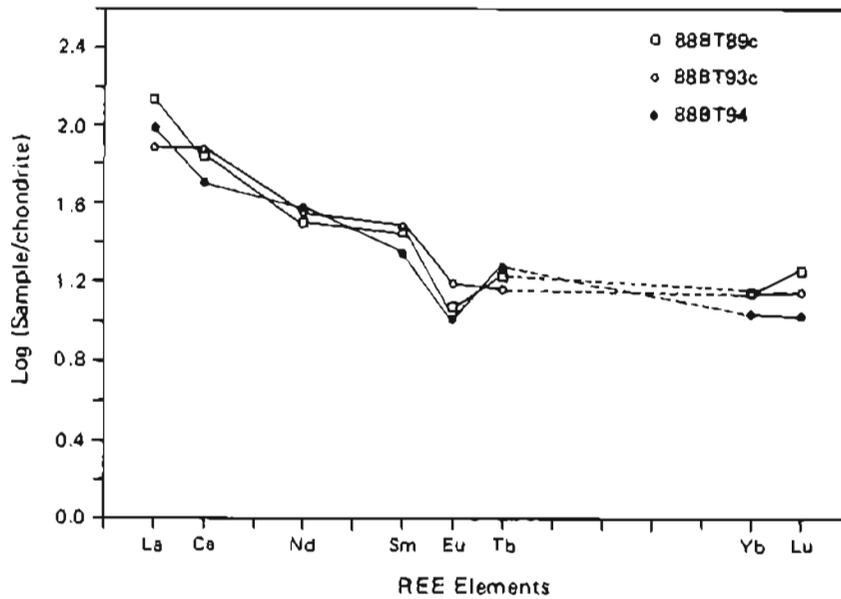


Figure 4. Rare-earth element variation diagram showing three basaltic andesite samples from Russian Mountains, Alaska. Analyses by Nuclear Activation Services, Ontario, Canada.

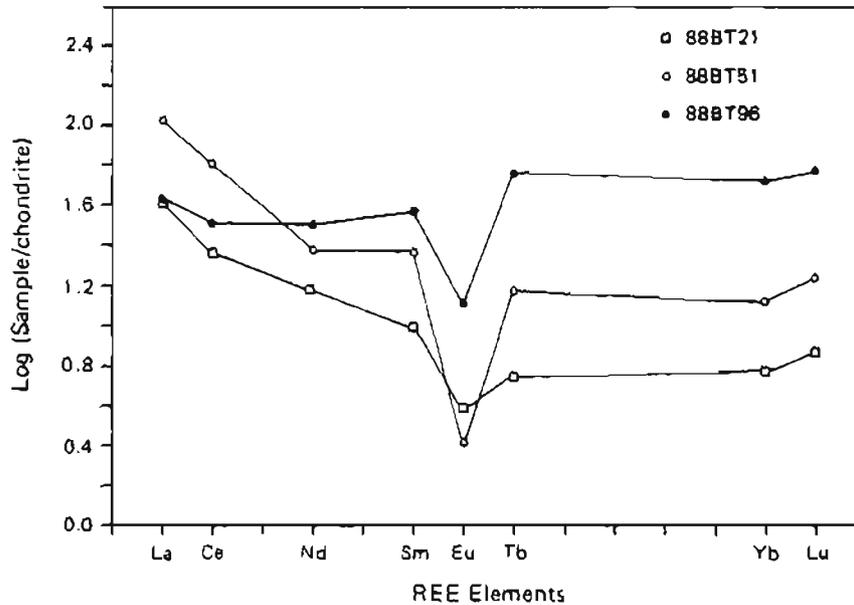


Figure 5. Rare earth element variation diagram of intrusive rocks from Russian Mountains, Alaska. Analyses by Nuclear Activation Services, Ontario, Canada.

'Quartz' syenite (TKsy) is the most common intrusive phase in the Russian Mountains comprising about 80 percent of the total plutonic mass. It is a light greenish-gray, medium grained, equigranular to hypidiomorphic rock that contains biotite, orthoclase, quartz, and oligoclase as major mineralogical constituents with minor or trace amounts of axinite, zircon, diopside (≥ 1 percent), and hematite. Xenoliths of the slightly more mafic TKsym unit are found in TKsy. The axinite in thin section appears to have formed during primary igneous crystallization instead of in a secondary, commonly accepted, replacement origin for this mineral. Distinctive northwest trending, linear zones of ankerite-sericite alteration mapped in the Cobalt and Mission Creek valleys are believed to be associated with hydrothermally mineralized joints and fractures in the TKsy plutonic complex.

Porphyritic quartz monzonite to granite (TKmp) crops out as a structurally high intrusive phase in the western Russian Mountains. It consists of a fine grained to porphyro-aphanitic, diopside bearing biotite quartz monzonite or granite. Biotite occurs both as separate grains and as inclusions in altered diopside. Subhedral feldspar grains up to 2 cm long exhibit classic rapakivi texture. The TKmp unit has undergone pervasive hydrothermal alteration that includes prophyzation of biotite, diopside, silicification, and sericitization (of feldspar). Axinite grains and clots to 1 cm in diameter also occur in TKmp but in less abundance than found in the TKsy phase.

The three mapped intrusive phases (TKsym, TKsy, TKmp) generally form sharp contacts with each other but are believed to be end products of the same differentiation process. The average differentiation indices for the three phases (TKsym = 63.5; TKsy = 79.2; TKmp = 93.7) suggests that a parent, syeno-monzonite magma progressively differentiated to quartz syenite and finally to granite, similar to processes described for the Chicken Mountain and Black Creek plutons near Flat northeast of the Russian Mountains (Bundtzen and others, 1988; Bull, 1988).

Dikes and Sills (TKdi, TKf, TKdm)

Dikes and small sills intrude along faults and joints in the Russian Mountains pluton and in older layered lithologies. The most abundant dikes are 1-3 m wide, up to 1 km long, and are medium green, chloritized porphyro-aphanitic, hornblende andesite porphyry (TKdi) and lighter green quartz orthoclase porphyry (TKf). Ubiquitous hydrothermal alteration of hornblende prevented any radiometric age dating, analyses; secondary biotite clearly postdates amphibole and minor pyroxene but is also altered. Andesite porphyry dikes (TKdi) often contain axinite and appear to be associated with sulfide mineralization described in the Economic Geology section (p. 16).

Minor olivine-clinopyroxene mafic dikes (TKdm) described by Bundtzen and others (1989) crop out on Kuskokwim River about 4 km upstream from Chauthbaluk. The prominent mafic dike system cuts dark gray Kuskokwim group calcareous sandstone and siltstone (Kls). During its intrusion, one 15-20 m thick dike trending N. 30 W. generated enough heat to produce a hornfels aureole 15 m wide, which is unusual for such a small intrusive body. Cumulate-like grains of olivine and intermeshed clinopyroxene comprise up to 25 percent of the rock; unfortunately, no major oxide analyses are available from this small intrusive body.

Quartz-orthoclase porphyry sills 100 m wide and 3 km long intrude the MzPzvs unit parallel to northeasterly structural grain west of Owhat River. Because the felsite sill is compositionally the same as those intruding the Russian Mountains stock, they are believed to be genetically related to the latter.

Petrogenesis and Age of Volcanic-plutonic Complex, Dikes and Sills

The Russian Mountains igneous complex is a circular shaped field of basaltic andesite and dacite tuff ($\text{SiO}_2 = 56.17-59.66$ percent) that flanks and overlies a granodiorite-granite pluton ($\text{SiO}_2 = 61.89-72.69$ percent). The volcanics are slightly older but probably co-magmatic with the pluton. Normative mineral plots show the expected compositional ranges of plutonic rocks (figs. 6, 7) and an AFM plot shows the pluton to have the same alkali-calcic signature as the volcanics (fig. 8). One whole rock analyses of proxene andesite (#3, table 2) yielded a K-Ar age of 75.77 m.y. while an age of 69.76 m.y. (#4, table 2) was obtained from another sample of andesite. Thin section analysis of sample #4 shows a pervasive biotite and sericite overprint of the fabric suggesting that a thermal event has re-equilibrated the $\text{K}^{40}\text{-Ar}^{40}$ isotopic system. The former age is in close agreement with ages ranging from 75-77 m.y. age range obtained from basal parts of the Iditarod volcanics in the Iditarod Quadrangle (Miller and Bundtzen, 1988).

The quartz syenite phase of the Russian Mountains pluton syenite yielded a radiometric age of 70.31 m.y. (#2, table 2). The thermally altered lava (#4, table 2) is, within analytical error, the same age as the stock and was probably partially equilibrated by the latter intrusion. Overall contact relationships reinforce the contention that the volcanic rocks are hornfelsed and partially assimilated by underlying plutons. Rare earth element distribution (figs. 4, 5) also supports a co-magmatic origin of the plutons and lavas. A Peacock diagram plot of both plutonic and volcanic rocks (fig. 9) shows a meta-aluminous alkali-calcic classification, similar to other volcanic-plutonic complexes studied in the Iditarod and McGrath Quadrangles north of the Russian Mountains (Bundtzen and Laird, 1982, 1983; Bundtzen and others, 1988; Bundtzen and Swanson, 1984). Overall, the Russian Mountains volcanic-plutonic complex shows potassium enrichments similar to many shoshonitic suites (McBirney, 1984). Their unusual pattern of mineralogy and geochemistry distinguish the Russian Mountains igneous complex from typical orogenic calc-alkaline magmas.

HORNFELS (TKhf)

The Russian Mountains pluton and some large dikes have thermally recrystallized enclosing host rocks. A pronounced thermal aureole forms a sharp high angle boundary with the plutonic rocks in the southern and western limits of the massif. The mapped hornfels (TKhf) is manifested in a resistant rib of dark gray,

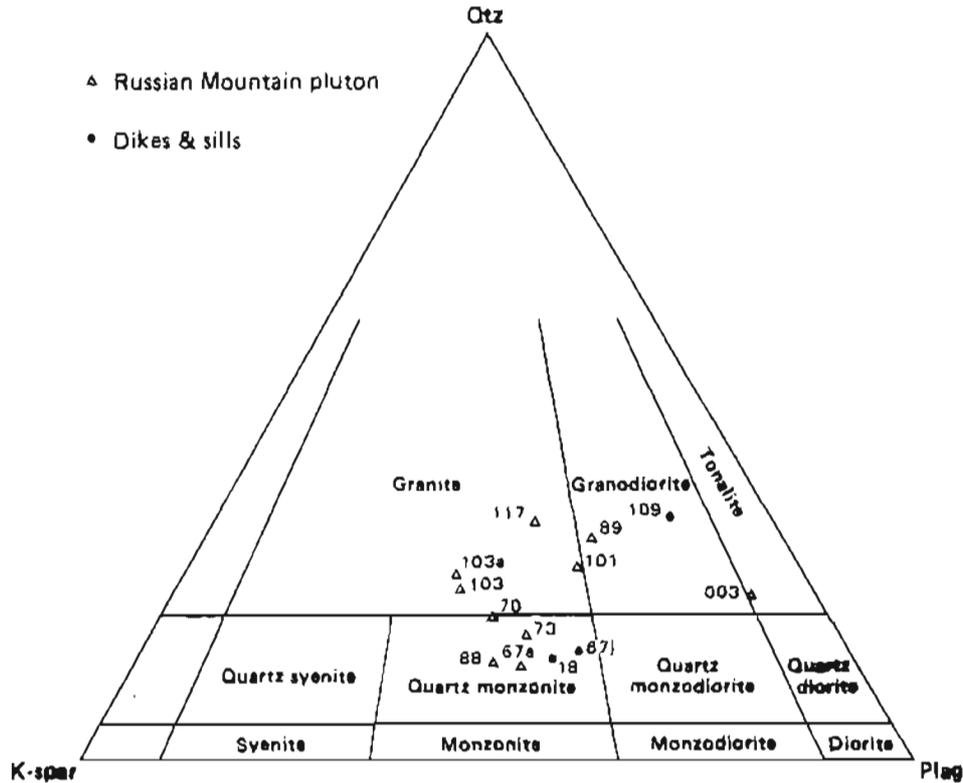


Figure 6. Quartz-K-spar-plagioclase plutonic classification scheme for Cretaceous granitic rocks from Russian Mission C-1 Quadrangle.

conchoidally fractured, massive metasilstone-argillite and metasandstone. In thin section hornfels is recognized as recrystallized sandstone and siltstone, but locally in outcrop, is nearly indistinguishable from aphanitic igneous rocks. The metasilstone-argillite contain white mica, epidote, and rarely biotite porphyroblasts but the metasandstone is simply recrystallized quartz and feldspar from the parent sedimentary rocks. Rare porphyroblasts of andalucite occur in the eastern pluton-hornfels contact zone within 100 m of the pluton. The hornfels grades transitionally from massive "aphanite" near the plutonic contact to dominantly "cherty argillite and metasandstone" 200-400 m away from the contact to slightly recrystallized sandstone mudstones and siltstone 400-700 m from the pluton. The total width of the thermally disturbed rocks is about 1 km.

Overlying volcanic strata has also been thermally affected by the pluton but are not mapped as hornfels because thermally affected areas are indistinguishable from fresh exposures in the field. However, the volcanic "hornfels" are more reactive than metasedimentary rocks and have created a more pervasive static metamorphic mineral assemblage of biotite, albite, epidote, actinolite, and locally pumpellyite. In local areas biotite overprinting is pervasive, resulting in a distinctive reddish-brown outcrop and talus, in contrast to non-hornfelsed gray and purple-hued lavas. A total extent of hornfels in volcanics could not be determined without additional detailed petrography.

Metamorphic conditions in both hornfels (TKhf) and the thermally affected lavas in (TKvm) ranged from the epidote-hornfels to hornblende hornfels metamorphic facies (Turner, 1968).

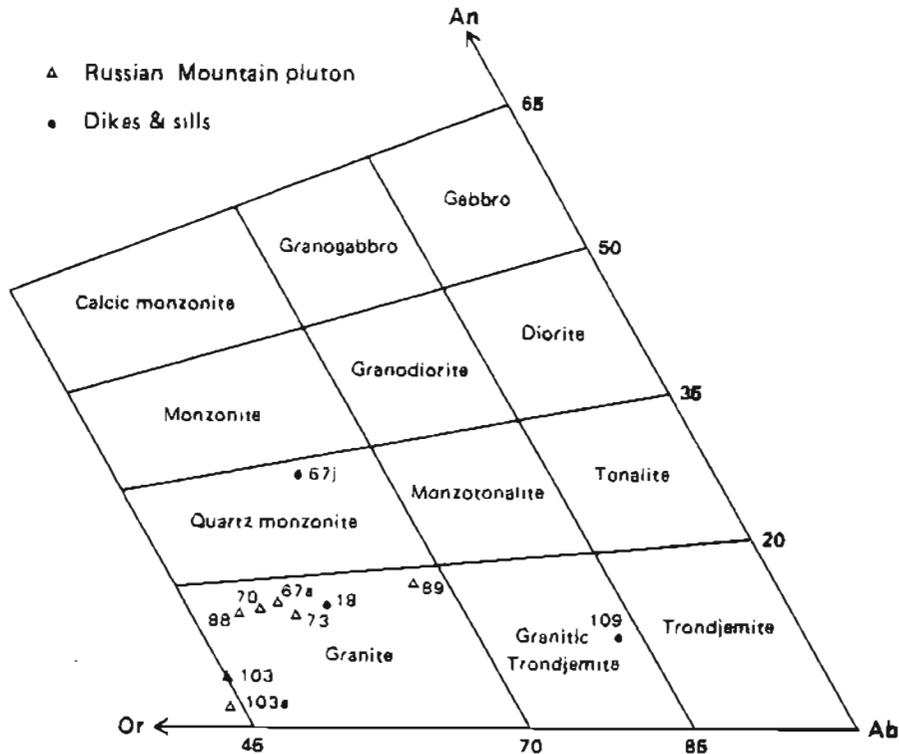


Figure 7. Normative orthoclase-albite-anorthite plot of plutonic rocks, Russian Mission C-1 Quadrangle. Norms from Table 1. Rock classification fields from Hiatanen (1963).

PLIOCENE-EARLY QUATERNARY BASALT (QTvb)

Essentially unaltered olivine-pyroxene, cavity-rich basalt flows cover a 7 km² elliptically shaded area on the western boundary of the map area. The lavas occur as a slightly inclined series of three or four columnar jointed flows each about 10 m thick that cap both the Kuskokwim Group flysch (Kus) and older 'Gemuk Group' greenstone, and argillite immediately west of Owhat River. In one thin section, olivine grains partly antigorized, and orthopyroxene are enclosed in a fine grained felted groundmass of calcic plagioclase (An₆₅) and undetermined oxides.

Evidently the basalt flows straddle the "Owhat" fault, probably a splay of the Iditarod-Nixon Fork (INF) fault, a major transcurrent fault system in western-southwestern Alaska. A single K-Ar radiometric age of 6.16 m.y. (table 2) was obtained from the QTvb unit.

QUATERNARY DEPOSITS

Six glacially related deposits, four colluvial dominated deposits, and four fluvial deposits have been subdivided in the map area.

Deposits of Glacial Origin (Qgt₁₋₄, Qrg, Qof)

Till (Qgt₁₋₄) has been subdivided into four distinctive lithologies on the basis of morphology, lateral extent, and age, mainly in the Russian Mountains area. These till units generally correspond to glacial stratigraphy summarized in the Kuskokwim Mountains and Alaska Range by Bundtzen (1980) and Kline and

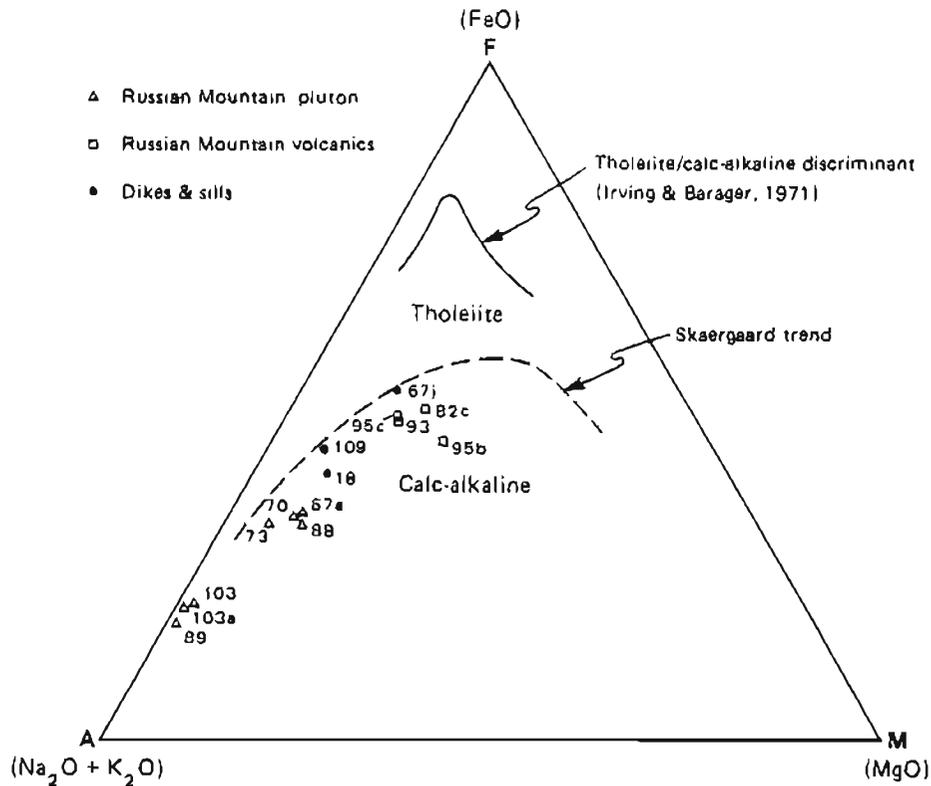


Figure 8. AFM plot of igneous rocks from Russian Mission C-1 Quadrangle, Alaska.

Bundtzen (1986). No radiometric ages or fossils have been reported from till in the study area and age assignments are based on geological inference. A summary of glacial advances is depicted in figure 10.

The oldest till (Qgt₁) consists of isolated patches of diamicton on two planated, north facing pediment surfaces north of Russian Mountains (pl. 1, fig. 7) at about 400 m altitude. Additionally, isolated intrusive erratics found on similar flat ridge crests west and east of the Russian Mountains (marked 'E' on pl. 1) are believed to be associated with Qgt₁ deposits. Planated summit levels dissected by erosion show the till is composed of intrusive dominated clasts to 20 cm diameter nested in silt rich matrix. Erosion has completely erased glacial morainal topography in Qgt₁ deposits. These oldest deposits are correlated with the pre-Wisconsin--probably pre-Illinoian--"Beaver Creek" glaciation in the northern Iditarod Quadrangle (Bundtzen, 1980). Judging from the wide fan-like configurations of the Qgt₁ till, and associated elevated terrace levels, the Russian Mountains may have supported a small 150 km² ice cap during Beaver Creek time.

Till of Qgt₂ age is expressed in two distinct terminal and recessional moraines on Mission and Cobalt Creeks, on the east fork of Owhat River and in less extensive moraines on seven other unnamed streams originating in the Russian Mountains. Ice occupied at least 24 cirques and drainages of all directional aspects contained some ice (Kline and Bundtzen, 1986, p. 147; fig. 10). Unlike the Qgt₁ Beaver Creek Glaciation, all ice was apparently confined to valley glaciers and no major divides were breached. The largest trunk glacier on Cobalt Creek of Qgt₂ age was fed by both tributary forks and was nearly 12 km long and up to 2 km wide during glacial maximums. Glacial deposits of the Bifurcation Lake drift of Early Wisconsin age in the Beaver Mountains (Bundtzen, 1980) are essentially identical in morphology to Qgt₂ deposits in the Russian Mountains.

Till deposits of Qgt₃ age are defined by several arcuate, steep fronted terminal moraines in the north directed Cobalt Creek and the east fork of Owhat River and till in cirques of distinct northerly orientations. Ice advanced a maximum 3 km down Cobalt Creek and the east fork, Owhat River. Till of Qgt₃ age is largely

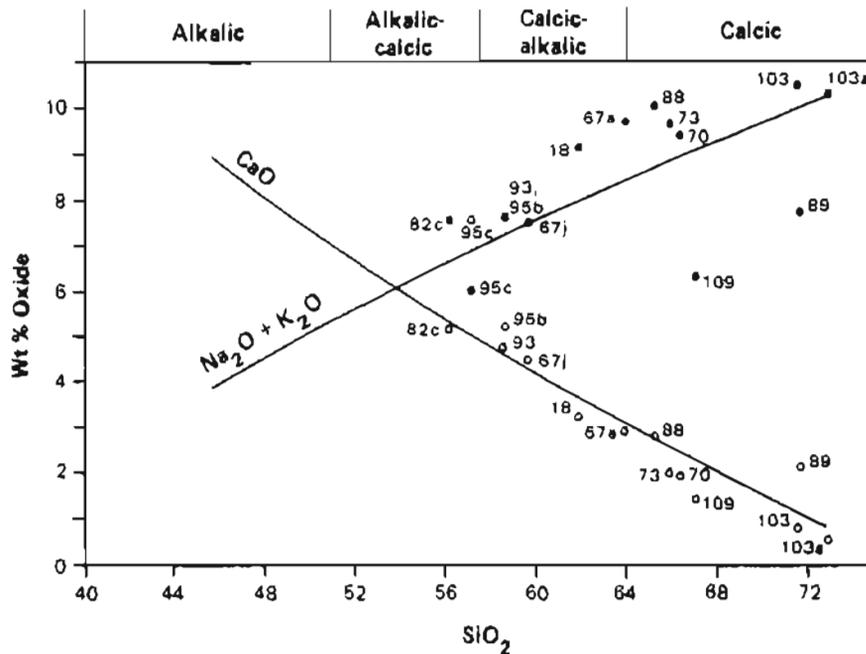


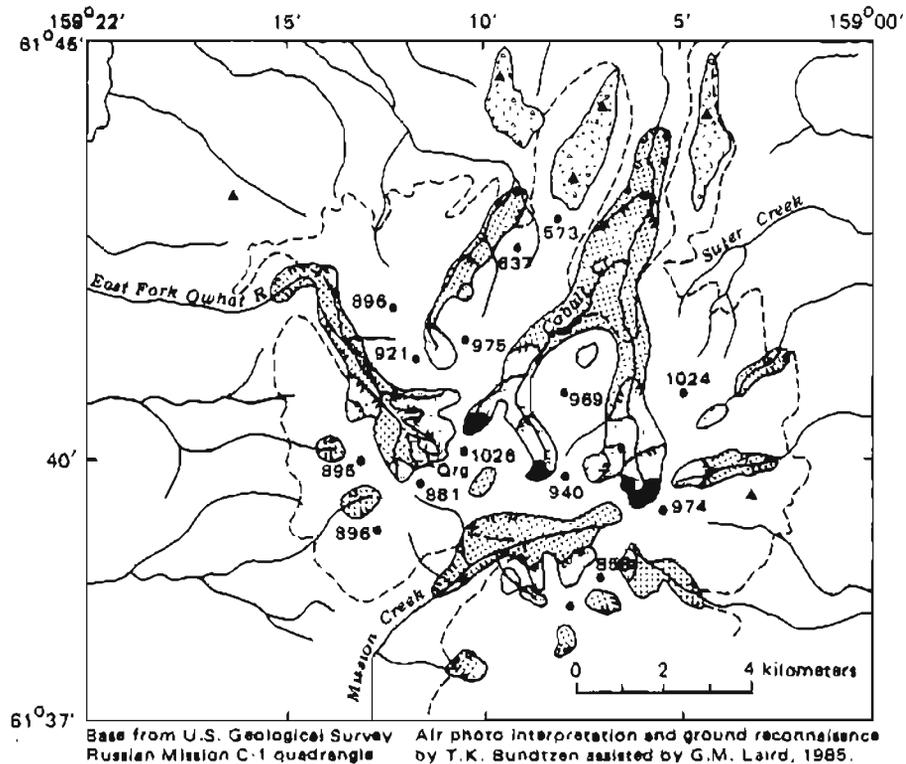
Figure 9. Peacock diagram plot of volcanic and plutonic rocks from Russian Mission C-1 Quadrangle, Alaska.

undissected by stream erosion in contrast to well dissected moraines of Qgt₂ age. Thirteen north-facing cirques were occupied by ice during Qgt₃ time. No valleys or cirques of southerly or westerly aspect contained Qgt₃ deposits. Till (Qgt₃) of this sequence is correlated with the Late Wisconsin Tolstoi Lake Glaciation in the northern Iditarod Quadrangle (Bundtzen, 1980).

Till believed to be of Early Holocene age is confined to three, anomalously high level, north facing cirques at the extreme headwall of the Cobalt Creek drainage (Qgt₄, pl. 1). Twenty-four cirques in the Russian Mountains average 620 m in elevation, but the suspected Holocene cirques average 690 m in elevation. Till of Qgt₄ age is essentially unmodified by stream erosion and cirque headwalls exhibit little colluvial modification. No soil development occurs on Qgt₄ deposits. The Qgt₄ deposits may be correlative with similar deposits of Holocene age described in the Beaver Mountains and Alaska Range (Kline and Bundtzen, 1986).

Eight rock glaciers (Qrg)--all believed to be presently inactive--occupy cirques in the Russian Mountains. Spatulate shaped masses of poorly sorted angular boulders and smaller rock fragments are usually derived from plutonic lithologies. In the east fork Owhat River a cirque headwall composed completely of more play volcanic detritus have formed rock glaciers. All rock glaciers probably formed in cirques of Tolstoi Lake (Late Wisconsin) age at altitudes of 550-610 m and probably formed immediately following deglaciation.

During an Early or pre-Wisconsin glacial maxima (Qgt₂, pl. 1), several large fan-shaped outwash plains (Qof) formed in nearly all directions away from the Russian Mountains. The deposits are composed of near equal amounts of plutonic, volcanic, and hornfelsed rocks and appear as elevated, terrace-like deposits 20-150 m thick above modern dissected drainages. The largest Qof deposits on Mission Creek and east fork Owhat River, are 5-7 km long about 6 km wide, and average about 25 m thick, based on Kuskokwim River cuts of the former fan. The outwash fans represent distributary outwash from lateral or terminal positions of Early Wisconsin and possibly older glaciers. Similar features have been reported in the Beaver, Horn, and Chuilnik Mountains (Bundtzen, 1980; Cady and others, 1985; Waythomas, 1984).



EXPLANATION

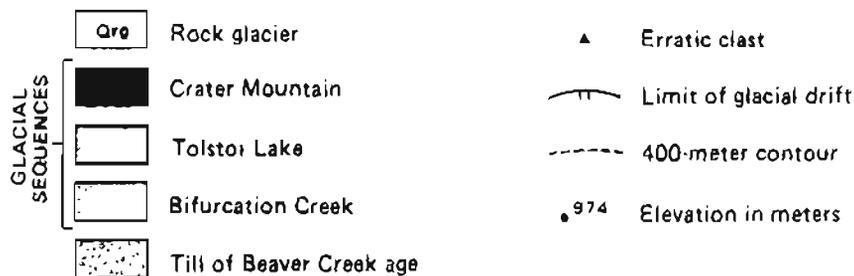


Figure 10. Map showing extent of Quaternary glacier advances in the Russian Mountains massif, modified from Kline and Bundtzen (1986).

Colluvial Dominated Deposits (Qctf, Qct, Qsp, Qca)

Following each successive glacial maxima and ice recession, valley walls collapsed and were rapidly modified by slope process including colluvial-alluvial fans (Qca), and buildups of colluvial-talus deposits at slope apexes (Qct). Along the southern limit of the Russian Mountains, poorly sorted composite alluvial-colluvial apron of fluvial fans and slope colluvium (Qctf) probably formed in part from the reworking of Early or pre-Wisconsin glacial fluvial deposits of the Mission Creek outwash fan (Qof).

Poorly stratified, organic rich, alluvial lacustrine and bog silt covers glacio-fluvial deposits in the Russian Mountains and floodplains of the Kuskokwim on Aniak Rivers in the southern part of the study area. In both

instances, Qsp deposition reflect stagnation of previous higher energy fluvial environment that existed in both areas. Peat deposits (Qsp) in the Russian Mountains consist of well stratified, frozen, peat layers 2 cm to 2 m thick in mound-like palsas that reach thicknesses of 10 m.

Fluvial Deposits (Qat, Qas, Qag, Qa)

Older fluvial deposits relict from paleostreams parallel modern drainage patterns (Qat). Compositionally Qat deposits are composed of limonitically stained clasts of igneous and sedimentary rocks derived from local sources. Most deposits are presumably of Quaternary age, but high level deposits could be deposited on Late Tertiary terrace levels. Sandy to cobble sized floodplain alluvium (Qa, Qag) continue to be deposited in rivers and streams in the study area. Those in upland areas are mainly coarse cobble-sand-silt deposits derived from erosion of local bedrocks sources. However, fluvial deposits in the valley of the Kuskokwim River are finer grained sand-silt-clay dominated and in part derived from bedrock and glacial debris that originated from sources many kilometers upriver. During seasonal flooding overbank muds up to 1 m thick cap floodplain deposits up to 3 m above normal highwater levels; these overbank deposits are depicted as Qas when of mappable size.

STRUCTURE

Pre-Cretaceous layered rocks have undergone at least two episodes of northeast trending, subisoclinal to open folding (see cross sections A, B, pl. 1). The comparative nature and timing of the fold deformation between the Gemuk Group and Kuskokwim Group were not accurately determined during this study. Fold axis of F₁ folds in outcrop range from N. 10 E. to N 60 E. and plunge steeply to the northeast. Locally secondary low angle cleavage has cut the folds suggesting significant low angle compressional stress formed in the layered rocks. Bedding attitudes in the Kuskokwim Group appear to all be right-side-up in the study area but overturned beds were observed by Bundtzen and others (1989) at Gibraltar Point about 20 km upriver in the Sleetmute Quadrangle. The timing of most fold deformation in the MzPzus, Kus, and Kls units probably coincides with Late-Cretaceous compressional tectonics that is better documented in the McGrath, Lime Hills, and Iditarod Quadrangles north of the study area (Bundtzen and Gilbert, 1983).

The Late Cretaceous andesitic lavas and tuffs in the Russian Mountains have been warped into broad, north-south trending synclines suggesting that a mild compressional episode followed Late Cretaceous-early Tertiary igneous activity.

Several prominent, N. 25-30 W. trending, vertical faults cut the Russian Mountains volcanic-plutonic complex in Cobalt Creek and East Fork, Owhat River. These fractures parallel a prominent joint orientation mapped throughout the pluton (pl. 1). Hydrothermal fluids and polymetallic sulfide mineralization have bled into the northwest trending fractures--probably shortly after crystallization of the pluton--and created mappable sericite-ankerite alteration zones (described in Economic Geology section). In the valley of east fork Owhat River, syeno-monzonite appears to be juxtaposed against porphyritic quartz monzonite along a N. 20 W. trending fault.

Ring-like high angle faults juxtapose andesitic lavas against quartz syenite in the eastern Russian Mountains (pl. 1). Previous workers (Cady and others, 1955) have suggested this contact relationship represents caldera collapse into a rising magma chamber; however, this fault relationship is not typical of most volcanic-plutonic contacts in the Russian Mountains.

The delineation of the "Aniak Fault" which is west of our map area, was based largely on photogeologic reconnaissance by Hoare and Coonrad (1959). Previous workers have shown the north-south trending "Aniak Fault" offsetting the Iditarod-Nixon Fork fault in a left lateral sense in the northeast corner of the Russian Mission Quadrangle.

We have mapped the north-northeast trending high angle "Owhat Fault" west of Owhat River (pl. 1), which juxtaposes the Kuskokwim Group against older Gemuk Group lithologies in the western portion of the study area. This contact relationship is not shown on previous geologic maps (Hoare and Coonrad, 1959; Miller and others, 1989); rather these workers show units west of Owhat River as part of the Kuskokwim Group. Our "Owhat Fault"--probably a splay of the Iditarod-Nixon Fork fault (INF)--appears to have been sealed by a 6.2 m.y. old basaltic flow section (Q_{tvb}) previously described. However, Early Quaternary terrace deposits in the Moore Creek area of the central Iditarod Quadrangle may be offset by the INF fault (Bundtzen and others, 1988).

Miller and Bundtzen (1988) proposed a Late Cretaceous- to present right lateral offset solution of 88-94 km for the INF fault, based on an offset restoration of the Late Cretaceous Iditarod volcanics in the Beaver Mountains northwest of the fault with those in DeCoursey Mountain area southeast of the fault. This restored Late Cretaceous offset solution would place the Russian Mountain complex directly south of similar but more mafic volcanic-plutonic complexes at Flat in the Iditarod mining district.

ECONOMIC GEOLOGY

INTRODUCTION

Mineral deposits in the Russian Mission C-1 Quadrangle consists mainly of several intrusive-hosted, copper-gold-arsenic-antimony-tin deposits that contain anomalous levels of zinc, tungsten, uranium, and cobalt. Two deposits have been explored with pits, shafts, and drifts, but no commercial production has been recorded. Heavy mineral placer deposits have been identified in immature high energy glacial outwash on Cobalt and Mission Creeks but no mineral production (of gold) is known. Modest amounts of sand and gravel have been produced for local needs and riprap prospects have been recently identified in the Russian Mountains and along the Kuskokwim River.

LODE DEPOSITS

Owhat Prospect

The Owhat quartz-gold-sulfide deposit was first discovered by Native prospectors near the head of Cobalt Creek (pls. 1, 2) shortly before 1900 (Cady and others, 1955; Holzheimer, 1926). Upon receiving information from the discoverers, Gordon Bettles prospected the Owhat property for gold shortly after 1900. Maddren (1915, p. 359-360) reported that by 1914, four claims of the 'February Group' covered about 4,000 ft (1,220 m) of strike length along a "vein deposit of the fissure type." A 12 m deep shaft initially explored the deposit. Holzheimer (1926) showed three shafts on the vein along the eastern edge of the 'Mary' and 'Louise' claims, the number observed during our investigations (pl. 2).

The Owhat prospect occurs in a bedrock lip that separates two distinct levels of cirques at the immediate head of Cobalt Creek at an average elevation of 480 m (pls. 1, 2). The sulfide bearing veins strike N. 24-28° W. and dip 75-83° NE., and can be traced for 265 m (870 ft) before disappearing under talus and glacial till in both directions. Isolated mineralized float found along strike both to the northwest and southeast suggests that the zone runs additional 200 m in both directions.

The mineralized zone consists of 8-10, closely spaced sulfide-tourmaline-axinite-quartz 'greisens' each several centimeters to 1 m thick over total widths ranging from 1.5 to 8 m, averaging about 2.5 m thick. Near the northwest end of the zone, the vein-fault splays into two distinct zones separated by host syeno-monzonite country rock. The mineralization is exposed from its lower northwest end of 442 m elevation to its higher upper end at 527 m elevation for a total vertical extent of 86 m (280 ft). Axinite bearing andesite porphyry (TKdi) makes up most of the eastern hanging wall of the ore body while syeno-monzonite comprises all of the western foot wall and some of the eastern hanging wall.

Mineral species in the vein include major arsenopyrite, chalcopyrite, and pyrite, and minor bornite, galena, sphalerite, a lead-antimony sulfosalt--probably boulangerite--and marcasite, in a gangue of quartz, tourmaline, and axinite. Ore textures and field evidence indicates that the intrusive-hosted polymetallic deposits formed during multiple events in the fracture system.

The earliest mineralizing event is formation of distinctly banded, fine-grained, black schorl (tourmaline) frequently attached to the hanging wall andesite porphyry. The tourmaline bands or greisen contains small xenoliths of syenite-monzonite plutonic rock. Distinctly red-stained, euhedral quartz crystals formed along the footwall side of the tourmaline greisen during the second mineralizing event. This quartz stage does not carry sulfides or free gold.

A third mineral stage introduced base metal sulfides, chalcopyrite, auriferous arsenopyrite, and pyrite, and the oxide cassiterite, all replacing vugs and sheets of replaced tourmaline greisen and quartz. Pyrite distinctly infill interstices between euhedral quartz crystals of the second stage. Some chalcopyrite forms finely laminae bands in the tourmaline-rich zones. A mineralizing fourth stage introduced bornite, tetrahedrite, sphalerite, and boulangerite all of which clearly crosscut previous sulfide species. A fifth and final stage of ore formation introduced minor arsenopyrite subsequent to brecciation and fault movement along the Owhat structure.

Holzheimer (1926) reported that "three 40 ft deep (13 m) shafts sunk on massive arsenopyrite kidneys bottomed out in gold-barren chalcopyrite." However we noted no obvious vertical termination of arsenopyrite mineralization in the 90 vertical meters of the system that we examined.

During our investigations, 16 chip-channel samples were collected in intervals with an average width of 1.4 m (4.4 ft) over a total strike length of 262 m (860 ft). All samples were run for 22 elements but some samples were not run for copper, lead, tungsten, and tin (table 3). However Holzheimer (1926) provided additional channel sample grade control that includes copper, gold, and silver that can be keyed to sample locations taken during our work (pl. 2; table 3).

Anomalous gold was detected in all but one submitted sample, with values ranging from 380 ppb (.012 oz/ton) to 19 ppm (.41 oz/ton) gold. Additionally 13 of 16 contained anomalous antimony, 4 of 16 contained anomalous tin, and 3 of 16 contained anomalous tungsten. All samples analyzed for copper and lead contained anomalous levels of these two elements. High gold values clearly follow increases in the arsenic content of the ores at a remarkably consistent ratio of 390 ppb gold for every 1 percent arsenic.

The following reserve calculations assume that the assay data in our 16 samples and those reported by Holzheimer (1926) are representative of the mineralized system. We also assume that 8.5 ft³ (0.25m³) of mineralization weighs 1 short ton (.905 metric ton). Two reserve estimates can be calculated: (1) a minimum inferred reserve based on the volume calculation of a triangular shaped block of ore defined by known strike length, average width, and vertical extent of mineralization observed on the surface; (2) a 'half square' estimate that assumes vertical extent of mineralization is equal to half the known strike length of the ore body (Harding, 1923). Utilizing an average width of 1.4 m (4.4 ft), a strike length of 265 m (870 ft) and vertical control of 86 m (280 ft) the Owhat prospect contains about 57,060 metric tons (63,050 short tons) grading 5.3 ppm gold (.156 oz/ton gold), 13.4 percent arsenic, 0.21 percent antimony, 0.39 percent copper, 0.07 percent tin, .05 percent zinc, and 0.017 percent cobalt. The Owhat deposit contains a half-square reserve estimate of 120,230 metric tons (132,850 short tons) of presumed equal grades to that calculated for the surface reserve.

Louise Prospect

The Louise prospect was first reported by Holzheimer (1926) as a 320 m (1,000 ft) long arsenic-gold deposit exposed in the lower cirque basin west of the lowest shaft at the main Owhat prospect. The old 'Louise' claim also includes shafts sunk on the Owhat prospect previously described. It consists of arsenopyrite, chalcopyrite, quartz, and black tourmaline in a poorly exposed vein trending N. 25-35 W. for at least 80 m (245 ft) along strike; no vein widths could be estimated due to lack of control. No sketches were made of this occurrence. As at the Owhat prospect, altered andesite porphyry dike rock apparently forms part of the

hanging wall of the vein; the remaining vein is hosted in syenite. One grab sample (88BT68, #10, table 3) contained 4.1 ppm gold (0.12 oz/ton gold), 10.00 percent arsenic, 0.99 percent antimony, and 0.12 percent tin. The single analyses contains 410 ppb gold for every 1 percent arsenic--a ratio in remarkable agreement with results from the Owhat deposit. Cady and others (1955) reported that "two samples from a short shaft 1,000 ft west of the Owhat prospect are reported to assay 1.40 percent and 1.22 percent tin respectively"; these samples are probably from the Louise Prospect.

Headwall Prospect

The herein named Headwall prospect (pls. 1, 2, #14, table 3) is located along the steep western headwall of a cirque basin about 1 km south of the Owhat deposit. Although primitive remains of tools and shovels were encountered by the authors, there are not published references for the deposit. The Headwall prospect consists of a wide tourmaline-quartz-sulfide greisen trending N. 32-34 W., dipping steeply southwest, for a minimum distance of 240 m (790 ft). The northwest extension of the zone disappears under talus and till in a glacial cirque; the zone may continue to the southeast for an unknown distance into the cliff face of the cirque headwall.

Sulfide mineralization and paragenesis is similar to that observed at the Owhat and Louise deposits but more disseminated in nature. Several, 3 m thick banded tourmaline greisen zones are well developed in southeast exposures, and replaced by euhedral quartz and sericite. Arsenopyrite, pyrite, and minor chalcopyrite cut the quartz and tourmaline and xenoliths of the former gangue minerals are found nested in sulfides. Post mineral movement has broken up the sulfide zone suggesting fault movement subsequent to mineralization. Unfortunately no copper or lead assays are available from the prospect. Vertical assay and geologic control of about 120 m (400 ft) is somewhat uncertain due to extensive talus cover over 40 percent along the strike of the vein. However, we still assume assay and geologic criteria calculations as the Owhat prospect. Volume and grade calculations using an assay width of 1.36 m (4.46 ft) a strike length of 240 m (790 ft) and a vertical extent of 120 m (400 ft), and six channel samples indicates an inferred reserve of 75,030 metric tons (82,900 short tons) grading 3.3 ppm (0.09 oz/ton) gold, 7.32 percent arsenic, 0.16 percent antimony, and 0.04 percent tin. A 'half square' reserve estimate is essentially the same as the surface calculated reserve. Gold values clearly correlate with high arsenic content and indicate 450 ppb gold for every 1 percent arsenic. The gold-arsenic ratio is also in remarkable agreement with results from the Owhat and Louise deposits.

Mission Creek or 'Konechney' Prospect

A complexly mineralized quartz-sulfide-tourmaline greisen vein has been explored by trenching and two levels of underground drifts at the head of Mission Creek about 1.2 km due south of the Headwall prospect and on the south side of the Russian Mountains drainage divide (pls. 1, 2). The 'Konechney' prospect has been described by Holzheimer (1926) and briefly by Cady and others (1955) and has undergone the most development of any prospect in the Russian Mountains.

Nine claims were located in 1921 and 1924 by prospectors Joseph Konechney and Charles Warden after discovering sulfide float on a low saddle above Mission Creek. Prior to 1926, a 100 m (360 ft) long drift was driven at the 2,150 elevation about 60 m (196 ft) below the discovery outcrops. A sketch of the underground workings from Holzheimer (1926) is included in our mine map on plate 2. (The original sketch by Holzheimer refers incorrectly to a S. 25 W. strike direction of the vein. True direction is N. 25 W.) Another drift was completed by Konechney approximately 62 m (204 ft) vertically below the 2,150 drift probably between 1937-42 (Ken Dahl, personal commun., 1988). We were unable to locate underground mapping control from this later drift. A rock cabin and blacksmith shop, both in a state of disrepair, were still visible at the 1,950 ft (595 m) elevation below the mine workings. The portals of both drifts were caved and inaccessible during our visits.

The Konechney deposit consists of quartz-sulfide tourmaline greisen veins similar to that observed at the Owhat, Louise, and Headwall prospects. Axinite bearing andesite porphyry dike rock parallels the N. 33 W. average strike of the mineralized zone in the upper levels, but splays off to the north in the lower workings. The zone dips 75-80° to the southwest in most surface exposures and underground sketches.

Sulfide-gangue paragenesis differs somewhat from the Owhat and Headwall deposits. Chalcopyrite, tourmaline, and quartz appear to be introduced simultaneously, followed by arsenopyrite, pyrite, metazeunerite (a copper-uranium-arsenic mineral), free gold and cassiterite. The cassiterite occurs as small, nearly black crystals interspersed in the quartz-tourmaline gangue on the hanging wall of the structure. The last mineral species to be introduced into the structure are the low temperature sulfides chalcocite, bornite, stibnite(?) and covellite. Abundant cuprite, azurite, malachite, goetbite, and chrysocolla appear on the mine dumps. Wedow and others (1953) and West (1954) investigated the Konechney deposit because of its anomalous uranium content. We obtained up to 106 ppm uranium in our samples (table 3).

The zone was traced for 150 m (470 ft) along strike before it is covered on its northwest limit by valley talus and vegetation. However the mineralized zone is clearly truncated on its southeast limit as trenching and sampling failed to find its extension beyond the high saddle. We use similar geometric and geologic assumptions employed at the Headwall and Owhat deposits. Assuming an average assay width of 1.05 m (3.4 ft) a minimum vertical extent of 120 m (400 ft) and strike length of 150 m (470 ft), 11 channel samples collected during our work and five channels collected by Holzheimer (1926) suggest an inferred reserve of 37,600 short tons (34,030 metric tons) averaging 4.44 ppm (0.13 oz/ton) gold, 1.64 percent copper, 1.14 percent arsenic, 0.24 percent antimony, and anomalous levels of tin, cobalt, uranium, and silver. Holzheimer (1926) reports up to 9.3 oz/ton (317 ppm) silver but our maximum for silver is 5.3 oz/ton (182 ppm). Volume estimates using the 'half square' method actually understates vertical dimension and overall tonnage based on the surface calculations.

Evidence of gold-arsenic association in the Konechney deposit is less convincing than those at Headwall and Owhat deposits. Examination of limited underground assay data from Holzheimer (1926) might also suggest a gold-copper association as well as an arsenic-gold correlation. If arsenic carries the gold, then there is 1,140 ppb gold for every 1 percent arsenic, about three times the ratio calculated for the three previous deposits.

Other Lode Prospects in the Russian Mountains

Isolated and generally poorly exposed quartz-sulfide occurrences were noted during the course of geologic mapping in the Russian Mountains. Gossan rich quartz veins occur in N. 30 W. trending fractures and joints in quartz syenite, about 2.5 km southeast of the Konechney deposit (#16, 17, table 3, pl. 1). The two occurrences, each about 0.5 m wide and about 150 m apart, contain up to 0.30 percent arsenic, 1.50 percent antimony and 353 ppm neodymium. No sulfides were recognized in the oxidized zones. The dimensions of the occurrence are severely limited by rubble and vegetation; however, both may be associated with nearby andesite porphyry dikes. Significantly the occurrences project northwesterly along strike toward the Konechney deposit.

A small drift (now caved) explored a gossan rich quartz vein in hornfels within 100 m of the hornfels/intrusive contact zone in the southern Russian Mountains (#9, table 3, pl. 1). Euhedral quartz crystals are particularly well developed in vugs in a sheeted vein, but poor exposure prevented measurement of the dimensions of the occurrence. The quartz vein rich material contains anomalous gold (250 ppb), arsenic (250 ppm), and tin (62 ppm).

A poorly exposed amethyst bearing vein containing anomalous uranium (38 ppm) occurs at 365 m (1,200 ft) elevation about 5 mi (8 km) north of Chauthbaluk (#20, pl. 1). Rubble material indicates that the crystals have grown in small vugs in a brecciated quartz flooding zone in hornfels. The amethyst ranges in size from 1-5 cm in length and is frequently double-terminated in crystal habit. Colors vary from light purple to a blue hue and average a moderate purple. Lack of exposure prevented further examination of the property.

A discontinuous sulfide-quartz vein is hosted in syeno-monzonite intrusive cupola zone immediately below thermally altered andesite flow rocks (TKvm) in the western Russian Mountains (#2, table 3, pl. 1). Veins mineralization appears to be confined to intrusive host rock and does not extend upward into hornfelsed volcanic cap rocks. Two thin veins 1-3 cm thick have intruded along N. 40 W. trending joints in the plutonic rocks for a total traceable length of about 20 m. Malachite stained rubble crop contains minor chalcopyrite,

arsenopyrite, and galena in quartz gangue. One grab sample contained anomalous arsenic (0.46 percent), antimony (0.30 percent), silver (45 ppm), but no gold. The occurrence, although small, is similar to those in the Cobalt Creek and Mission Creek prospect, previously described.

Lode Deposit Paragenesis

Lode deposits in the Russian Mountains all share many similarities in structural style, geologic relationships, and metallic and mineralogic content. Nearly all are hosted in N. 20-40 W. trending joints and fractures in host plutonic rocks, and exhibit a ubiquitous association of axinite bearing andesite porphyry dike rocks in the hanging and footwalls of the vein-fault structures. We are unsure whether or not the andesite dikes have a genetic association with the ore bodies or are simply intruding along the same favorable structural channel ways. Deposits in the Russian Mountains are high temperature, 'greisen-like' vein faults with fluid inclusion data from the Mission Creek Prospect (N=4) indicating temperatures of formation ranging from 280-410°C. Limited microprobe analyses from the Owhat Prospect show atomic percent arsenic in arsenopyrite ranging from 29.0 to 33.0 percent. Compositional plots using techniques described by Kretschmar and Scott (1976) would indicate arsenopyrite-crystallization temperatures averaging 320°C. If cassiterite and arsenopyrite formed synchronously at the Mission Creek Prospect, then temperatures of formation should have been at least 400°C.

The quartz-sulfide deposits are similar in many ways to those of the Bolivian tin-silver belt--specifically deposits in the Cordillera Quimsa Cruz near LaPaz (Lindgren, 1932; Sillitoe and others, 1975). However, the deposits exhibit a puzzling association of gold and tin. Worldwide, the presence of gold usually implies the absence of tin and vice versa and gold is not a noteworthy occurrence in the Bolivian tin deposits (Lindgren, 1936; Cox and Singer, 1986). Similar deposits rich in copper and arsenic are described in the Beaver Mountains and Golden Horn area near Flat (Bundtzen and Laird, 1982; Bull, 1988; Bundtzen and others, 1988b).

Although each deposit in Cobalt and Mission Creeks are of modest size, all four and associated mineral occurrences represent a definable structurally controlled zone of vertically dipping, intrusive-hosted ore shoots striking N. 25-35 W., and continuous over 5 km of strike and 3 km of width. Limited channel sampling at the four deposits show a minimum inferred reserve of 229,300 metric tons (253,350 short tons) grading .12 oz/ton gold, 0.19 percent antimony, 9.95 percent arsenic, 0.61 percent copper, .014 percent tin, and anomalous silver, cobalt, tungsten, uranium, and zinc. It is likely that a larger resource exists in the Russian Mountains mineral zones.

Miller and Bundtzen (1988) suggest that, when right lateral translation along the Iditarod-Nixon Fork Fault is restored, the Russian Mountains 'line up' in a north south configuration with the volcanic-plutonic complexes in the Iditarod district. We herein note similarities between the arsenic enriched, intrusive hosted gold deposits in the Russian Mountains with those such as the Golden Horn arsenic-scheelite gold deposits hosted in the Black Creek monzo-gabbro of the Iditarod district. However, tourmaline enrichments that typify the Russian Mountains system are generally lacking in the latter mineral district.

Bundtzen and Miller (1989) presented a metallogenic model for ore deposits in the Kuskokwim region associated with meta-aluminous and peraluminous, alkali-calcic, Late Cretaceous-Early Tertiary stocks, volcanics, and sills in the Kuskokwim Mountains. The model classifies polymetallic deposits formed in epithermal to hypothermal ore conditions by comparing temperature-pressure, mineralogical, alteration, structural, and geological data. Bundtzen and Miller (1989) suggest that all deposits represent similar vertically zoned systems exposed in several erosional levels in the Kuskokwim Mountain. Intrusive hosted polymetallic deposits in the Russian and Beaver Mountains and Black Creek stock are indicative of the highest temperature/pressure, intrusive-hosted ore deposits of the 'Kuskokwim mineral belt.'

PLACER DEPOSITS

There has been no known production of placer gold or other heavy minerals in the study area despite the presence of gold bearing lode sources for placer concentrations in streams of the Russian Mountains. The

existence of multiple glacial-fluvial cycles may have buried or diluted concentration of placer minerals in the Russian Mountains. Previous prospectors have searched for but did not find economic concentrations of placer gold in the adjacent Owhat Upland (Maddren, 1915).

However, two placer occurrences are known in the Russian Mountains. According to Maddren (1915, p. 339) "prospects of placer gold are present in the gravels of Mission Creek below the (Konechney) prospect, and the placer gold is presumed to be derived from the mineralized zones." We did not investigate the placer deposits of Mission Creek. We panned placer gold in Cobalt Creek about 1.5 km below the Owhat gold-arsenic deposit (#12, pl. 1, table 3). Concentrates from three panned gravel samples yielded 68 ppm (2.0 oz/ton) gold, .042 percent arsenic, 0.15 percent tin, and .013 percent tungsten. The samples were obtained from extracting fine sands and gravels tightly locked between a coarse boulder pavement of syeno-monzonite float up to 1 m in diameter. Hence, despite positive gold values, the nature of the placer material could pose significant engineering obstacles.

Bundtzen and others (1987) reported anomalous placer gold below dissected till of Early Wisconsin age on Tolstoi Creek in the Beaver Mountains about 100 km north of the Russian Mountains. Both the Beaver and Russian Mountains contain similar hardrock metallic lodes, and a similar glacial history but lack economic placer deposits. However, Early or pre-Wisconsin, auriferous till, if reworked by Holocene streams, might produce economic concentrations of heavy minerals. Hence we suggest that sites below the terminuses of Qgt₂ and Qgt₁ till on Cobalt and Mission Creek deserve to be prospected for placer gold and other heavy minerals.

INDUSTRIAL MINERALS AND FUEL

Aggregate

Coarse cobble-to-boulder bearing outwash deposits form two large fans on the east fork Owhat River and in the Mission Creek drainage (pl. 1). The Mission Creek fan includes a huge, multi-million cubic meter resource accessible by the Kuskokwim River. Gravel at rivers edge consist of 20-35 m thick zones of interbedded coarse cobble gravel and sand containing equal amounts of volcanic and intrusive float from the Russian Mountain. Sieve analysis of gravel, where coarse cobbles have been selectively removed of a 20 kg sample, indicate a coarse silty-sandy gravel aggregate classification. Approximately 35 percent of this material was coarser than 9.5 m (3/8 sieve) and nearly 10 percent was coarser than 37.5 mm (1-1/2 in.) sieve testing (fig. 11). In 1987, 16,100 short tons of the Mission Creek fan were used in Chauthbaluk for road repairs, airport maintenance and foundation preparation.

Several hundred thousand tons of channel lag sands and pea gravels in the Kuskokwim River at Birch Tree crossing about 40 km below Chauthbaluk have been dredged and shipped to Bethel for construction needs. Similar resources exist beneath the active flood plain and in oxbow bends (Qag) of the Kuskokwim within the map area, but none, to our knowledge, have been developed.

Riprap

Bundtzen and others (1989) assessed three river front bedrock sites in the study area for potential riprap applications. The City of Aniak immediately downstream from the study area in the Russian Mission C-2 Quadrangle has experienced sever bank erosion problems due to spring flooding and migration of the active channel of the Kuskokwim River. Location of a local riprap source has been assigned a high priority for proposed erosion control project.

At the "southcentral Russian Mountain site, 87MDT32" (Bundtzen and others, 1989) a steep bluff of coarse sandstone, 8 km upriver from Chauthbaluk, was tested and judged to be a submarginal riprap source. At "Chauthbaluk site, 87MDT32," prominent mafic dikes and hornfels were investigated and found to contain 13,500 tons (11,000 m³) Class I and Class II riprap (Bundtzen and others, 1989). However, Alaska T-13 degradation testing value of 10 from this locality is below that recommended for riprap.

UNIFIED SOIL CLASSIFICATION

Cobbles	Gravel		Sand			Silt or clay
	Coarse	Fine	Cr. s.	Medium	Fine	
U.S. sieve size in inches			U.S. standard sieve no.			Hydrometer

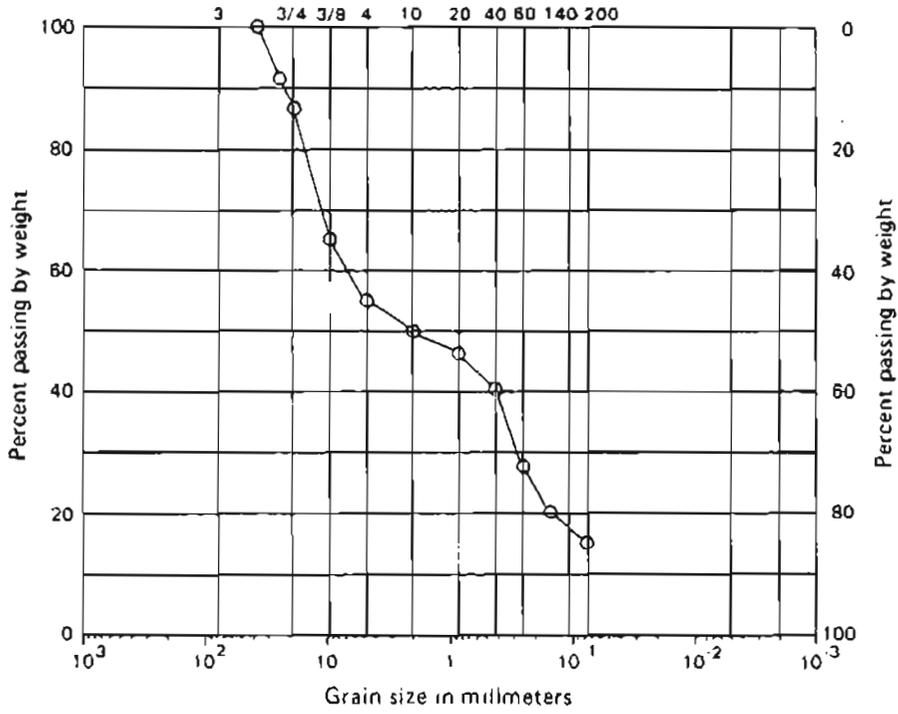


Figure 11. Grain size distribution of Mission Creek, Fan, Russian Mission C-1 Quadrangle, Alaska.

Quartz monzonite exposures at the southwest toe of the Russian Mountains were judged by Bundtzen and others (1989) to contain the best resources of riprap. Nearly 2,000,000 cubic meters of shallow, near surface Class I-III riprap can be accessed from Chauthbaluk 4 km south of the site. Additionally a T-13 degradation value of 86 was obtained from the quartz monzonite, the highest quality result of any obtained during the Kuskokwim riprap study. The quartz monzonite could be influenced by ground water weathering encountered in the Flat and Candle areas (Bundtzen and others, 1989); however, we judge that shallow surface reserves alone constitute a large enough resource to satisfy riprap projects in the area. Further subsurface (drilling) and blasting should be conducted at the site for conformatory testing, if a positive decision to further evaluate the site is reached.

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Table 1. K-Ar analyses for selected rock samples from Russian Mission C-1 Quadrangle, Alaska^a

Map (field) no. Rock type	1 (88BT113) Vesicular basalt	2 (85BT174) Biotite pyroxene quartz monzonite	3 (88BT85) Pyroxene andesite tuff	4 (88BT115) Thermally altered pyroxene andesite
Mineral dated	Whole rock	Biotite	Whole rock	Plagioclase
K ₂ O (wt%)	0.667	8.962	4.355	0.608
Sample wt (g)	2.1695	0.1197	0.8317	1.7766
⁴⁰ Ar [*]	0.5944	92.4975	48.5118	6.2247
(mol/g) × 10 ⁻¹¹				
⁴⁰ Ar [*]	0.3600	4.1658	4.4960	4.1322
⁴⁰ K × 10 ⁻³				
% ⁴⁰ Ar [*]	37.87	80.58	90.28	93.75
Age ^b ± 1 σ (m.y.)	6.19 ± .19	70.31 ± 2.11	75.77 ± 2.27	69.76 ± 2.09 (minimum age)

^aAnalyses by Robin Cottrell, DGGS-University of Alaska Cooperative Geochronology Laboratory, Fairbanks, Alaska.
 Constants used in age calculations: $\lambda_{\beta} = 0.581 \times 10^{-10} \text{ yr}^{-1}$; $\lambda_{\alpha} = 4.962 \times 10^{-10} \text{ yr}^{-1}$; and $^{40}\text{K}/\text{K}(\text{total}) = 1.167 \times 10^{-4} \text{ mol/mol}$.
^{*} Radiogenic isotope.

Table 2. Major oxide analyses and CIPW norms of igneous rocks from Russian Mission C-1 Quadrangle, Alaska^a

Map no. Field no. Rock type	1 88BT109 Quartz porphyry (TKf)	2 88BT107 Altered basalt (MzPzvs)	3 88UT95c Andesite tuff (TKv)	4 88BT95b Andesite (TKvm)	5 88BT193 Basaltic andesite (TKvm)	6 88BT103B Quartz monzonite (TKmp)	7 88BT103A Quartz monzonite (TKmp)	8 88BT62C Basaltic andesite (TKvm)	9 88BT67J Syeno- monzonitic (TKsym)	10 88BT67A Quartz syenite (TKsy)	11 88BT89 Felsic porphyry (TKf)	12 88BT88 Quartz syenite (TKsy)	13 88GL18 Quartz syenite (TKsy)	14 88BT70 Quartz syenite (TKsy)	15 88BT73 Quartz syenite (TKsy)
Major oxides (weight %)															
SiO ₂	67.07	45.63	57.15	58.66	58.56	71.57	72.69	56.17	59.66	63.95	71.16	65.22	61.89	66.37	65.90
Al ₂ O ₃	16.38	12.80	20.16	15.44	17.44	14.75	14.42	16.61	16.44	16.46	16.02	16.25	17.20	15.89	16.25
Fe ₂ O ₃	1.67	6.50	1.98	2.10	1.21	1.36	1.18	1.55	1.59	0.63	0.67	0.87	1.31	1.30	1.07
FeO	2.13	14.60	3.04	3.98	4.41	0.76	0.81	4.85	4.74	2.64	0.52	2.45	3.00	2.38	1.97
MgO	0.96	2.41	2.26	4.97	2.82	0.29	0.21	3.81	2.39	1.60	0.16	1.74	1.74	1.48	0.97
CaO	1.42	7.85	7.56	5.20	4.78	0.79	0.55	5.19	4.50	2.92	2.12	2.80	3.23	1.92	2.00
Na ₂ O	4.85	1.71	3.33	2.84	3.17	3.55	3.49	2.68	2.94	3.63	4.03	3.43	3.92	3.27	3.84
K ₂ O	1.64	1.03	2.70	4.78	4.45	6.92	6.82	4.87	4.56	6.05	3.69	6.59	5.22	6.12	5.80
TiO ₂	0.57	1.30	1.12	0.88	1.11	0.32	0.28	1.02	0.91	0.58	0.10	0.60	0.70	0.58	0.47
P ₂ O ₅	0.26	0.79	0.60	0.42	0.52	0.08	0.07	0.50	0.41	0.26	0.07	0.21	0.24	0.17	0.18
MnO	0.08	0.50	0.09	0.10	0.08	0.02	0.02	0.07	0.11	0.05	<0.01	0.06	0.07	0.05	0.06
LOI	2.67	3.00	0.54	0.77	0.16	0.54	0.62	1.68	1.30	0.55	1.73	1.02	1.66	1.49	1.35
CO ₂	0.47	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	1.43	<0.20	<0.20	<0.20	<0.20	<0.20	0.51
26 Total	100.17	98.12	100.53	100.14	98.71	100.95	101.16	99.00	100.98	99.32	100.28	101.24	100.18	100.82	100.37
CIPW norms (weight %)															
Quartz	28.913	4.744	8.869	6.246	7.785	22.450	24.826	4.690	10.791	10.773	29.326	11.362	8.978	17.267	15.435
Corundum	4.807	0.000	0.000	0.000	0.000	0.174	0.462	0.000	0.000	0.000	1.735	0.000	0.008	0.808	0.456
Orthoclase	9.988	6.536	15.956	28.425	26.683	40.724	40.084	29.570	27.426	36.195	22.126	38.856	31.309	36.408	34.791
Albite	42.293	15.537	28.178	24.182	27.216	29.914	29.371	23.300	25.319	31.096	34.000	28.958	33.666	27.854	32.982
Anorthite	5.511	25.996	32.089	15.361	20.512	3.383	2.259	19.430	18.518	10.885	10.208	9.460	14.128	8.472	8.879
Diopside	0.000	8.845	1.208	6.289	0.087	0.000	0.000	2.995	1.225	1.699	0.000	2.476	0.448	0.000	0.000
Hypersitene	4.256	23.610	7.312	13.774	12.577	0.719	0.607	14.526	11.651	6.702	0.663	6.008	7.630	5.789	4.552
Magnetite	2.496	10.121	2.871	3.064	1.780	1.845	1.702	2.309	2.346	0.925	0.986	1.259	1.928	1.898	1.575
Ilmenite	1.116	2.651	2.127	1.682	2.139	0.605	0.529	1.991	1.759	1.115	0.193	1.137	1.349	1.109	0.906
Apatite	0.620	1.964	1.389	0.979	1.222	0.184	0.161	1.190	0.966	0.610	0.164	0.485	0.564	0.396	1.423
Total	100.000	100.004	99.999	100.002	100.001	99.998	100.001	100.00	100.001	100.000	100.001	100.001	100.000	100.001	100.999
Differentiation index	81.193	26.818	53.003	58.853	61.684	93.089	94.280	57.560	63.535	78.065	86.052	79.176	73.953	81.529	83.209
Plagioclase coop. (An)	11.520	62.591	53.245	38.84	42.977	10.160	7.143	45.471	42.242	25.927	22.782	24.623	29.560	23.221	21.211

^aAnalyses by Chemex Laboratories, Sparks, Nevada; using X-ray fluorescence method.

Table 3. Analytical results from prospects and mineral occurrences in the Russian Mission C-1 Quadrangle, Alaska*

Map no.	Field no.	Cu	Pb (%)	Zn	Au (ppb)	Ag (ppm)	As (%)	Sb	Mo	Sn	W	Ni	Co	Cr	U	Th	La	Ta	Cd	Remarks	
1	88BT96	--	--	ND	8	ND	008	.006	7	9	ND	ND	3	180	8	28	38	1	--	Iron stained syenite	
2	85BT177a	<u>02</u>	<u>94</u>	ND	ND	<u>45</u>	<u>0.46</u>	<u>0.30</u>	--	ND	ND	--	--	<u>700</u>	<u>41</u>	9	--	--	<u>900</u>	Quartz veinless in syenite	
3	88BT94	--	--	<u>0.10</u>	36	<u>75</u>	<u>0.27</u>	<u>0.20</u>	ND	23	ND	ND	4	210	7	12	32	ND	--	Shear zone, andesite	
4	88BT93c	--	--	.006	<u>180</u>	<u>7</u>	<u>0.02</u>	ND	6	12	ND	ND	17	310	5	10	36	ND	--	Columnar jointed, pyroxene andesite	
5	85BT778	004	001	ND	ND	ND	.001	.002	--	ND	3	--	--	76	7	14	--	--	ND	Iron shear zone in andesite	
6	88GL31	--	--	.01	ND	ND	.004	.005	10	ND	ND	ND	6	140	2	5	22	ND	--	Iron shear breccia in felsite	
7	85BT780	.003	.001	ND	ND	2	.003	.004	--	ND	ND	--	--	310	5	11	--	--	ND	Iron shear zone in hornfelsed andesite	
8	88BT101	--	--	.01	ND	ND	.005	.002	ND	ND	ND	ND	31	620	4	6	19	ND	--	Euhedral quartz vugs in basaltic andesite	
9	88GL21	--	--	ND	ND	ND	.007	.009	ND	<u>300</u>	ND	ND	4	310	6	11	14	1	--	Iron shear zone in peraluminous felsite	
10	88BT68	--	--	<u>0.70</u>	<u>4,100</u>	ND	<u>10.00</u>	<u>0.99</u>	ND	<u>1,200</u>	ND	ND	<u>40</u>	<u>200</u>	ND	ND	ND	<u>8</u>	--	Louise Prospect, arsenopyrite-chalcopyrite quartz vein in greisen	
11	88BT91	--	--	.004	15	ND	<u>0.33</u>	.002	ND	7	25	ND	8	230	6	14	28	ND	--	Pan concentrate, Cobalt Creek	
12	88BT92	--	--	<u>0.37</u>	<u>68,000</u>	ND	<u>0.42</u>	.006	16	<u>1,500</u>	<u>130</u>	<u>500</u>	<u>62</u>	<u>930</u>	16	22	66	<u>16</u>	--	Pan concentrate, Cobalt Creek tributary fan	
13	88BT67a	--	--	<u>0.52</u>	<u>1,600</u>	<u>130</u>	<u>2.80</u>	<u>0.21</u>	ND	ND	ND	ND	8	500	ND	3	8	5	--	Owheat prospect, 45 in. chip-channel of vein	
	88BT67b	--	--	ND	<u>9,600</u>	<u>460</u>	<u>23.00</u>	<u>0.46</u>	ND	ND	ND	ND	<u>79</u>	<u>300</u>	ND	ND	ND	ND	--	Owheat prospect, 48 in. chip-channel of greisen-sulfide vein	
	88BT67c	--	--	ND	<u>9,500</u>	ND	<u>26.00</u>	<u>0.29</u>	ND	ND	<u>340</u>	ND	<u>170</u>	<u>300</u>	ND	25	ND	ND	--	Owheat prospect, 32 in. chip-channel, greisen-sulfide vein	
	88BT67d	--	--	ND	<u>1,100</u>	ND	<u>4.30</u>	<u>0.39</u>	ND	ND	ND	200	7	7	ND	ND	ND	ND	--	Owheat prospect, 22 in. chip-channel, sulfide quartz vein	
	88BT67e	--	--	ND	<u>4,000</u>	ND	<u>17.00</u>	<u>0.25</u>	ND	ND	ND	ND	<u>600</u>	<u>34</u>	290	0.5	3	ND	5	--	Owheat prospect, 45 in. chip-channel, sulfide vein
	88BT67f	--	--	.004	<u>5,400</u>	ND	<u>20.00</u>	<u>0.25</u>	ND	ND	ND	ND	<u>900</u>	<u>300</u>	0.5	3	ND	<u>11</u>	--	Owheat prospect, 28 in. chip-channel, massive arsenopyrite vein	
	88BT67g	--	--	<u>0.13</u>	<u>14,000</u>	ND	<u>23.00</u>	<u>0.40</u>	ND	<u>620</u>	ND	<u>800</u>	<u>170</u>	<u>110</u>	ND	3	ND	<u>25</u>	--	Owheat prospect, 44 in. chip-channel, massive sulfide greisen vein	
	88BT67h	--	--	<u>0.25</u>	<u>19,000</u>	ND	<u>14.00</u>	<u>0.19</u>	ND	<u>2,900</u>	ND	<u>500</u>	<u>160</u>	<u>150</u>	ND	2	ND	ND	--	Owheat prospect, 18 in. channel, sulfide rich greisen	
	88BT67i	--	--	ND	<u>4,200</u>	ND	<u>21.00</u>	<u>0.36</u>	ND	ND	<u>320</u>	ND	40	200	0.5	4	0.5	ND	--	Owheat prospect, 38 in. channel, sulfide greisen	
	88BT67j	--	--	0.03	<u>2,900</u>	ND	<u>1.00</u>	<u>0.36</u>	ND	ND	ND	<u>900</u>	41	250	0.5	5	0.5	<u>7</u>	--	Owheat prospect, 72 in. channel, tourmaline greisen	
	82MR318A	<u>0.21</u>	<u>0.04</u>	--	<u>1,240</u>	17	<u>5.70</u>	0.06	--	ND	<u>13</u>	--	--	--	--	--	--	--	--	Owheat prospect, grab sample, tourmaline rich	
	82MR318C	<u>0.16</u>	<u>0.06</u>	--	<u>4,650</u>	<u>85</u>	<u>20.80</u>	ND	--	ND	3	--	--	--	--	--	--	--	--	Owheat prospect, quartz-tourmaline with arsenopyrite	
	82MR318D	<u>0.14</u>	<u>0.07</u>	--	<u>6,510</u>	<u>175</u>	<u>33.60</u>	ND	--	ND	3	--	--	--	--	--	--	--	--	Owheat prospect, massive arsenopyrite with cpy in tourmaline	
	82MR318E	--	0.01	--	<u>310</u>	6	<u>0.24</u>	0.01	--	ND	3	--	--	--	--	--	--	--	--	Owheat prospect, 92 in. channel, quartz-tourmaline	
	82MR318F	--	<u>0.02</u>	--	<u>1,550</u>	<u>53</u>	<u>1.37</u>	ND	--	ND	13	--	--	--	--	--	--	--	--	Owheat prospect - 36 in. channel, quartz-tourmaline	
	82MR318G	--	0.01	--	ND	<u>3</u>	<u>0.47</u>	0.04	--	<u>59</u>	ND	--	--	--	--	--	--	--	--	Owheat prospect - 15 ft channel, tourmaline greisen	
14	88BT89A	--	--	.007	<u>470</u>	ND	<u>0.41</u>	0.02	ND	<u>22</u>	10	ND	3	250	9	15	26	3	--	Headwall prospect, 38 in. chip-channel in greisen	
	88BT89B	--	--	<u>0.07</u>	<u>1,900</u>	ND	<u>5.10</u>	<u>0.05</u>	ND	<u>250</u>	ND	ND	1	110	3	2	4	ND	--	Headwall prospect, 27 in. chip-channel with arsenopyrite	
	88BT89C	--	--	0.007	<u>80</u>	ND	<u>0.12</u>	0.02	ND	24	26	ND	4	230	17	25	46	1	--	Headwall prospect, 85 in. chip-channel in greisen	
	88BT89D	--	--	ND	<u>7,900</u>	ND	<u>18.00</u>	<u>0.20</u>	ND	ND	10	ND	<u>170</u>	<u>310</u>	0.5	2	ND	ND	--	Headwall prospect, 34 in. chip-channel with arsenopyrite	
	88BT89E	--	--	0.05	<u>9,000</u>	ND	<u>20.00</u>	<u>0.70</u>	ND	<u>2,200</u>	ND	<u>900</u>	<u>75</u>	190	ND	5	ND	<u>9</u>	--	Headwall prospect, 72 in. channel in greisen	
	88BT89G	--	--	0.01	<u>210</u>	ND	<u>0.29</u>	0.005	ND	<u>13</u>	19	ND	30	310	3	6	23	ND	--	Headwall prospect, 65 in. chip-channel in greisen	

15	88H1724F	--	--	0.03	ND	7	0.61	0.56	ND	ND	ND	ND	ND	410	5	3	26	ND	--	Mission Creek prospect, 40 m chip-channel in horizontal
	88H1724	--	--	ND	1,900	ND	1.20	0.70	ND	300	ND	ND	ND	360	15	8	13	5	--	Mission Creek prospect, 65 m chip-channel with sulfides
	88H1724	--	--	0.01	900	ND	1.50	0.11	ND	ND	ND	ND	ND	120	10	11	22	1	--	Mission Creek prospect, chip sample in gossan
	88H1724	--	--	0.03	360	ND	0.77	0.77	ND	ND	ND	ND	ND	270	ND	18	28	4	--	Mission Creek prospect, 24 m chip-channel
	85H1784C	0.76	0.08	0.01	1,000	182	1.39	0.32	ND	100	ND	ND	ND	700	11	11	--	--	900	Mission Creek prospect, 36 m chip-channel
	85H1784B	2.20	0.03	0.02	5,580	9	2.35	0.18	ND	200	9	--	--	220	66	3	--	--	300	Mission Creek prospect, high grade from jump
	85H1784A	3.24	0.06	0.02	8,300	26	3.00	0.21	ND	200	19	--	--	220	106	3	--	--	300	Mission Creek prospect, 15 m chip-channel
	82MR315A	--	--	--	90	--	0.66	0.12	--	--	--	--	--	--	--	--	--	--	--	Mission Creek prospect, grab sample
	82MR315D	--	--	--	90	--	0.08	0.26	--	--	--	--	--	--	--	--	--	--	--	Mission Creek prospect, grab sample
	82MR315I	0.91	0.14	--	18,600	50	0.21	0.32	--	ND	3	--	--	--	--	--	--	--	--	Mission Creek prospect, high grade with retrograde quartz vein
	82MR315F	--	--	--	ND	--	0.02	0.02	--	--	--	--	--	--	--	--	--	--	--	Mission Creek prospect, grab sample
16	88H176	--	--	--	22	ND	0.02	0.03	ND	ND	8	900	900	180	14	21	27	ND	--	Quartz vein with gossan, grab sample
17	88H175	--	--	--	ND	ND	0.30	1.50	ND	ND	ND	ND	ND	310	52	11	51	ND	--	Quartz vein with gossan; contains 153 ppm neodymium
18	88G136	--	--	0.08	220	ND	0.06	ND	ND	ND	13	ND	ND	510	7	9	81	ND	--	Gossan shear zone in intrusive
19	87H151	--	--	0.029	250	ND	0.25	ND	ND	22	62	ND	ND	750	15	11	58	12	--	Lutiferous quartz vein 12 in. wide in hornfels; grab sample at dunp
20	87G137	--	--	ND	ND	ND	0.01	0.06	ND	10	ND	ND	ND	100	18	16	35	1	--	Amythest bearing vein in hornfels

Analyses of 87-88G1 and 87 samples by Nuclear Activation Services Ltd., Hamilton, Ontario, gold with fire assay methods and the remaining elements by ICP and Nuclear activation techniques. Analyses of 82MR and 85BT samples by Bondar-Clegg, Vancouver, British Columbia using fire assay. X-ray fluorescence, and induced nuclear activation methods. qv = quartz veins; epy = chalcopyrite; aspy = arsenopyrite. Undeclined samples are those considered anomalous by inspection.

-- = not analyzed.

ND = below limit of detection or masked by interference.