GEOLOGY AND MINERAL RESOURCES OF IDITAROD MINING DISTRICT, IDITAROD B-4 AND EASTERN B-5 QUADRANGLES, SOUTHWESTERN ALASKA

By Thomas K. Bundtzen, Marti L. Miller, Gregory M. Laird, and Katherine F. Bull

Professional Report 97

Prepared in cooperation with U.S. Geological Survey and Doyon Limited

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Discovery Camp, Otter Creek Valley, circa 1913. Photo courtesy of Dorothy Loftus Collection, University of Alaska Fairbanks Archives.

Cover: *Beaton and Donnelly (left) and Riley Investment Company (right) dredges in operation on adjoining claims near the mouth of Black Creek during the 1916 season. The two companies could not initially resolve a dispute concerning the location of a claim boundary. At one point the bucket lines were only 6 ft apart. The Beaton and Donnelly Dredge began mining up Black Creek later in the season. Photo courtesy of John Miscovich.*

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Richard E. Fullerton was born on May 17, 1921, in the Iditarod-Flat district and passed away in Anchorage July 29, 1990 after a brief battle with cancer. Both he and his brother John placer mined for a half century in southwest Alaska.

Like many family mining enterprises, the Fullterton operation began small. They started on Flat Creek with limited mechanized equipment consisting of second-hand tractors and simple sluicing devices. Through the years Fullerton mining ventures expanded to include elevated sluices, hydraulic stripping apparatus, draglines, and larger-scale heavy equipment with mines on Chicken, Happy, and Willow Creeks in the Iditarod district and on Colorado Creek north of McGrath.

For many years during the winter months Rich worked as an accountant for Northern Air Cargo Inc. and helped establish the company's bush routes. The information in this report has been greatly enhanced by the invaluable unpublished production statistics and gold geochemistry data that Rich supplied to us, and by his own ideas that he shared on the geological evolution of placers in the Iditarod-Flat area.

The picture from the Fullterton family files shows Rich with a series of gold pans filed with yellow metal from a typical cleanup on Happy Creek a few years ago.

We dedicate the report to Richard E. Fullerton--longtime miner and resident of the Iditarod-Flat district.

The authors

METRIC CONVERSION FACTORS

Factors for converting U.S. customary units to international metric units are as follows:

To convert from	to	multiply by
Mass		
Ounce, troy (oz tr)	kilogram (kg)	0.0311
Ounce, avoirdupois (oz avdp)	kilogram (kg)	0.0283
Pound, avoirdupois (lb)	kilogram (kg)	0.4536
Ton, short (2,000 lb)	tonne (mg)	0.9072
Tonne (mg)	ton (2,000 lb)	1.102
Length		
Foot (ft)	meter (m)	0.3048
Mile (mi)	kilometer (km)	1.609
Area		
Mile^2 (mi^2)	kilometer^2 (km^2)	2.590
Acre	hectometer^2 (hm^2)	.4047
Volume		
Yard^3 (yd^3)	meter^3 (m^3)	0.7646
Gallon	liter	3.785

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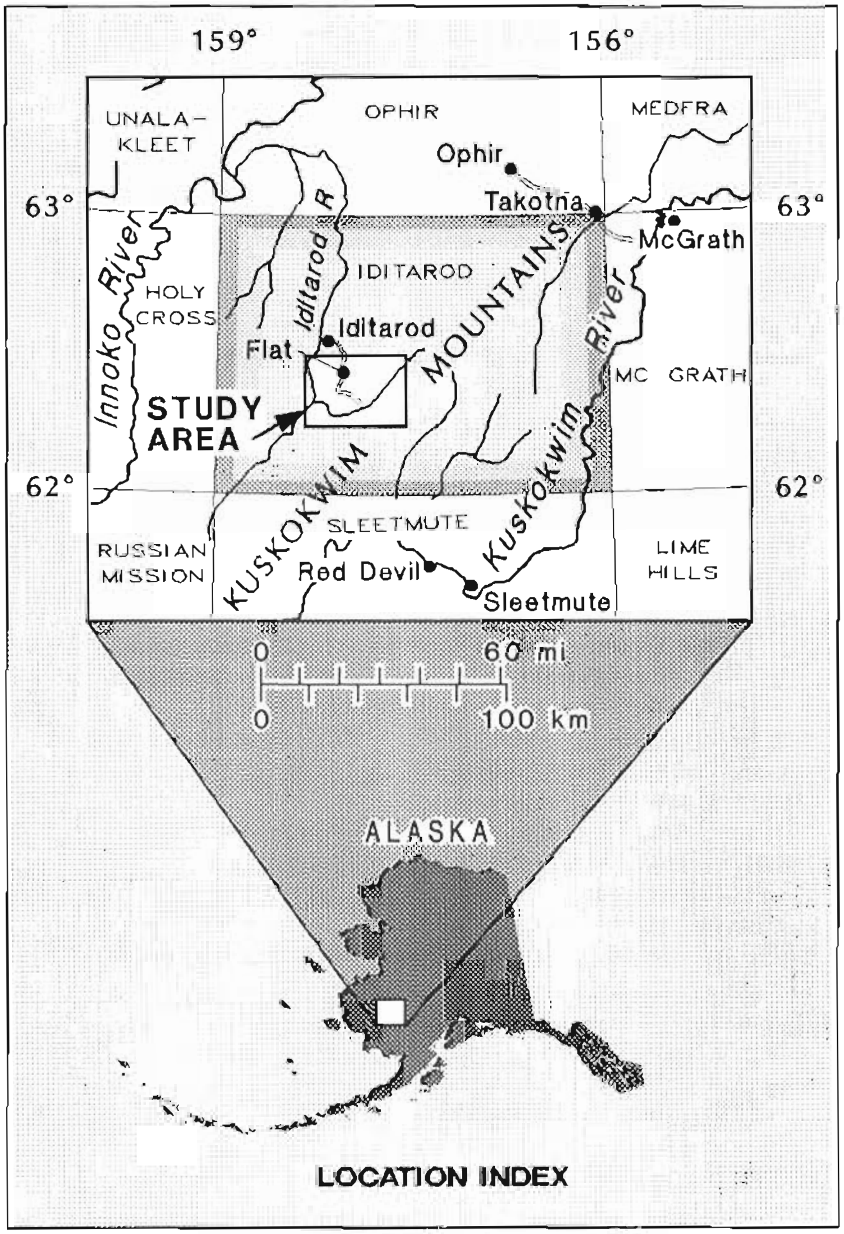

Figure 1. *Location map of Iditarod mining district, Iditarod B-4 and eastern B-5 Quadrangles, Alaska.*

GEOLOGY AND MINERAL RESOURCES OF IDITAROD MINING DISTRICT, IDITAROD B-4 AND EASTERN B-5 QUADRANGLES, SOUTHWESTERN ALASKA

By
Thomas K. Bundtzen,[1] Marti L. Miller,[2] Gregory M. Laird,[1] and Katherine F. Bull[3]

ABSTRACT

The Iditarod B-4 and eastern B-5 Quadrangles cover a 1,150 km² (480 mi²) area in the central Kuskokwim Mountains of southwestern Alaska. The region is dominated by accordant rounded ridges, underlain by sedimentary and volcanic rocks, that average 426 m (1,400 ft) in elevation and by steeper plutonic-cored massifs that average 700 m (2,300 ft) in elevation. A trellis stream drainage developed in the region underlain by sedimentary and volcanic rocks, whereas a radial-drainage configuration characterizes the plutonic-cored massifs at Chicken Mountain and Boulder Creek. The area is drained by the Iditarod River whose waters eventually empty into the Yukon River.

The region is sparsely populated. The population of Flat reaches about 45 during the summer's gold mining production and exploration activities.

Bedrock units range in age from Mississippian(?) to Late Cretaceous. The oldest lithologies are mafic metavolcanic and siliciclastic metasedimentary rocks of the Innoko terrane which have fauna dated as Mississippian(?) to Early Jurassic northeast of the study area.

Clastic sedimentary units of the Kuskokiwm Group, which ranges in age from early Late to middle Late Cretaceous, are in fault contact with or overlie the Innoko terrane along an angular unconformity. The Kuskokwim Group contains contrasting shallow water- and turbidite-dominated sections that are juxtaposed along the northeast striking Iditarod-Nixon Fork transcurrent fault.

Conformably overlying the Kuskokwim Group are subaerial, potassium-enriched (shoshonitic) intermediate and mafic volcanic rocks associated tuffs and sedimentary rocks that average about 76 m.y. Comagmatic with the volcanic rocks are intermediate plutons, peraluminous granite porphyry dikes and altered mafic sills. The plutons are metaluminous to peraluminous and range from alkalic-calcic to quartz alkalic rocks with an average composition of monzonite. We conclude from geochemical and isotopic evidence that the Upper Cretaceous volcanic and plutonic rocks were emplaced within a back-arc setting where extensional tectonics and partial crustal melting (high heat flow) took place.

Late Tertiary to Quaternary unconsolidated deposits formed in a periglacial environment beyond the limits of Pleistocene glaciation.

Sedimentary and volcanic units have been subjected to at least two periods of open to subisoclinal folding episodes with the most intense compressive stress directed at the rock formations southwest of the Iditarod-Nixon Fork fault, a major transcurrent fault.

Principal lode mineral deposits consist of zoned, hydrothermal, mesothermal to epithermal, gold-polymetallic deposits hosted in Late Cretaceous plutonic and volcanic rocks. The Golden Horn deposit contains minimum inferred reserves of 134,000 tonnes (148,000 tons) grading 9.9 g/tonne (0.29 oz/ton) gold, 21.8 g/tonne (0.64 oz/ton) silver, 1.9 percent arsenic, 1.2 percent antimony, and 2.0 percent tungsten. A larger lode that envelopes the Golden Horn deposit contains minimum inferred reserves that amount to 2.85 million tonnes (3.15 million tons) grading 1.2 g/tonne (0.035 oz/ton) gold, with anomalous silver, antimony, zirconium, tungsten, and arsenic values. Additional significant bulk-tonnage, polymetallic-gold resources within the district are indicated by similar deposits within the drainage of Black, Granite, and Boulder Creeks and on Chicken Mountain.

The gold-polymetallic deposits in the Iditarod district in some respects compare to alkalic, pluton-associated deposits in western North America. But, there are enough morphological differences to suggest that a separate plutonic-hosted deposit classification in the study area is warranted.

The well known heavy-mineral placer deposits in the study area, Alaska's third largest placer gold district, yielded 45,196 kg (1,453,000 oz) gold through 1990 and with byproducts of silver, tungsten, and mercury. Asymmetrical valley evolution and cryoplanation development in mineralized plutonic masses played dominant roles in the heavy-mineral placer development of the Iditarod mining district.

INTRODUCTION AND GEOGRAPHY

The Iditarod B-4 and eastern B-5 Quadrangles lie in the central part of the Kuskokwim Mountains, a maturely dissected upland of accordant rounded ridges and broad, sediment-filled lowlands (fig. 1). Elevations range from 85 m (280 ft) in the Iditarod flats near the abandoned townsite of Iditarod (sheet 1) to a 870 m (2,850 ft) unnamed mountain 5 km (3 mi) north of Discovery (sheet 1). The study area comprises most of the Iditarod mining district, an important Alaskan gold camp which has been in nearly continuous development and production since its discovery on Christmas Day, 1908. The technical results presented here are prepared in cooperation with the U.S. Geological Survey (USGS), which is completing studies in the Iditarod

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Quadrangle under the Alaska Mineral Resource Assessment Program (AMRAP). DGGS and USGS have shared data, personnel, and logistical services during the field and laboratory investigations.

Underlain by Paleozoic-Mesozoic sedimentary and volcanic rocks, accordant rounded ridges average 425 m (1,400 ft) in elevation. These formations contrast with steep, rugged Late Cretaceous plutonic and volcanic rocks and associated hornfels which average 2,300 ft (200 m) in elevation at Chicken Mountain and north of Discovery.

The study area is not connected to the Alaska state road network. About 58 km (36 mi) of improved secondary roads connect Flat with the abandoned townsite of Iditarod on the Iditarod River 10 km (6 mi) north of Otter Creek valley and with placer mining sites located on streams radially draining Chicken Mountain (fig. 1). Immediately east of Flat townsite on the Otter Creek flood plain, a 1,430 m (4,900 ft) airstrip serves as the transportation hub of the district. The airstrip is long enough for C-130 (Herculese) and DC-6 aircraft to land. Weekly U.S. mail service is available via the main Flat airstrip. Alaska Department of Transportation and Public Facilities (DOTPF) provides some maintenance support to the road system and to the Flat airstrip in Otter Creek valley. Other private airstrips at Willow and Prince Creeks can serve single engine Cessna-type aircraft. Only three to six people live in the area during cold winter months, but as many as 45 arrive for the summer. The summer population increases reflect the seasonal nature of placer mining and hard-rock exploration ventures.

State and Federal governments and private organizations all have landholdings in the area. Doyon Limited has selected four core townships in the main mineral district. The Federal government owns lands adjacent to the Doyon holdings. About 25 patented and 150 unpatented mining claims are held by various mining concerns. As of this writing, the State of Alaska has selected parts of three townships flanking Chicken Mountain; this selection amounts to about 30 percent of the project area.

BEDROCK GEOLOGY

INTRODUCTION

Eighteen mappable rock units ranging in age from Mississippian(?) to early Tertiary are exposed in the study area. All rock units were also studied in the laboratory using standard thin section (transmitted light) petrographic techniques, fossil identifications, multi-element and major oxide geochemical analyses, microprobe analyses of mainly ores, and ^{40}K-^{40}Ar radiometric dating of igneous rocks (tables 1-6).

Table 1. *Fossil identifications in the Iditarod B-4 and eastern B-5 Quadrangles, Alaska*[a]

Map no.	Field no.	Location and description of collection site	Fossil identification and age estimate
1	84BT239	Lat 62°29'00"N., long 157°53'10"W.; on eastern slope at 1,700 ft elevation in hornfels.	Conifer leaf shoot similar to those described by Hollick (1930) as *Sequoia obovata*, now regarded as *Metasequoai cuneata*. However, specimens here have spiral phyllotaxy which are exhibited in *Sequoia*. Dicot leaves of platanoid affinity; vein orientation most similar to those in the later Late Cretaceous and early Tertiary.
2	84BT17	Lat 62°26'10"N., long 157°40'00"W.; along bluff on northwest bank of Bonanza Creek at 600 ft elevation. Shells found at base of turbidite cycle.	Three *Inoceramus* sp., *I. teshioensis* shells; probably early Late Cretaceous (Turonian).
3	84AAi591	Southernmost knob in sec. 32, T. 27 N., R.45 W.	*Inoceramus* fragments; probably Cretaceous.
4	84BT97	Lat 62°21'15"N., long 157°53'50"W.; in placer mine cut along Prince Creek at 380 ft elevation; in Ksh unit.	*Inoceramus* pelecypod; probably Cretaceous.

[a]Fauna identifications by John W. Miller and William Elder (USGS) and flora identifications by Robert Spicer (University of London Goldsmith's College, England).

INNOKO TERRANE (JPzc)

The oldest exposed units crop out in the western part of the study area and consist of recrystallized, radiolarian chert, tuffaceous sandstone, basaltic andesite flows and flow breccia, and volcanic agglomerate (JPzc, sheet 1). In thin section, basaltic andesite is composed of relict phenocrysts of clinopyroxene altered to iddingsite and antigorite(?), leucoxene, albitized plagioclase, pumpellyite, and chlorite suggesting that metamorphic conditions reached the prehnite-pumpellyite facies. In chert and fine-grained clastic rocks, original sedimentary clasts have been blurred by metamorphism. This poorly exposed unit is believed to be equivalent to the Innoko terrane described farther to the northeast by Patton and others (1980); Chapman and others (1982, 1985); and Miller and Bundtzen, (1987, 1992). Based on field mapping in the Iditarod D-1, D-2, and C-3 Quadrangles (Bundtzen and Laird, 1982, 1983; Bundtzen and others, 1988a), we believe that Innoko terrane lithologies underlie much of the Cretaceous section north of the Iditarod-Nixon Fork fault.

KUSKOKWIM GROUP (Ksl, Ks, Ksc, Kssq, Ksl, Ksqf, Kac, Ksh, Kslt)

The major stratigraphic units in the study area are poorly exposed sandstone, conglomerate, siltstone, and shale of the Kuskokwim Group, which was first defined by Cady and others (1955) and ranges in age from late early Late to middle Late Cretaceous (fig 2). Limited fauna collections made during this investigation have been identified as Turonian (early Late Cretaceous) age (table 1). The most abundant fossil remains consist of plant debris and leaves in shallow-to-deep water facies and *Inoceramus* sp. pelecypods in marine sedimentary rocks (fig. 3).

Two contrasting stratigraphic sections of the Kuskokwim Group are juxtaposed against the Iditarod-Nixon Fork fault, which bisects the region into two roughly equal areas. Layered rock units southeast of the Iditarod-Nixon Fork fault consist of a folded and highly deformed section of undifferentiated turbidites (Ksl) successively overlain by lithic sandstone (Ks), coarse volcaniclastic pebble sandstone (Ksc), and siliceous fine-grained sublithic sandstone (Kssq) units that may indicate a coarsening and then shallowing(?) upward marine regime section at least 5,000 m (16,400 ft) thick. The stratigraphic base is not exposed in the study area. The Ksl, Ks, and Ksc units comprise graded beds, flute casts, and other indicators at high-energy-flow regimes. In contrast, the Kssq unit contains stacked cosets and other cross stratification features generally lacking in high-energy-flow regime environments. In the Ruby Creek area, the stratigraphic succession may be a series of at least two nearly identical, large-scale, cyclic, depositional sequences. Another viable explanation for the apparent repetition of beds would be one or several poorly exposed thrust faults structurally juxtaposing the older Ksl unit above younger Ksc-Ks-Kssq-Ksqf lithologies. Poor exposure and lack of disturbed fossil evidence prevented the authors from reaching any firm conclusions that could adequately explain the apparent repetition of the stratigraphic section; an inferred thrust plane is shown on sheet 1.

Poorly exposed, somewhat enigmatic volcanic agglomerate and brecciated chert (Kac) crop out in the Widgeon Creek drainage. The stratigraphic position of the

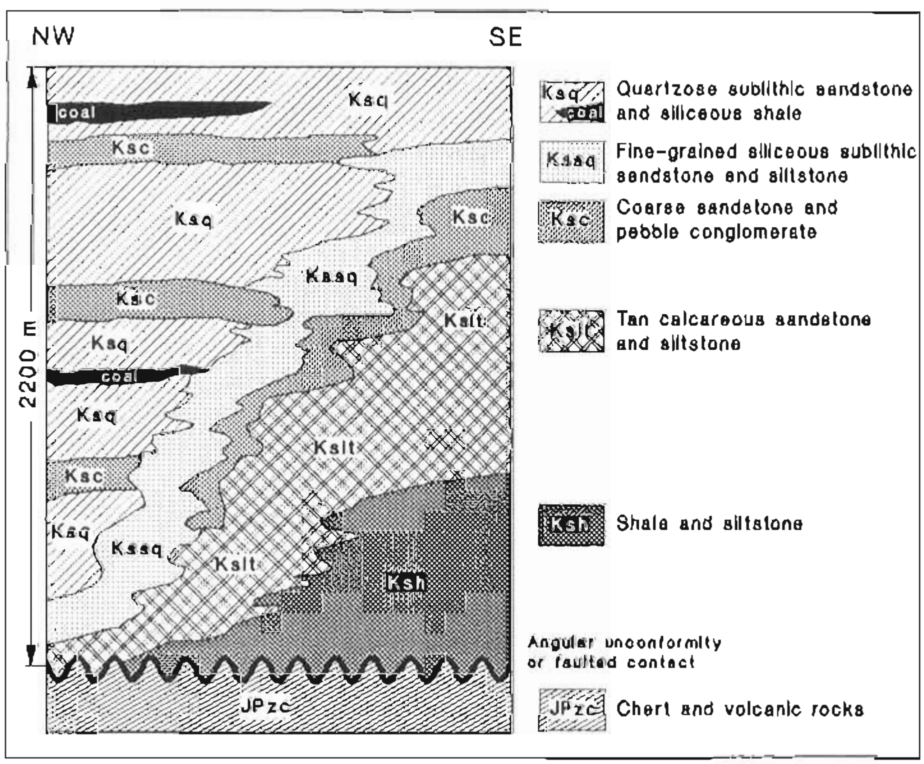

Figure 2. *Schematic section of Cretaceous sedimentary rock units in Iditarod B-4 and eastern B-5 Quadrangles showing interfingering relationships of lithologic units.*

Figure 3. *Inoceramid pelecypod recovered from bedrock cut in Ksh unit, Prince Creek drainage near sample site 84BT97; speciman supplied by Mr. Alvin Agoff. Inoceramids are the dominant fauna in the Kuskokwim Group of southwest Alaska.*

Kac unit is unknown, but it may be equivalent to initial volcanogenic units of Late Cretaceous age exposed throughout the Iditarod Quadrangle (Miller and Bundtzen, 1987, 1992). We infer that the Kac unit is, in fact, part of the Kuskokwim Group and interbedded with the clastic deposits near the top of the basinal section.

Northwest of the Iditarod-Nixon Fork fault the estimated 2,200-m-(7,200-ft)-thick sedimentary rock section is similar to that described near Moore Creek (Bundtzen and others, 1988a) to the northeast. The oldest recognized unit consists of shale (Ksh) overlain by calcareous turbidites rich in *Inoceramus* shell fragments and plant debris (Kslt). Increasing amounts of flora-rich, medium- to coarse-grained lithic sandstone and siltstone (Ks, Ksc) overlie the calcareous sands. In these units the presence of Ta-c Bouma intervals (Mutti and Ricci Lucchi, 1972), sand-shale ratios of about 4:1, and channeled sandstone bodies suggest multiple, wedge-shaped, turbidite fan cycles. Near the top of the section, significantly cleaner sublithic quartz-rich sandstone, and plant-rich shale (Kssq) dominate the rock lithologies. The Kssq lithologies do not have turbidity current or high-flow regime sedimentary structures; instead they contain siltstone and shale interbeds with abundant stacked cosets and other low-flow-regime cross-stratification features. The sedimentary structures present suggest that the Kssq unit may represent a marginal sea or shallow marine depositional environment. The Kssq unit is believed to be equivalent to lithologies at the top of the Cretaceous section southeast of the Iditarod-Nixon Fork fault previously discussed. Sparce paleocurrent data (table 2) from high energy flow regime structures in turbidites indicate southerly or southwestly current directions.

Table 2. *Paleocurrent data from Cretaceous sedimentary rocks, Iditarod B-4, eastern B-5 Quadrangles, Alaska*

Map no	Field no.	Azimuth (corrected for tilt)	Azimuth mean	Flow regime
1	84BT18	190°	182°	upper (flute casts)
		185°		
		180°		
		165°		
		190°		
2	84BT17	245°	234°	lower (crossbeds)
		220°		
		230°		
		240°		

Quartz-rich sublithic sandstone, quartz pebble conglomerate, and plant-bearing shale and siltstone of the Ksq unit form the highest stratigraphic unit in the study area. There are no unidirectional cross laminations, and coarse siliceous conglomerate and sands are poorly sorted. Quartz rich, fine-sand intervals in both the Ksq and Kssq units are laminated with bands of sand and silty sand one millimeter to several centimeters thick. The presence of leaf beds, uncommon coal seams, and coquina composed of brackish, subtidal, and nonmarine pelecypods suggest that the unit represents a shoreline section that contains nonmarine components. This distinctive assemblage of rock types extends to Mosquito Mountain (Iditarod A-6 Quadrangle) some 65 km (40 mi) southwest of Flat and discontinuously extends to Fossil Mountain (Medfra Quadrangle) some 150 km (93 mi) to the northeast. The formation represents the western edge of the Kuskokwim Group sedimentary basin (Miller and Bundtzen, 1987, 1992). Field relationships suggest that the Ksq unit represents a stable shoreline sequence that successively overlapped the deeper water sedimentary sequence during a marine regression (fig. 2, sheet 1).

VOLCANIC AND PLUTONIC ROCKS

Intruding and overlying the Cretaceous clastic rocks are Late Cretaceous subaerial volcanic rocks, monzonitic plutons comagmatic with the volcanics, and peraluminous rhyolite sills and altered mafic dikes. Igneous rocks have been classified according to schemes advocated by Streckheisen and LeMaitre (1979), McBirney (1984), Irvine and Barager (1971), and Peacock (1931).

VOLCANIC ROCKS (TKvm, TKvi)

Volcanic rocks are exposed in mine cuts at Otter Creek, as roof pendants on Chicken Mountain, and on outlier ridges east of Swinging Dome. These volcanic rocks are subdivided into two mappable lithologies: (1) porphyritic andesite and altered crystal tuff (TKvi) and (2) olivine augite basaltic andesite (TKvm). As seen in thin section, basaltic andesite retains much of the original mineralogy of olivine, diopside, and calcic plagioclase (fig. 4). Near the head of Boulder Creek, rocks of more intermediate composition (TKvi) contain interbedded flows and light green, graded, tuff layers 1-4 cm (0.4-1.5 in.) thick that we believe to have been deposited as distal air-fall debris. Conspicuous hornblende dacite flows cap the TKvi unit in the study area. Both TKvi units sometimes metasomatically altered by underlying and slightly younger monzonitic plutons; volcanic rocks commonly contain biotite, chlorite, and sphene replacing original mafic minerals in phenocrysts and in the groundmass. However, because thermally altered volcanic rocks retain much of their original extrusive textures and mineralogy and are indistinguishable from unaltered lithologies in the field, they are not depicted as hornfels on sheet 1.

We have provisionally correlated both TKvm and TKvi with the Iditarod volcanics both southeast and northwest of the study area, as described by Miller and Bundtzen (1988). The Iditarod volcanics range in age from 58 to 77 m.y. We believe that the volcanic units in the study area correlate with the oldest Iditarod volcanics which predate the latest Cretaceous plutonic rocks.

PLUTONIC ROCKS (TKm, TKqm, TKgb, TKg, TKum)

The late Cretaceous volcanic pile and Kuskokwim Group are intruded by several heterogeneous meta-aluminous to peraluminous, multiphase plutons that average monzonite in composition (table 3 and sheet 1). Separate plutonic bodies are exposed on Chicken Mountain, in the valley of Otter and Black Creeks at the head of Boulder Creek, and on Swinging Dome. The Chicken Mountain, Boulder Creek, and Black Creek bodies contain variable amounts of equigranular to porphyritic, olivine biotite monzodiorite, and biotite diopside monzonite (TKm), and minor biotite quartz monzonite (TKqm). The Chicken Mountain pluton also contains a small but significant percentage of biotite olivine gabbro (TKgb, fig. 5) and olivine-bronzite picrite–variation wehrlite (TKum; fig. 6). Small lamprophyre dikes cut the monzonite and

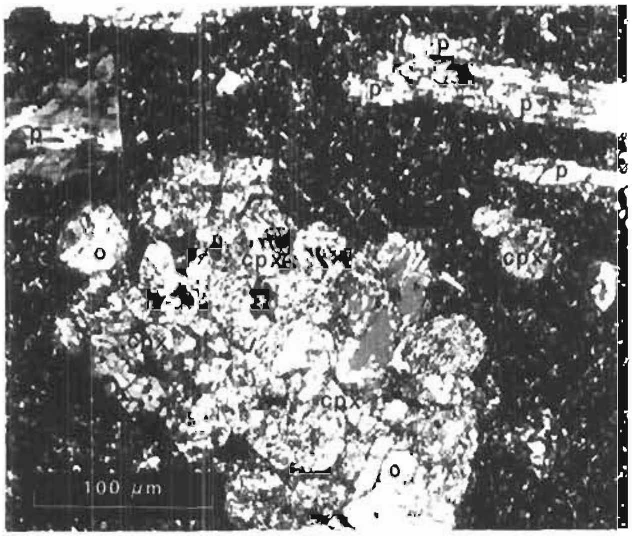

Figure 4. *Photomicrograph of basaltic andesite north of the summit of Chicken Mountain (84BT306a), showing olivine (o), glomeroporphyritic bundles of diopside (cpx), and calcic plagioclase (p) (An_{55}), in groundmass of plagioclase microlites and undetermined opaques.*

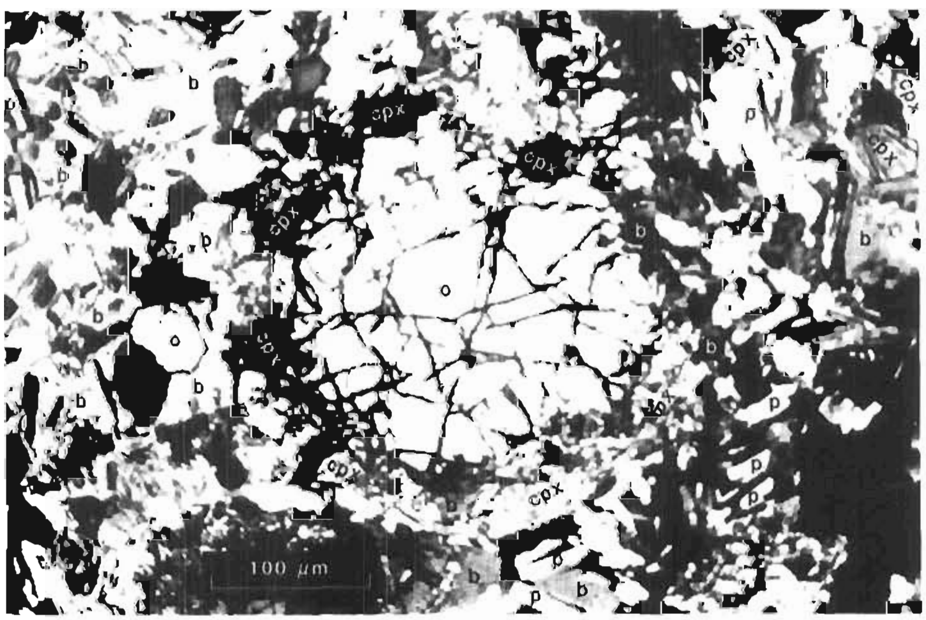

Figure 5. *Photomicrograph of olivine alkali gabbro (88BT51) showing large fractured olivine grain (o) successively rimmed by clinopyroxene (cpx) and biotite (b) in finer grained phaneritic groundmass of calcic plagioclase (p) (An_{60}), and inclusion-charged biotite (b).*

monzogabbro on both Chicken Mountain and Black Creek. The Swinging Dome pluton appears to be composed of nearly equal amounts of mainly porphyritic and porphyro-aphanitic, biotite-diopside monzonite (TKm) and biotite quartz monzonite (TKqm). Both equigranular and seriate textures are common in monzonitic phases (TKm) throughout the study area. The quartz monzonite on Chicken Mountain locally contains abundant miarolitic cavities and graphic replacement of quartz and feldspar.

A progressive, concentric, reaction rim generally following the sequence olivine clinopyroxene orthopyroxene biotite ± amphibole was observed in thin section from all four plutons; these textural relationships suggest that a well developed differentiation process occurs in the plutons (fig. 5). Based on texture, biotite is thought to be an early crystallizing phase that can coexist with olivine and clinopyroxene, whereas amphibole forms distinctly later, which can suggest a water-poor magma.

Accessory minerals in the plutons include zircon, edenite, chrome spinel, and ilmenite; magnetite is rare in the plutonic samples examined and overall opaque mineral content is low ($\leq$3 percent)-unusual for these mainly intermediate rocks. Swanson and others (1987) report that rare magnetite grains contain up to 14 percent Cr_2O_3, whereas the more common ilmenite contains 1-3.5 percent hematite. Pan-concentrate data from residual sites directly on plutonic rocks also contain richterite, radioactive zircon, fluorapatite, hyperstene, hastingsite, and enstatite-suggesting these minerals also occur in the plutons (Bundtzen and others, 1987).

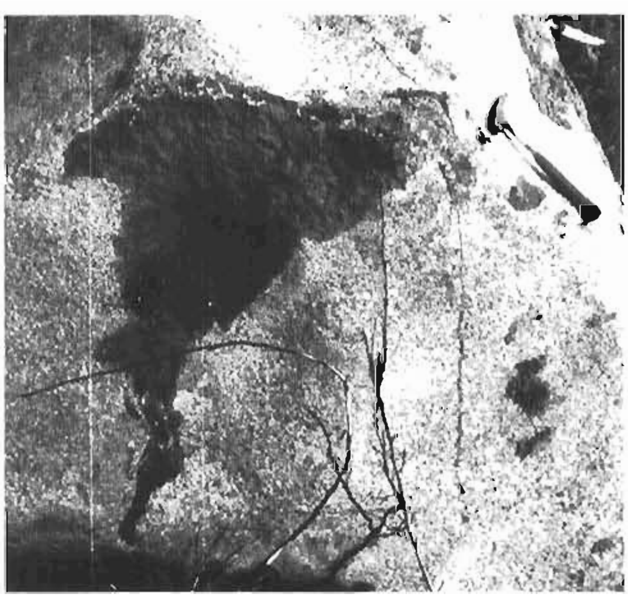

Figure 6. *Xenolith of picrite (TKum), encased in monzodiorite (TKgb) along eastern edge of Chicken Mountain pluton near sample site 88BT51.*

Trace element analyses of selected plutonic rocks also show anomalous levels of thorium and uranium (table 4), which confirm earlier descriptions by Bundtzen and Laird (1980) of similar plutonic suites in the McGrath and upper Innoko River area.

The three plutonic bodies on Chicken Mountain, Black Creek, and Boulder Creek appear to be aligned in a N. 5° E. direction over a distance of 15 km (9.3 mi), which is similar to a nearly identical alignment of monzonitic plutons north of the Iditarod-Nixon Fork fault in the Moore-Moose Creek area 75 km (47 mi) northeast of Chicken Mountain (Bundtzen and others, 1988a).

Granite porphyry and alaskite dikes, sills, and small plugs (TKg), also intrude the Kuskokwim Group in the Bonanza Creek drainage-especially within the Iditarod-Nixon Fork fault zone. Granite porphyry in lower Prince Creek and south of Bonanza Creek contain abundant spessartine garnet, resorbed quartz phenocrysts and biotite and alkali feldspar grains in a porphyro-aphanitic texture.

DIKES AND SMALL SILLS (TKdm, TKd, TKdi)

Altered dikes and small sills (TKdm, TKd) of intermediate and mafic composition intrude the Kuskokwim Group in distinctive, northeasterly swarms north of the Iditarod-Nixon Fork fault. In all cases, during major oxide analytical techniques (table 3) excessive "loss-on-ignition" renders specific classification of TKdm and TKdi dikes, based on chemistry, practically impossible. Exposures in the field are conspicuously altered to a tan-colored, silica-carbonate rock that suggests original mafic or perhaps, less likely, ultramafic compositions. However, small, isolated patches of fresh dike rock can be seen in thin section to be composed of augite, sparse olivine, calcic-plagioclase, and a opaque-rich groundmass. X-ray identification of isolated opaque grains from selected dike localities reveal magnesiochromite, which has been identified in pan concentrates in the Iditarod and Innoko districts (Bundtzen and others, 1985, 1987).

The altered mafic dikes seem to occur in northeast trending structures throughout the study area and may be intruding along these high-angle faults. Although their origins remain somewhat unclear due to lack of reliable dates and chemistry, they may have been feeders for TKvm and TKvi volcanism described on page 5.

PETROGENESIS AND AGE

Plutonic and volcanic rocks of Late Cretaceous-early Tertiary age are found in three separate complexes centered on Chicken Mountain, along Otter Creek near the mouth of Black Creek, and near the head of Boulder Creek. Despite the spatial separation, all are believed to be part of a larger igneous complex now exposed at several erosional levels subsequent to uplift and removal of their roof zones.

Table 3. *Major oxide analyses[a] and CIPW norms of igneous rocks, Iditarod B-4, eastern B-5 Quadrangles, Alaska*

Major oxide composition

Map no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Field no.	84BT242	84BT241b	84BT280	84AM140a	84AM137a	84AM135a	84AM125a	84GL003	84GL004	81BTFG	81BTFM	89BT2	84BT306a	84BT311	85BT117	84BT98	84BT101	88BT51	86K2E	84MSL155	84BT288
Rock type	Alkali-gabbro (TKgb)	Andesite (TKvi)	Mafic dike (TKdm)	Mafic dike (TKdm)	Mafic dike (TKdm)	Mafic dike (TKdm)	Mafic dike (TKdi)	Altered monzonite (TKdi)	Mafic dike (TK??)	Gabbro (TKgb)	Monzonite (TKm)	Alkali gabbro (TKgb)	Basaltic andesite (TKvm)	Andesite (TKvm)	Quartz monzonite (TKqm)	Monzonite (TKqm)	Monzo-diorite (TKgb)	Monzo-diorite (TKgb)	Wehrlite (TKum)	Quartz monzonite (TKqm)	Granite porphyry (TKg)
Major oxides (weight percent)																					
SiO_2	54.73	62.80	53.10	54.24	50.17	54.01	45.71	60.68	50.35	53.89	60.96	52.70	55.64	59.07	69.64	58.41	59.94	49.90	40.33	65.29	74.93
Al_2O_3	17.20	17.47	13.05	15.03	14.40	14.87	15.29	15.02	15.73	13.88	15.74	12.50	11.98	17.88	17.17	16.61	17.34	10.90	2.71	15.45	14.35
Fe_2O_3	2.35	2.11	2.27	2.21	2.20	2.31	3.20	2.21	2.93	1.31	.78	1.40	2.08	2.86	1.73	2.31	2.26	.79	16.90	1.90	.15
FeO	3.09	1.68	5.57	4.56	4.73	4.68	6.18	2.55	4.39	5.44	3.44	6.20	5.07	2.84	.52	2.89	3.25	8.30	.00	2.03	1.28
MnO	.09	.03	.17	.16	.12	.14	.17	.08	.12	.15	.08	.10	.16	.10	.01	.08	.05	.21	.26	.07	.00
MgO	5.95	1.89	7.42	8.08	8.55	6.40	7.22	2.61	4.19	8.25	4.24	12.30	9.56	2.23	.42	4.27	3.32	14.00	27.20	2.75	.04
CaO	6.19	.87	8.44	5.01	6.17	5.62	8.90	4.41	7.49	6.03	3.29	6.73	6.40	5.65	.62	3.92	2.49	8.63	8.25	3.14	.11
Na_2O	3.46	3.28	1.72	2.55	2.30	2.75	2.59	4.41	3.46	2.69	3.93	2.35	2.05	3.28	3.81	3.55	3.02	1.50	.40	3.72	.61
K_2O	4.09	6.49	.38	.88	.36	.35	.28	.98	.56	3.84	4.47	3.02	2.38	2.86	4.17	5.28	3.34	2.14	.91	3.50	5.39
TiO_2	.85	.61	.77	.71	.70	.81	.32	.71	1.43	.79	.50	.72	.58	1.36	.23	.81	.76	.82	.32	.40	.06
P_2O_5	.59	.33	.26	.14	.13	.19	.70	.21	.28	.45	.30	.41	.30	.41	.17	.52	.54	.42	.97	.23	.03
LOI	1.08	1.92	6.23	5.88	9.40	6.37	8.60	5.22	8.18	1.40	1.27	.85	1.44	1.11	1.82	.51	1.54	.00	1.10	.78	2.73
Total	**99.67**	**99.48**	**99.38**	**99.31**	**99.23**	**98.50**	**99.16**	**99.09**	**99.12**	**98.12**	**99.00**	**99.28**	**97.64**	**99.65**	**100.31**	**99.16**	**97.85**	**97.61**	**99.35**	**99.26**	**99.68**
CIPW norms (weight percent)																					
Quartz	0.00	15.33	13.69	11.83	8.36	14.20	NA	19.37	7.76	0.00	6.68	0.00	7.51	14.62	30.51	3.80	20.24	0.00	0.00	19.64	53.14
Corundum	.00	4.36	.00	1.19	.00	.22	NA	.00	.00	.00	.00	.00	.00	.10	5.76	.00	5.73	.00	.00	.39	7.62
Orthoclase	24.52	39.31	2.41	5.56	2.37	2.25	NA	6.17	3.64	22.69	26.41	18.12	14.62	17.15	25.02	31.63	20.49	12.96	.40	21.00	32.85
Albite	29.70	28.44	15.62	23.05	21.66	25.25	NA	39.75	32.20	22.76	33.25	20.19	18.03	28.16	32.73	30.45	26.53	13.00	.00	31.96	5.32
Anorthite	19.60	2.22	28.73	25.58	31.06	28.92	NA	19.49	28.30	14.46	12.11	14.87	17.11	25.73	2.00	13.98	9.17	17.10	2.90	14.29	.36
Diopside	6.05	.00	11.58	.00	1.66	.00	NA	1.88	8.46	10.06	1.82	13.05	11.07	.00	.00	1.82	.00	19.27	25.40	.00	.00
Hyperstene	11.12	5.23	22.20	27.57	29.53	23.39	NA	7.97	11.28	18.98	14.67	16.74	26.66	6.45	1.06	12.16	11.63	17.14	.00	8.61	.10
Olivine	2.55	.00	.00	.00	.00	.00	NA	.00	.00	3.32	.00	12.62	.00	.00	.00	.00	.00	16.78	56.90	.00	.00
Magnetite	3.46	3.13	3.53	3.42	3.55	3.64	NA	3.41	4.67	1.90	1.13	2.06	3.14	4.21	1.06	3.40	3.40	1.17	2.50	2.80	.00
Hematite	.00	.00	.00	.00	.00	.00	NA	.00	.00	.00	.00	.00	.00	.00	1.02	.00	.00	.00	.00	.00	1.48
Ilmenite	1.63	1.19	1.57	1.44	1.48	1.67	NA	1.44	2.99	1.50	.95	1.39	1.15	2.62	.44	1.56	1.50	1.60	.60	.77	.06
Apatite	1.38	.78	.65	.35	.33	.48	NA	.52	.71	1.04	.70	.06	.72	.96	.40	1.22	1.30	1.00	2.30	.54	.07
Differention index	**54.21**	**83.08**	**31.73**	**40.45**	**32.39**	**41.70**	**NA**	**65.28**	**43.59**	**45.40**	**66.34**	**38.31**	**40.16**	**59.93**	**88.26**	**65.87**	**67.26**	**25.96**	**3.40**	**72.32**	**90.31**

[a]Analytical results by T.A. Benjamin and M.K. Polly using X-ray fluorescence methods, DGGS Minerals Laboratory, Fairbanks, Alaska and by X-ray Assay Laboratories, Don Mills, Ontario. Ubiquitous alteration of mafic dikes (note high LOI) makes their respective norms questionable.
Bull (1988) reports 18 additional major oxide analyses from igneous rocks in the study area.

Andesitic volcanic rocks (SiO_2 = 55.6-62.80 percent) flank and overlie the plutonic rocks (SiO_2 = 40.33-69.64 percent). The volcanic rocks are believed to be slightly older but otherwise comagmatic with the plutons. The Chicken Mountain and Boulder Creek volcanic fields lack iron enrichment typical of tholeiitic suites and instead show high alumina and normative plagioclase indicative of calc-alkaline igneous rocks (table 3). Andesites show potassium enrichment similar to many shoshonitic suites and fall within the compositional fields of high-K andesite and banakite (fig. 7).

The differentiated nature of the Chicken Mountain, Black Creek, and Boulder Creek plutons is well illustrated in a normative QAPF diagram (fig. 8). Most samples plot in the expected normative fields, however, some samples classified modally as monzonite fall within the quartz monzonite and syenite fields. Likewise, alkali gabbro and monzodiorite fall within the monzodiorite and monzonite fields, respectively.

All represented intrusive phases (TKm, TKgb, TKum, TKqm) form sharp contacts with each other, and field evidence suggests that more mafic phases were progressively assimulated by more felsic variants. Five (half the plutonic samples) have no normative quartz but fail to generate normative feldspathoids; we conclude that the plutonic rocks are compositionally near or on the alkaline-subalkaline boundary. Bull (1988) reports that 10 of 18 pluton samples collected from the Black Creek and Chicken Mountain plutons contain feldspathoids in the norms. Her samples are slightly more alkalic than samples analyzed in this study.

The average differentiation indexes for four mapped intrusive phases (TKum = 3.4 TKgb = 39.5; TKm = 68.1; TKqm = 88.3) coupled with petrographic and field evidence, suggest that a parent cumulate mafic magma of either ultramafic or gabbro composition progressively evolved to a felsic magma approximating a syenite. Although other studied complexes such as the Russian and Beaver Mountains (Bundtzen and Laird, 1982, 1991) are also compositionally differentiated, we believe that the volcanic-plutonic complex in the Iditarod Flat district is the more compositionally evolved compared to others in the Kuskokwim Mountains. Plots of plutonic rocks on an AFM diagram show a linear, somewhat flat trend in a calc-alkaline field. However samples of alkali gabbro (TKgb) plot in the tholeiitic field (fig. 9).

Selected plutonic and volcanic rocks (excluding the altered mafic dikes) are enriched in potassium group elements, which exhibit the following analytical ranges: K_2O, 2.14-6.49 percent; Rb, 93-276 ppm; Ba, 490-9,920 ppm; and Cs, 5.4-25.3 ppm (tables 3, 4). Related incompatible elements exhibit similar enrichment ratios: La/Tn = 2.5 and Ba/La = 38 - 244. The plutonic rocks are also enriched

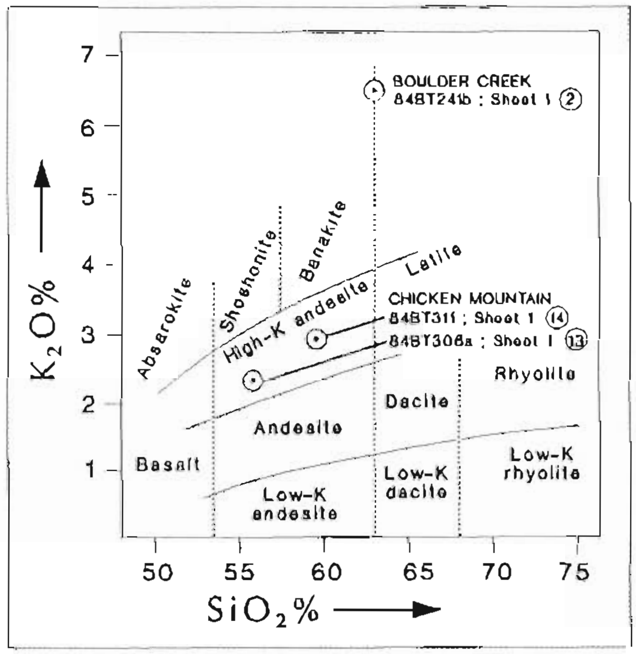

Figure 7. *Plot of Chicken Mountain and Boulder Creek volcanic rocks, Iditarod district, on K_2O-SiO_2 diagram; fields after McBirney (1984).*

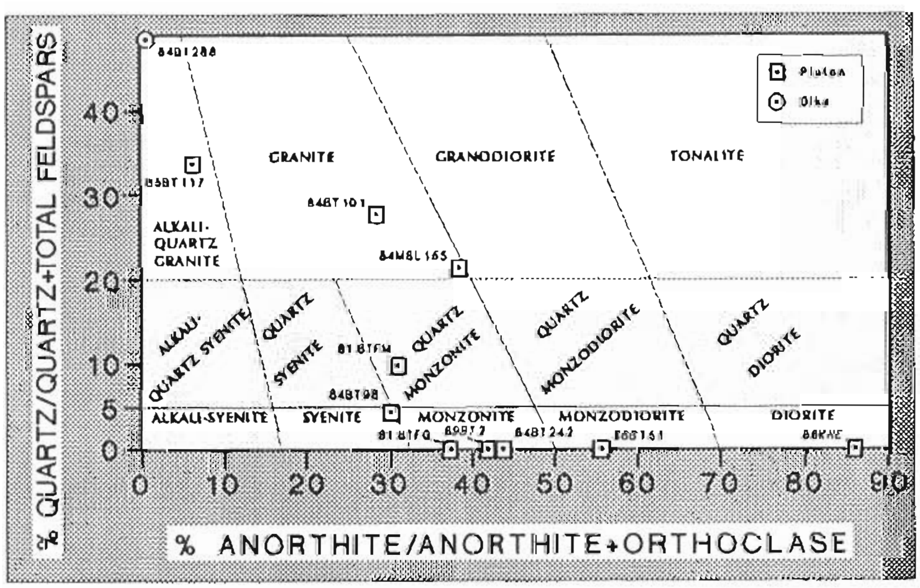

Figure 8. Normative QAPF diagram of plutonic and dike rocks from Iditarod district; fields after Streckeisen and LeMaitre (1979).

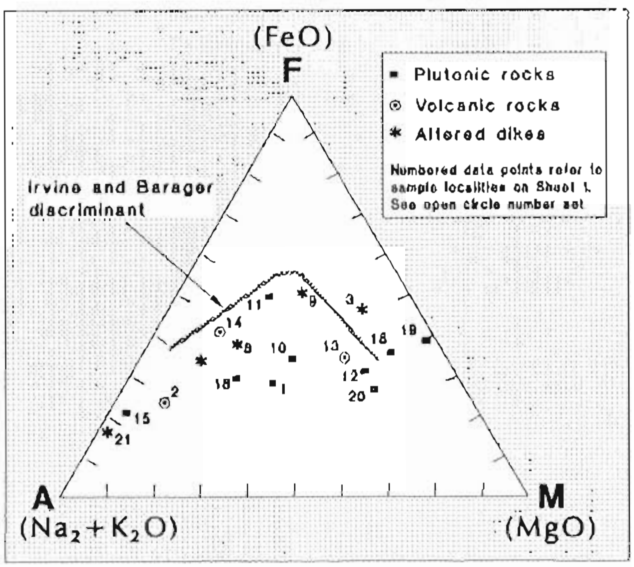

Figure 9. *AFM plot of Late Cretaceous-early Tertiary igneous rocks, Iditarod district.*

in thorium (N = 17.1 ppm) and uranium (N = 6.7 ppm) (table 4).

Rare-earth distribution generally supports a comagmatic origin for the volcanic and plutonic rocks of the study area. The patterns of rare earth elements (REE) variation in both andesitic volcanics and the plutons are generally similar as are overall levels of heavy-REE enrichment (fig. 10). More mafic plutonic variants such as alkali gabbro (84BT101) show the strongest fractionation pattern. However, extreme patterns of fractionation and depletion exhibited in the granite porphyry (84BT288) are unusual and distinguish them from the other volcanic and plutonic rocks. Rb-Sr isotope analyses (table 5) from a single sample of alkali gabbro from the Black Creek pluton yield an initial ^{87}Sr-^{86}Sr ratio of 0.70472, which show that the mafic magmas probably originated from mantle or lower crustal sources. Unfortunately, we have no Rb-Sr data from the unusual granite porphyry suite.

No ^{40}K-^{40}Ar ages are available from volcanic rocks in the study area. Miller and Bundtzen (1987, 1992), Robinson and others (1984), and Bundtzen and Laird (1991) have

Table 4. *Trace element analyses (in ppm except for Na_2O) from igneous rocks, Iditarod B-4 and eastern B-5 Quadrangles, Alaska*[a]

	Alkali gabbro 84BT101 (TKgb)	Monzonite 84BT98 (TKm)	Alkali gabbro 84BT242 (Tkgb)	Andesite 84BT311 (TKvi)	Basaltic andesite 84BT306a (TKvm)	Granite porphyry 84BT288 (TKg)
Na_2O (%)	2.27	3.92	3.68	3.15	2.37	0.78
Rb	93	276	197	94	105	168
Cs	6.2	25.3	12.6	6.7	7.1	5.4
Ba	9,920	1,640	1,590	1,620	1,930	490
Sc	7.1	12.4	16.2	16	23.6	1.5
Cr	163	248	373	52	464	28
Co	11.1	18.7	23.6	13.5	31.1	0.6
Hf	5	6.8	4.1	4.9	2.5	2.9
Ta	1.01	1.70	0.94	0.68	0.37	0.63
Th	14.5	23.6	13.2	8.2	4.8	7.8
U	5.7	9.7	4.9	3.6	2.8	2.8
La	40.6	36	29.7	27.6	18	12.7
Ce	74	76	61	64	40	26
Nd	24	29.7	25.7	30	19	10.6
Sm	3.48	5.48	4.90	6.10	4.12	2.71
Eu	0.89	1.24	1.36	1.52	1.23	0.27
Tb	0.63	0.52	0.67	0.78	0.64	0.12
Yb	1.01	2.36	2.12	2.75	1.80	0.06
Lu	0.19	0.35	0.31	0.39	0.27	0.005
La/Yb	40.2	15.2	14	10	10	212
Ce/Yb	73.3	32.2	28.8	23.3	22.2	437

[a]Analyses by F.A. Frey, Massachusetts Institute of Technology; funding by Doyon, Ltd.

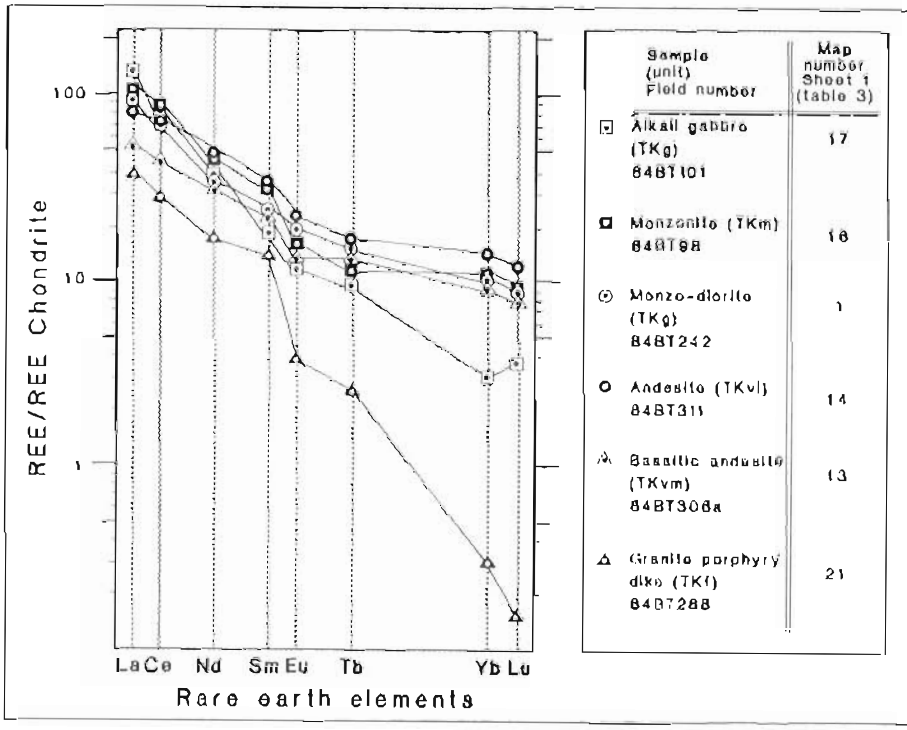

Figure 10. *Chondrite normalized logarithmic diagram of rare-earth element variation in selected volcanic, plutonic, and dike samples, Iditarod district. Plots in figure 10 are derived from data reported in table 5.*

shown that regionally equivalent volcanic rocks average 75 m.y. and predate underlying or associated plutons by 3-5 m.y. The Chicken Mountain, Black Creek, and Boulder Creek plutons all yield ^{40}K-^{40}Ar biotite ages of 63.4-70.9 m.y. (table 6). Concordant amphibole and biotite ages of 68.7 m.y. and 70.9 m.y. respectively were obtained from the Chicken Mountain pluton. Two samples of peraluminous granite porphyry yield ages ranging from 64.3 to 69.3 m.y.; within analytical error, the granite porphyry ages are the same as those from the larger plutons, despite significant differences in compositional makeup.

Feldspar geothermometry from samples on Chicken Mountain indicate the following temperatures of crystalization: (1) 608°-694°C for monzodiorite; (2) 583°-741°C for monzonite; and (3) 417°-1137°C for quartz monzonite (Bull, 1988). Emplacement pressures of the Chicken Mountain stock were calculated by Bull (1988) to be at 1.0-1.5 kilobars or 1-4 km (0.6-2.5 mi) depth, based on plotting feldspar crystallization temperatures on a granite minimum curve. These results indicate shallow, epizonal conditions of magma formation.

From petrographic, whole rock chemistry, and isotope results, we conclude that the Late Cretaceous-early Tertiary igneous suite is similar to calc-alkaline to quartz-alkalic belts emplaced within subduction related(?) intracontinental, back-arc settings that exhibit a significant extensional component, as orignally proposed by Bundtzen and Swanson (1984). Components of the volcanic and plutonic rocks primarily plot in the alkali-calcic and quartz alkalic fields, based on the alkali-lime index of Peacock (1931) (fig. 11). The volcanic

Table 5. *Rb-Sr isotope data from monzo-diorite (84BT101) of Black Creek pluton, Iditarod B-4 and eastern B-5 Quadrangles, Alaska[a]*

Rb (in ppm)	Sr (in ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr$ (initial)
155.25	619.35	0.725	0.70544 (±0.00007)	0.70472

[a]Analyses by Jonathan A. Powell, Teledyne Isotopes, Westwood, New Jersey. Accuracy of the concentration data (1 σ) ± 1.0%. Precision of $^{87}Sr/^{86}Sr$ ratio is generated from each mass spectrometer run.

and plutonic rocks were probably derived from the mantle, but the chemical and isotopic signature of the granite porphyry intrusive bodies suggests that melted crust was incorporated into those magmas.

HORNFELS (TKhf)

A conspicuous hornfels aureole overlies and flanks plutons throughout the study area (sheet 1). Mapped hornfels usually consists of resistant, dark gray, frequently conchoidally fractured massive meta-argillite and metasandstone derived from the Kuskokwim Group. Intensely thermally altered zones are difficult to distinguish from aphanitic volcanic rocks. Maximum effects of recrystallization can range from 0.5 to 2.0 km (0.3-1.3 mi), away from the intrusive contact. A typical thin section of

Table 6. *Analytical data for K-Ar determinations*

Map no.	1	2	3	4	4	5	5
Field no.	84BT42[a]	84BT240[a]	81BTFlat[b]	83BT360a[a]	83BT360b[a]	84BT288a[a]	84BT288b[a]
Rock type	Monzo-diorite	Rhyolite dike	Gabbro	Monzo-diorite	Monzo-diorite	Peraluminous rhyolite	Peraluminous rhyolite
Mineral dated	Biotite	Whole rock	Biotite	Amphibole	Biotite	Biotite	Whole rock
K_2O (wt. %)	9.229	4.148	7.423	0.313	7.857	8.479	5.468
Sample wt. (g)	0.1211	1.6184	0.1892	0.9128	0.2398	0.0977	1.4318
$\frac{^{40}Ar_{(rad)}}{(moles/g) \times 10^{-11}}$	95.7145	42.5965	68.8885	3.1500	81.80	86.2536	51.5209
$\frac{^{40}Ar_{(rad)}}{^{40}K \times 10^{-3}}$	4.1862	4.1448	3.7466	4.0700	4.200	4.1061	3.8030
$^{40}Ar_{(rad)}$	84.05	85.96	70	37.61	20.20	86.77	97.09
Age (Ma)[c]	70.65 ± 2.12	69.97 ± 2.1[d]	63.4 ± 3.9	68.70 ± 2.1	70.9 ± 2.1	69.32 ± 2.1	64.30 ± 1.9

[a]Analyses by R.M. Coutell and D.L. Turner, Alaska Cooperative Geochronology Laboratory.
[b]Analyses by D. Krummenaker, San Diego State University.
[c]Constants used in age calculations: $\lambda_\varepsilon = 0.581 \times 10^{-10}$ yr^{-1}; $\lambda_\beta = 4.962 \times 10^{-10}$ yr^{-1}; and $^{40}K/K$ total = 1.167×10^{-4} mol/mol.
[d]Minimum age.

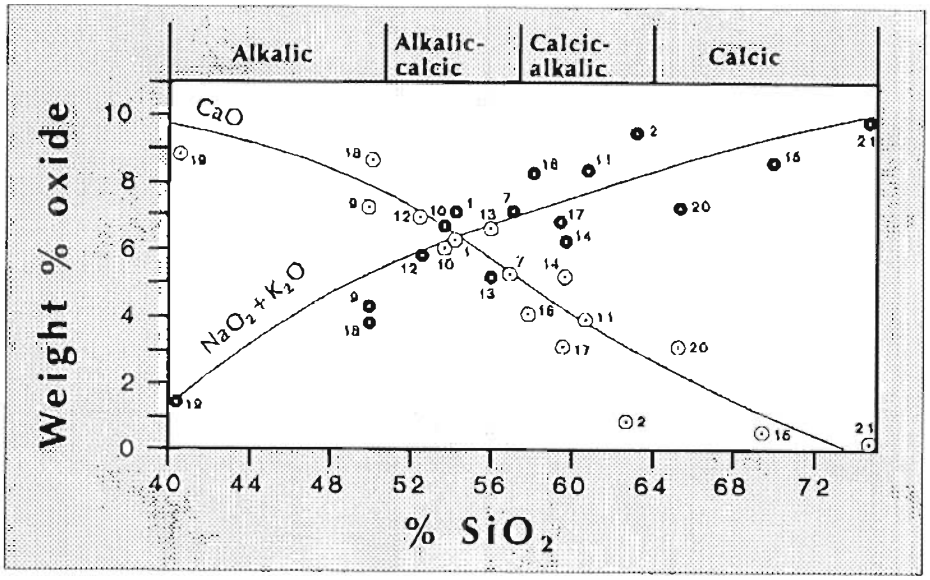

Figure 11. *Classification of volcanic and plutonic rocks in Iditarod district using alkali-lime index of Peacock (1931).*

siltstone-hornfels is composed of biotite, epidote, and uncommon prehnite porphyroblasts in a recrystallized grainstone matrix of lithic fragments, organic debris, and detrital feldspar and quartz. No rigorous petrographic studies were completed of hornfels in the study area. The prominant hill immediately north of Flat, the upland east of Granite Creek, and most of the dredged valley of Otter Creek from Discovery to Flat townsite is underlain by hornfels. Evidently a much larger intrusive mass underlies the Otter Creek drainage than is presently exposed.

LATE TERTIARY(?)-QUATERNARY GEOLOGY

GEOLOGIC UNITS

Nine late Tertiary to Quaternary geologic units were subdivided on the basis of photogeology and ground reconnaissance. Most deposits described below and on sheet 1 were formed in a periglacial environment beyond the known limits of Pleistocene glaciation in the Kuskokwim Mountains (Kline and Bundtzen, 1986). However, morphological features including breached divides, planated summit levels, and crude U-shaped valley forms in upper Flat, Boulder, and Slate Creeks suggest that early Pleistocene(?) glacial ice or permanent snow fields may have occupied these areas and perhaps the summit of Chicken Mountain as well.

COLLUVIAL DEPOSITS (Qc, Qcl, Qu)

The region has been buried by colluvial and slope deposits of variable thickness, age, and origin. Unsorted silt, sand, and minor bedrock colluvium (Qc) mantles upper slopes near timberline and lower valley fill deposits. In the Willow and Bonanza Creek drainages, Qc deposits imperceptively grade into silt-rich undifferentiated Quarternary deposits, which are dominated by ice-rich eolian loess and palsen. Placer mine development of an ancestral terrace level of lower Willow Creek exposed a 15-m-(49-ft)-thick section of retransported silt and ice-rich palsen of the Qc unit (fig. 12; sheet 1). Pleistocene megafossil collections rich in *Mammuthus* yielded a radiocarbon age from bone collagen of about 36,000 B.P. (Richard Fullerton, oral commun., 1985), which provides a late Pleistocene age for palsa-rich Qc deposits in the Willow Creek drainage.

A landslide deposit on lower Chicken Creek (Qcl; sheet 1) consists of angular blocks of hornfels (Tkhf) and monzonite (Tkm), vegetation mats, and undifferentiated bedrock-derived colluvium that moved downslope in a westerly direction by mass failure. The heavily vegetated landslide probably failed in pre-Wisconsin time, judging from its eroded upper escarpment and the relative antiquity of stream diversion of Chicken Creek.

Undifferentiated Quaternary deposits (Qu) include alluvial, eolian, and colluvial deposits but are mainly dominated by sheets of colluvium transported downslope from bedrock sources. The Qu deposits are ice-rich in valley fills and covered with climax vegetation and wetlands in most of the study area.

ALLUVIAL DEPOSITS (QTat, Qat, Qaf, Qa, Qht, Qelr)

Alluvial deposits include early to late Pleistocene terrace alluvium (QTat, Qat), silt-fan deposits (Qelr), alluvial fan deposits (Qaf), modern alluvium (Qa), and placer mine tailings (Qht). The terrace deposits occur in at least two distinct levels in the valley of Bonanza Creek, but on only one recognized level in most of the remaining

Figure 12. *Ice-rich palsa (about 50 percent ice by volume) in eolian loess and sphagnum peat overlying auriferous paystreak on ancestral channel of Willow Creek, Iditarod B-5 Quadrangle.*

drainages. Detailed airphoto analysis coupled with studies of mine exploration data on both Prince and Flat Creeks indicate that as many as four distinct paleo-channels are represented in the QTat deposits in those areas. Where dissected by erosion or exposed in placer mine cuts, the QTat and Qat deposits are composed of moderately to well-sorted, well-stratified sand and gravel, weakly to strongly cemented by ferrous oxides, depending on the relative age of the deposit. No absolute age control is available for any of the terrace deposits. We infer an early to mid Quaternary age for Qat deposits on the basis of regional correlation with similar terrace levels exposed throughout interior and western Alaska (Pèwè, 1975). Frequently, older terrace levels are covered with late Quaternary ice-rich silt (fig. 12). We believe that the oldest terrace levels may include late Tertiary gravels. This hypothesis is based on the growing recognition that older terrace levels in interior and western Alaska are Pliocene or even late Miocene in age (Hopkins and others, 1971; Karl and others, 1988).

Alluvial fan deposits (Qaf) consist of partially channelized silt, sand, and gravel localized at the intersection of tributary and trunk streams. The largest and best developed Qaf fan deposit occurs on lower Chicken Creek as it breaks away from Chicken Mountain and enters Bonanza Creek valley. We judge the age of Qaf deposits ranges from middle to late Quaternary; none are being formed today.

Silt-fan deposits (Qelr) contain stratified silt, fine sand and minor pea-gravels produced mainly by erosion of hillslope loess and colluvial deposits produced by seasonal water runoff. The Qelr unit forms distinctive fan-shaped landforms on heavily vegetated slopes below timberline.

Modern stream alluvium (Qa) is composed of unconsolidated silt, sand and gravel deposited by modern streams within active flood plains. Although composed of the same locally derived bedrock units as terrace alluvium (QTat, Qat), the Qa deposits in the study area are uncemented, generally thawed, and covered with youthful pioneer flora such as willow (*Salix* sp.), alder (*Alnus* sp.), and cottonwood (*Populus balsamifera*), in contrast to the climax cover of sphagnum moss, and wetland-dominated communities of older terraces.

Placer mine tailings were former QTat, Qa, Qat, deposits and colluvium (Qc) that were washed by water and stacked in a variety of configurations during placer mining activities. Cobbles are resistant metavolcanic rocks and plutonic rocks, and hornfels derived from Chicken Mountain and the Otter Creek drainage. Finer silt and clay fractions were removed during placer mining activities, and the relative amount of remaining fines depends largely on the mining methods involved and the number of times the material was processed for gold. Most Qht tailings in the study area appear as stacked, curvilinear, or "herring-bone" ribs 2-6 m (6-20 ft) high that were stacked by three floating bucket-line dredges in operation from 1912 to 1966. Tailings in smaller tributary streams are more irregularly stacked by bulldozers and draglines. All tailings older than about 20 years are successively being revegetated. Because the dredges dug bedrock and deposited bedrock rubble on the tops of tailing piles, we infer bedrock control in Otter and Flat Creeks with the symbologies.

GEOMORPHOLOGY

Accordant rounded ridges underlain by Paleozoic-Cretaceous sedimentary and volcanic rocks average 426 m (1,400 ft) elevation, whereas steep, igneous-cored, volcanic-plutonic complexes average 700 m (2,300 ft) elevation. Ridgelines throughout the study area strongly trend northeast, which reflects the northeast strike direction of sedimentary units. The lower ridges are characterized by a trellis drainage system, whereas a radial drainage system characterizes the igneous-cored Chicken Mountain area.

Terrace and slope deposits (QTat, Qaf, Qelr, Qc) evolved in response to several factors: slopes and stream valleys eroded in a periglacial environment during late Tertiary and Quaternary time; structural movement, mainly faults and folds, uplifted and tilted landforms in the region.

An asymmetrical valley, one in which opposing valley sides have markedly different slope angles, is the characteristic stream profile in the Iditarod mining district. Steep valley walls of asymmetrical valleys face north or east while the more gentle slopes face south or west. This is considered normal asymmetry (Melton, 1960) and is probably the result of greater solifluction activity resulting from the larger intervals of thermal exposure on south or southwest slopes. In contrast, the steeper valley slopes of north or east aspect receive less sunlight and are frequently frozen. As a result, the permafrost thaws differentially, and colluvial materials are moved down the south or west facing slopes and advance toward east- or north-facing frozen buttresses. This process forces perennial streams to migrate south or west and position active channels against the opposite, steepened, valley wall. During migration, the stream leaves a successive series of older bench or alluvial terraces, depicted within QTat or Qat units on the map (sheet 1). A southwest or west stream migration has taken place in most stream valleys in the study area. Effects of asymmetrical valley evolution on distribution of heavy-mineral placer deposits are discussed in the Economic Geology section of this report.

The summit of Chicken Mountain and the upland north of Granite Creek contain inactive but well preserved cryoplanation terraces (fig. 13). Cryoplanation occurs on ridge crests and hilltops when nivation erodes bedrock in transverse nivation depressions. Frost action, water piping, and wind deflation act in concert with nivation to produce the terrace-like rubble products of the intense frost action (Reger, 1975). On Chicken Mountain both ridge crest and hilltop cryoplanation forms are present between 646 m (2,120 ft) elevation and the 725 m (2,380 ft) summit. Scarp heights vary from about 2.5 m (8 ft) to more than 10 m (35 ft) and average 22° angle of repose. From a distance the surfaces appear planar, but they are actually broad convex slopes dipping several degrees to the south that contrast with steeper surrounding surface features. Prominant plutonic tors, remnant of earlier cryoplanation levels, characterize the western slopes of Chicken Mountain. The main Chicken Mountain cryoplanation terrace covers some 6 km^2 (2.3 mi^2), and the prominant upland surfaces north of Granite Creek also total about 6 km^2 (2.3 mi^2) in area. Bedrock rubble veneer ranges from 1 to 3 m (3 to 10 ft) deep and in some places is thicker on the oldest rims of the terrace levels.

Eolian silt deposits of varying thickness covered most of the area during Pleistocene time, but subsequently water transported silt downslope to form silt fans at valley wall apexes. These silt deposits are generally ribbed with ice and continuously freeze in valley fills, although some patches thaw on southerly slopes.

STRUCTURAL GEOLOGY

The Iditarod-Nixon Fork fault, a major 500 km (310 mi) transcurrent fault in western Alaska, bisects the map area diagonally along a southwest-to-northeast line.

Volcanic and sedimentary rocks northwest of the Iditarod-Nixon Fork fault have been folded into broad, open northeast trending synclines and anticlines with amplitudes of 2-3 km (1-2 mi); plunge directions of these structures appear to be to the southwest. The structural deformation southeast of the Iditarod-Nixon Fork fault consists of a series of doubly folded anticlines and synclines and transcurrent high angle faults that show right lateral drag features (sheet 1). An apparent repetition of the Kuskokwim Group section south of Ruby Creek may be represented by several nearly identical cycles of sedimentary deposition

Figure 13. *Otter and Black Creek valleys looking south-southwest. Chicken Mountain is in the left foreground.*

(fig. 14). Another alternative hypothesis would be one or a series of imbricate thrust faults in the rock section.

The valley of Bonanza Creek marks its trace for most of its length in the study area (fig. 15). The Iditarod-Nixon fault juxtaposes a relatively thin 2,200-m (7,200 ft) thick section of the Cretaceous Kuskokwim Group to the northwest against a much thicker >5,000 m (16,400 ft) section of Kuskokwim Group in the southeast. Faint escarpments in surficial material along Bonanza Creek may suggest Quaternary offset. However, Bundtzen and Laird (1991) reported that 6.16 m.y. old basalt flows intrude and overlie a probable splay of the Iditarod-Nixon fault near Aniak and which document the latest movement along the fault. Since 65-69 m.y. old granite porphyry sills were also emplaced along the fault, the Iditarod-Nixon Fork fault is at least as old as Late Cretaceous. Miller and Bundtzen (1988) have proposed a right lateral offset solution of 94 km (58 mi) since Late Cretaceous time for the Iditarod-Nixon Fork fault. This theory suggests that Cretaceous to early Tertiary volcanic stratigraphy in the Donlin Creek area (Iditarod A-5 Quadrangle) is equivalent to similar aged rocks in the Moore Creek area (Iditarod C-3 Quadrangle) to the northeast.

Formerly referred to as Golden Horn fault by Bundtzen and others (1988), the Granite Creek fault, in the northcentral part of the study area juxtaposes hornfels against stratigraphically lower volcanic rocks north of Otter Creek. The fault trends N. 5°-25° E. and might control the emplacement of the Chicken Mountain, Black Creek, and Boulder Creek plutons. The Granite Creek fault is similar to a N. 5°-10° E. plutonic alignment described by Bundtzen and others (1988a) near Moore Creek.

Exploration trenches completed by Fairbanks Gold Inc. in 1990 uncovered a prominant N. 20° E. fault zone on the northwest flank of the summit of Chicken Mountain. This shear zone continues northeast for at least 2 km (62 mi) and we believe it is equivalent to the Golden Horn vein structure zone described in the Economic Geology section.

Late drag features and disrupted fold axes suggest that more compressional stress was directed at the stratigraphic section southeast of the Iditarod-Nixon Fork fault during one or more regional folding events. The main Iditarod-Nixon Fork fault may have acted as a structural buttress against which regional compressional stress is directed from a southeast to northwest vector.

ECONOMIC GEOLOGY

INTRODUCTION

The study area centers on the Iditarod mining district, which has been in continuous production from 1909 to 1991 and ranks as Alaska's third largest producer of placer

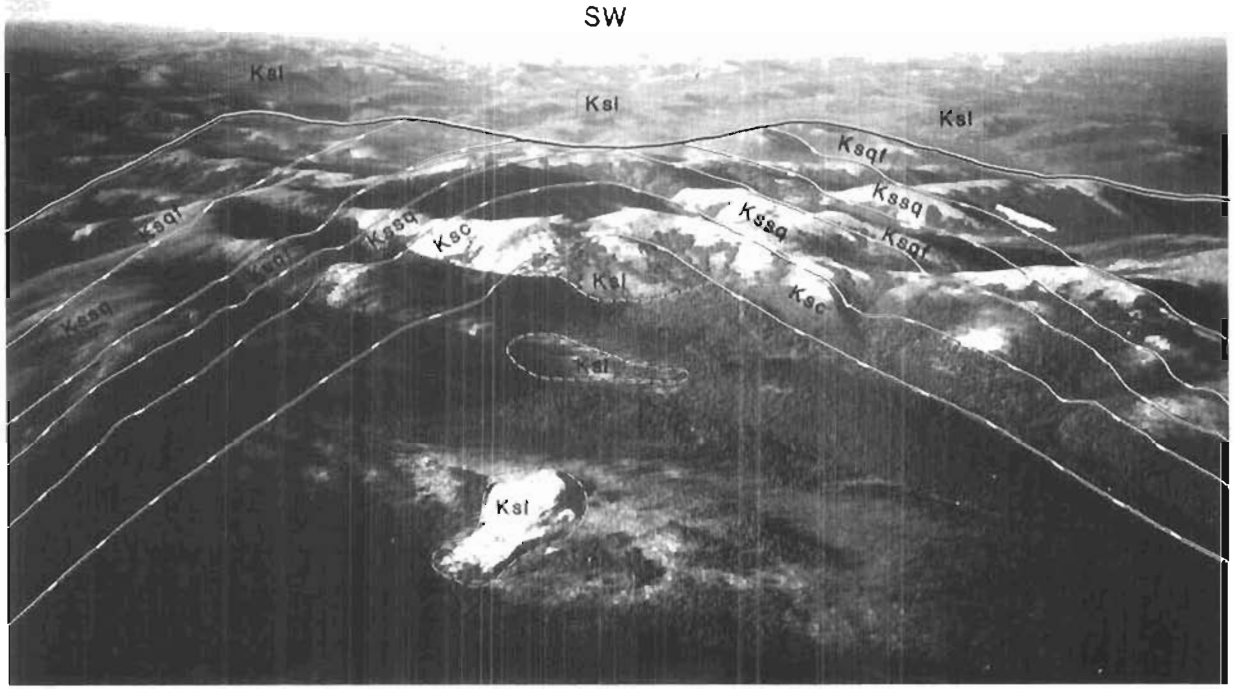

Figure 14. *Ruby Creek area south of Iditarod-Nixon Fork fault showing anticline of "upper" sands plunging under Kls section; inferred thrust fault plane shown.*

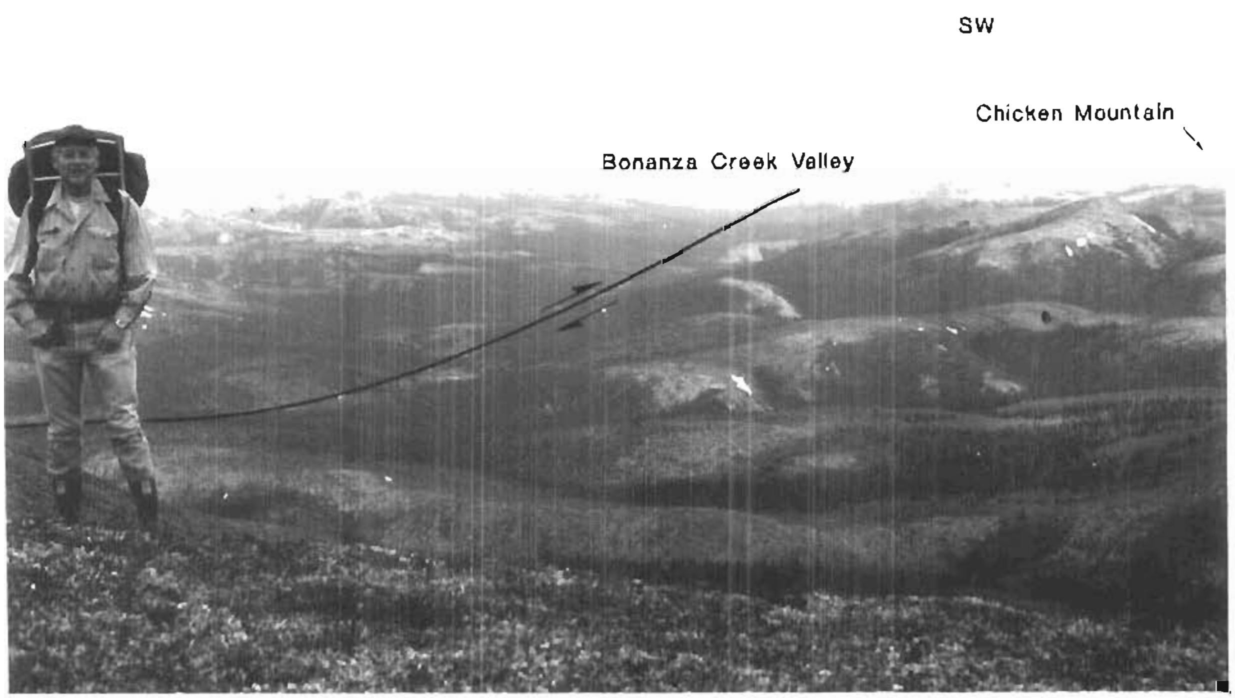

Figure 15. *Trace of Iditarod-Nixon Fork fault looking southwest down Bonanza Creek drainage through study area.*

gold. Through 1990, total production from the study area is estimated at 45,196 kg (1,453,078 oz) gold, 6,116 kg (196,624 oz) silver, and minor amounts of tungsten and mercury mainly from placer mineral deposits (table 7). Some 84,156 g (2,706 oz) of gold (or 0.19 percent of the district total) has been derived from the Golden Horn lode deposit (table 8).

Lodes consist of vein-disseminate and shear-zone deposits in both plutonic stocks and overlying cap rocks that contain gold, tungsten, mercury, antimony, and silver. A continium of residual, elluvial, modern stream, and terrace placer deposits derived from the lodes have all been exploited principally for their gold values.

Detailed Yukon Gold Co. dredge statistics are provided in table 9; trace elements are provided in table 10 (in pocket); and statistics for North American Dredging Co. and Riley Investment Dredging Co. operations are given in table 11.

Table 7. *Gold and silver production in the Iditarod-Flat district, 1910-90*[a]

Year	Volume gold (oz)	Volume silver (oz)	Mines or mining companies reporting	Employment	Total bullion value ($)[b]
1910	24,187	4,254	16	250	520,000
1911	120,937	21,270	30	850	2,610,000
1912	169,312	29,778	36	975	3,500,000
1913	89,977	9,551	30	750	1,860,000
1914	99,652	10,578	29	500	2,030,829
1915	99,168	10,526	24	485	2,059,000
1916	94,339	10,013	15	400	1,960,000
1917	72,568	11,050	12	NA	1,532,000
1918	59,990	8,278	4	NA	1,255,000
1919	35,074	4,770	15	90	726,000
1920	24,400	3,347	10	NA	505,000
1921	16,935	2,353	22	214	354,000
1922	13,550	1,828	17	164	282,000
1923	11,030	1,544	18	144	229,000
1924	10,019	1,653	30	135	207,100
1925	10,793	1,618	9	NA	223,100
1926	12,143	1,687	23	120	251,000
1927	7,270	1,090	9	NA	151,000
1928	14,329	2,221	15	NA	296,200
1929	13,401	2,412	17	102	277,000
1930	8,901	1,339	11	90	184,000
1931	11,850	1,599	10	90	231,000
1932	17,610	2,641	18	125	364,000
1933	13,050	1,774	19	125	261,000
1934	16,400	2,205	18	NA	574,000
1935	13,085	1,724	18	150	458,000
1936	15,608	1,769	10	135	546,300
1937	19,828	2,696	8	32	694,000
1938	21,171	2,880	11	250	741,000
1939	22,171	3,325	10	NA	776,000

[a]Source: Unpublished U.S. Mint Records, Mertie and Harrington (1924), Smith (1933a, b, 1934, 1937, 1938, 1940, 1942, 1944), Williams (1950), and unpublished State of Alaska questionnaires (1978-90)]
[b]Gold prices were $20.67 from 1910-33; $35/oz from 1934-72; and variable prices since then.
NA = records not available.

Table 7. *Gold and silver production in the Iditarod-Flat district, 1910-90--Continued*

Year	Volume gold (oz)	Volume silver (oz)	Mines or mining companies reporting	Employment	Total bullion value ($)[a]
1940	22,942	3,120	10	NA	803,000
1941	23,257	3,232	19	142	814,000
1942	16,628	1,394	15	NA	582,000
1943	4,225	659	6	NA	147,875
1944	NA	NA	NA	NA	NA
1945	1,114	171	8	NA	38,990
1946	8,301	1,178	12	NA	290,535
1947	10,550	1,392	13	NA	369,250
1948	9,850	1,008	NA	NA	344,750
1949	8,268	1,314	11	62	289,380
1950	8,183	975	12	59	286,405
1951	6,096	909	9	NA	213,360
1952	6,778	1,058	8	NA	237,230
1953	8,423	1,354	14	NA	294,805
1954	6,798	1,088	7	NA	237,930
1955	6,142	910	8	NA	214,970
1956	8,784	1,225	7	NA	307,440
1957	8,434	1,252	5	NA	295,190
1958	7,187	1,025	7	NA	251,545
1959	5,762	837	6	NA	201,670
1960	7,576	1,093	6	NA	267,200
1961	5,911	871	5	NA	206,885
1962	4,918	707	5	NA	172,130
1963	5,219	743	5	NA	182,665
1964	5,490	777	4	NA	192,150
1965	4,662	672	4	NA	163,170
1966	4,319	660	3	NA	151,165
1967	NA	NA	NA	NA	NA
1968	2,241	314	5	NA	78,435
1969	760	101	2	NA	26,600
1970	458	51	1	NA	16,030
1971-79	11,150	1,732	3	NA	3,200,000
1980	2,820	375	3	3	1,201,320
1981	3,535	445	3	22	1,452,885
1982	4,560	638	4	24	1,824,000
1983	4,400	590	4	23	1,760,000
1984	2,500	315	3	20	900,000
1985	3,630	486	5	20	1,179,750
1986	4,180	468	5	22	1,588,400
1987	4,500	612	4	23	2,025,000
1988	850	NA	4	20	358,700
1989	750	NA	4	20	286,500
1990	750	NA	4	20	288,750
Undistributed	35,728	NA	NA	NA	NA
Totals	**1,453,078 (45,196 kg)**	**196,624 (6,116 kg)**	--	--	**49,615,349**

Table 8. *Production statistics from the Golden Horn Lode Mine. Modified from Roehm (1937)*[a]

Year	Ore (tons)	Gold (oz)	Silver (oz)	Lead (lb)	Zinc (lb)	Value at time of sale ($)
1925	11.1	371.4	23.5	--	--	4,160
1926	11.0	131.5	14.0	--	--	2,719
1934-35	250.0	1,390.0	1,403.0	--	--	50,000
1936	21.0	103.8	107.0	--	--	3,634
1937	40.0	196.0	202.0	--	--	6,452
Undistributed[b]	194.9	514.1	871.0	9,336	653	6,790
Total	528.0	2,706.8	2,620.5	9,336	653	73,755

[a]Does not include development and production tests of tailings from Golden Horn dump by Golden Horn Mining Co. in 1986 and 1987. In the two test years, 7,500 tons of residual ores from the vein system were sluiced and yielded approximately 8 tons of gold-bearing scheelite and arsenopyrite concentrates and an undisclosed amount of free gold.
[b]Could not be broken down by calendar year.
-- = not recorded by year.

Table 9. *Operational statistics for Yukon Gold Company dredge, Flat Creek, Iditarod district*[a]

Season	Duration	Number of days	Yards[3] handled	Total gold yield oz	Grade oz/yd[3]	Operator costs
1912	8/15-10/29	75	172,333	19,547	0.113	$ 79,114
1913	5/8-11/25	201	496,756	40,029	0.081	319,560
1914	5/4-11/11	191	668,737	35,782	0.054	335,560
1915	5/4-11/17	196	926,956	40,928	0.044	NA
1916	NA	NA	1,015,920	53,205	0.052	NA
1917	NA	NA	871,045	43,085	0.050	NA
1918	NA	NA	644,125	30,452	0.047	NA
Total	--	--	4,795,872	263,028	0.055	--
	--	--	(3,666,923 m³)	(8,181 kg)	(2.23 g/m³)	

[a]Source: Perry (1915); the late Richard Fullerton, written commun., 1988.
NA = not available.
-- = not applicable.

MINING HISTORY

Portions of the following are discussed in detail by Smith (1915), Brooks (1914, 1916), Eakin (1913, 1914), Mertie and Harrington (1924), Mertie (1936), and Kimball (1969). Placer gold was first identified at Discovery near the present John Miscovich family mine on Otter Creek (sheet 1) on Christmas Day, 1908, by gold prospectors W.A. Dikeman and John Beaton. During the summer of 1909, many prospectors, including several hundred from the boom towns of Fairbanks and Nome, arrived into the remote country. Miners and equipment traveled by boat along the Yukon River, then traversed 900 km (560 mi) on the Innoko River and 200 km (125 mi) of the Iditarod River to the settlement of Iditarod. Equipment was then transported overland 10 km (6 mi) to the mining camps, principally to the settlement of Flat at the confluence of Flat and Otter Creeks. Due to access difficulties, actual production did not begin until the winter of 1909-10. Rich, shallow, easily accessible placer deposits were quickly exploited, and the gold production rapidly grew to an all time annual high of 5,265 kg (169,312 oz) gold and 926 kg (29,778 oz) silver by 1912 (table 7). Nearly 2,500 people were actively engaged in mining, prospecting, and general commerce in the region during this time (Eakin, 1914, p. 34); 975 of these were miners. Flat and the ajoining community of Discovery housed most of the miners and the small businesses that serviced the mineral industry. A comparison of Flat during its heyday and the present is

Table 11. *Gold production statistics from Riley Investment and North American Dredging Company operations, Iditarod-Flat district, Alaska, 1914-66*[a]

Year	Riley Investment Company (Riley and Martson) 99 liter (3.5 ft^3) dredge		North American Dredging Company (Beaton and Donnelly) 85 liter (3 ft^3) dredge	
	Gold (oz)	Pay processed (yd^3)	Gold (oz)	Pay processed (yd^3)
1914	NA	NA	- -	- -
1915	8,312	202,790	- -	- -
1916	10,006	222,350	12,433	189,000
1917	7,632	212,100	5,366	216,000
1918	7,619	200,500	4,326	114,320
1919	12,695	250,400	6,061	208,900
1920	10,099	243,600	5,575	214,700
1921	4,196	262,600	5,176	185,000
1922	2,361	258,000	6,746	169,600
1923	2,028	249,000	4,675	208,400
1924	2,747	281,000	2,265	169,000
1925	4,176	279,300	2,762	172,000
1926	4,746	260,290	2,418	208,220
1927	NA	NA	4,030	201,500
1928	NA	NA	5,106	200,300
1929	1,041	119,000	1,657	142,000
1930	1,821	117,500	2,461	168,000
1931	3,331	132,000	- -	- -
1932	4,414	261,000	- -	- -
1933	2,589	242,650	- -	- -
1934	2,809	212,800	- -	- -
1935	2,669	216,900	- -	- -
1936	3,348	222,900	4,296[b]	268,600[b]
1937	3,021	225,000	- -	- -
1938	- -	- -	- -	- -
1939	2,530	235,000	NA	NA
1940	3,111	216,600	3,498	193,600
1941	3,851	238,000	9,582	245,000
1942	2,077	148,000	3,019	NA
1943	- -	- -	3,035	NA
1944	- -	- -	- -	- -
1945	- -	- -	498	33,000
1946	- -	- -	2,704	120,000
1947	- -	- -	3,924	245,389
1948	- -	- -	2,171	114,263
1949	- -	- -	4,343	217,150
1950	- -	- -	2,991	152,300
1951	- -	- -	2,383	170,214
1952	2,464	212,600	3,190	161,625
1953	2,211	179,800	2,585	NA
1954	2,504	176,400	2,607	NA
1955	1,178	106,900	3,415	200,882
1956	2,290	181,100	5,341	242,772
1957	3,027	NA	3,310	228,275
1958	2,523	NA	1,487	106,214
1959	2,134	NA	1,332	95,600
1960	3,415	NA	2,171	144,750
1961	2,868	139,600	1,518	112,450
1962	1,668	119,900	1,648	147,142
1963	2,514	157,900	1,269	94,600
1964	2,669	230,086	- -	- -
1965	1,730	133,076	- -	- -
1966	2,174	167,800	- -	- -
Total	**148,598 oz (4,621 kg)**	**6,419,242 (4,908,152 m^3)**	**143,374 oz (4,459 kg)**	**5,457,566 (4,172,854 m^3)**

[a]Source: compiled from partially complete unpublished records for both dredges 1914-52, provided by the late Richard Fullerton (written commun., 1988); from written records of John Agriz; from Territorial Department of Mines annual and biennial summaries, 1929-54; from Mertie (1933a, 1933b, 1934, 1937, 1938, 1940, 1941, 1942, 1944); and discussions with John Miscovich (oral commun., 1990, 1991).

[b]Stewart (1939) does not indicate production activities for the North American Dredging Company unit for either 1936 or 1937. However, mint records show the indicated production of cubic yards processed and refined gold produced.

- - = No production known.

illustrated in figures 16 and 17. Based on examination of State and Federal production records, Otter and Flat Creeks became the largest producing streams and collectively accounted for an estimated 33,183 kg (1,067,000 oz) of gold from 1915 to 1990 or about 65 percent of total district production (Bundtzen and others, 1987).

By 1912 gold had also been discovered on Happy, Willow, Black, and Chicken Creeks and Glenn Gulch; gold was discovered on Prince and Granite Creeks in 1913, Slate Creek in 1915, and Boulder Creek in 1917. Virtually all known commercial placer deposits within the study area had been discovered in the nine years after the 1908 discovery. Gold production remained relatively high through 1917 but began to markedly drop off after the United States entered World War I, when many miners left the region to join the war effort. Production steadily fell in the late 1920's and early 1930's but picked up after President Roosevelt raised the price of gold to \$35/oz in 1934 from the long time standard of \$20.67/oz. Production activities peaked for a second time in 1941 at 722 kg (23,257 oz) refined gold but dropped off after the United States entered World War II. Federal Order L208 enacted in late 1942 allowed for gold mining in the Iditarod area only on a permit basis.

Placer mining in the Iditarod-Flat area again rose after the war for a number of years, but steadily declined in the 1950's due to inflation vs. the fixed price of gold. Small levels of activity continued through the 1960's although mining records are incomplete for the years 1967-79. The federal price decontrol of gold in 1972 led to a modest revival of placer mining in the area. At present (1991), five placer mines employing 20 individuals actively produce gold, and several mineral firms engage in exploratory activities.

Lode production and exploration have been largely confined to Golden Horn mine near Black Creek, Granite Creek Drainage, and the summit of Chicken Mountain. The Golden Horn gold-tungsten-antimony deposit located near the confluence of Black and Otter Creeks was discovered in 1921 by Rasmus Nielson, a Danish geologist. In 1922, Nielson sank a 15 m (50 ft) shaft on the property and drifted approximately 61 m (200 ft) along the vein. Later in 1922, John Warren became the property operator and sank a second 39 m (128 ft) shaft on the property, the site of the present head frame (sheet 2). Warren installed a small stamp mill and processed surface and underground ores. The property was later acquired and developed by W.E. Dunkle. From 1925 to 1937 extraction of 479 tonnes (528 tons) of high grade ores from underground workings yielded 84,156 g (2,706 oz) gold, 81,482 g (2,620 oz) silver, and 4,243 kg (9,336 lb) lead, mainly mined and shipped by Dunkle (table 8). John Popovich also mined and shipped selected ores in 1937. By 1938, underground workings totaled 551 m (1,808 ft) and consisted of 92 m (303 ft) in two shafts, 312 m (1,025 ft) of drifts, and 146 m (480 ft) of crosscuts, and raises. No further production from underground workings are known. Beginning in 1977 extensive subsurface rotary drilling and trenching of the Golden Horn lode deposit was undertaken by a consortium of Union Carbide, WGM Inc., General Crude, and GCO Minerals, but inconclusive results caused the exploration to cease in 1981. The present owner and operator, John Miscovich, has processed and shipped tungsten-rich, scheelite-gold concentrates from a residual placer deposit directly overlying or adjacent to the Golden Horn deposit. A detailed geological mine map is presented on sheet 2.

Several veins were explored by underground tunnels of undetermined length, a 10 m (35 ft) shaft, and surface trenches in the Granite Creek drainage between 1926 and 1934. These include the Malemute Pup and Golden Ground prospects, which were staked by prospector Gus Uotila in 1922 and the Nielson prospect which was staked in the 1920's by unknown individuals (Holzheimer, 1926). No production is known from these prospects.

A number of en echelon, quartz-gold-cinnabar veins on Chicken Mountain have been explored since 1926. In 1956, the U.S. Bureau of Mines (USBM) collected 276 soil samples and conducted limited auger drilling over a 3 km^2 (1.2 m^2) area but obtained inconclusive results (Kimball, 1969). James Walper staked the properties for gold, rare earth elements, and zirconium in 1960; in 1970, WECO Mining Corporation staked, trenched, and again sampled some of the properties worked on earlier by USBM. During 1987-90, Electrum Resources (now Fairbanks Gold Inc.), under option agreement with Doyon Limited, conducted extensive trenching, drilling, and sampling of the Chicken Mountain gold properties.

PLACER MINING METHODS

During the earliest mining days most placer gold was exploited from shallow, frozen or thawed ground in open cut mines through the use of steam plants and mechanical scrapers (fig. 18). Many mines used elevated sluices fed by chain-linked bucket lines. In the years prior to World War I these labor-intensive operations throughout the district frequently employed 40 to 80 men. We estimate that pre-World War I production from these open-cut, scraper-type mines was 12,892 kg (415,500 oz) gold or 29 percent of total historical production.

Beginning in 1912 and ending in 1966, three bucketline stacker dredges operated by the Yukon Gold, Riley Investment and North American Dredging Companies mined in the Flat and Otter Creek valleys leaving behind the prominent herring-bone tailings piles observed today. Figure 19 shows the paths of operations of the three dredges; a short narrative of their activities follows.

Figure 16. *Flat as seen in 1912, looking from north to south, with Flat Creek in background and Otter Creek in immediate foreground. Telegraph line to the town of Iditarod is left of center. Almost all of the buildings visible in the photograph were to be moved at least once to accommodate dredging activites. Photo courtesy of William and Margaret Taylor Collection, University of Alaska Fairbanks archives.*

Figure 17. *Flat as seen in 1986 showing similar perspective to that depicted in figure 16. The North American dredge, in foreground, made its last pass through town in 1963.*

In 1912 the Yukon Gold Company, with corporate headquarters in Dawson, Yukon Territory, installed the district's first Yuba manufactured floating bucket-line stacker dredge. The dredge was positioned for initial production below the Marietta Claim block, a large bowl-shaped area at the head of Flat Creek immediately downstream from mineralized source rock on Chicken Mountain (fig. 20). From 1912 to 1916 production was from wet ground that was approximately 60 percent virgin pay (Richard Fullerton, written commun., 1988). Numerous hand miners followed the operation and selectively worked dredge tailings. The dredge worked its way back and forth across the bowl and eventually moved downstream and northward to the confluence of Flat and Otter Creeks where it was permanently dismantled in 1918. The 170 liter-(6-ft^3-) capacity electric dredge processed rich pay averaging 2.23 g/m^3 (0.055 oz/yd^3) over the seven years of production and recovered 8,181 kg (263,028 oz) of gold or nearly one-fifth of all the gold mined in the Iditarod district (tables 7, 9).

In 1914, the Riley and Marston Company (later the Riley Investment Company) constructed a smaller capacity, flume dredge at Discovery on Otter Creek. The Riley Investment Company dredge began mining rich ground near the confluence of Black and Otter Creeks, which yielded the high gold output from 1914 to 1920 (table 11). The dredge then moved upstream toward Granite Creek, where low-grade ground was found. Subsequently the dredge moved down Otter Creek valley toward the present airstrip, where the dredge operated nearly continuously until World War II. In 1938 the dredge was rebuilt by the Washington Iron Works and a new steel hull and diesel power plant were installed. The dredge worked through mid-1942 before being mothballed during the war. Riley Investment Company attempted to restart the dredge in 1946, but the U.S. Army had taken essential components of the shop and power plant to assist in the war effort (Stewart, 1947). The Riley Investment Company Creek Dredge did not resume operations until 1952 when John Agriz refinanced and re-equipped the dredge under the new name–Otter Creek Dredging Company. In 1958, the John Miscovich family took over the Otter Creek Dredging

Figure 18. *Open-cut placer mine near head of Flat Creek, circa 1911, illustrating the mining of shallow, virgin ground in the Iditarod district during early gold-rush years. Note elevated sluice boxes on right; reprinted from Eakins (1914, p. 32).*

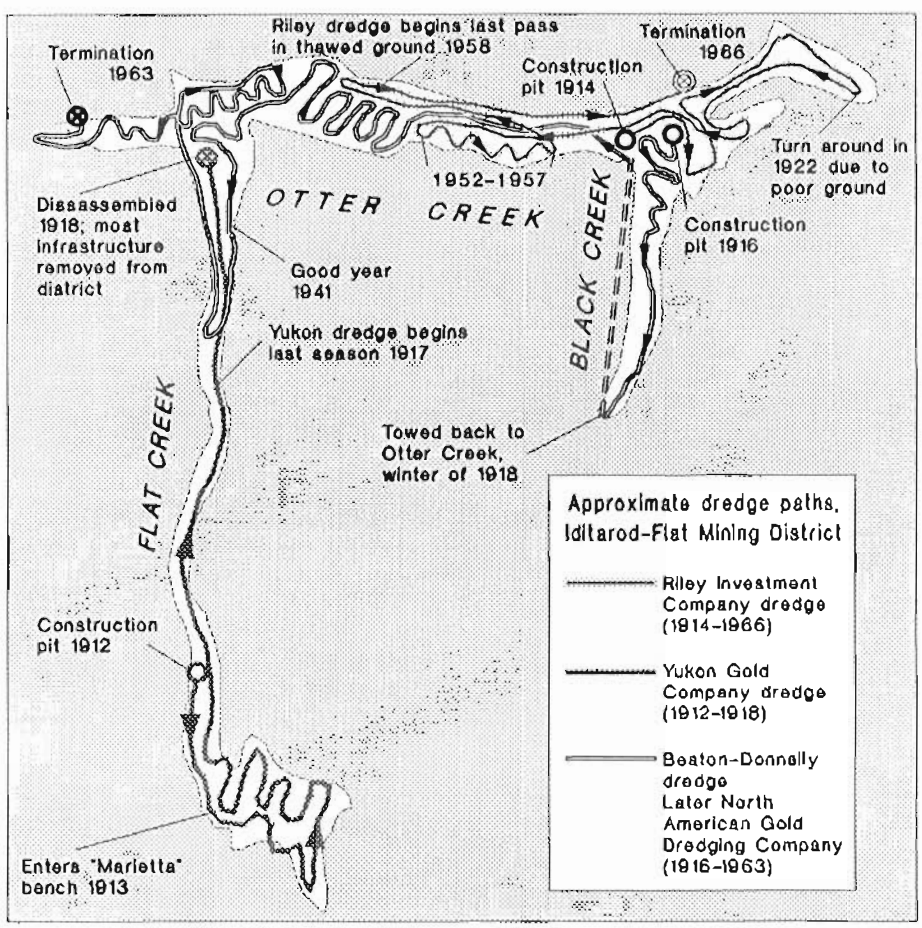

Figure 19. *Graphic summary of dredge paths of Yukon Gold, Riley Investment, and North American Dredging Company operations in Iditarod-Flat district 1912-66.*

Figure 20. *Yukon Gold Company 170 liter (6 ft³) capacity Yuba dredge in its construction pit on upper Flat Creek, August, 1912, shortly before production started. This dredge efficiently mined rich pay during seven operating seasons and was the Iditarod-Flat districts most successful mining venture. Total gold output was 8,181 kg (263,028 oz) or about one-fifth of all the gold mined in the Iditarod-Flat district. Photo courtesy of William and Margaret Taylor Collection, University of Alaska Fairbanks archives.*

Company, resumed operations, and mined every season until 1966 when a fire destroyed the company machine shop causing the operation to cease. In the last operating years Otter Creek Dredging Company confined its dredge mining to thawed ground immediately adjacent to the active channel of Otter Creek and did not process frozen pay under other sections of Otter Creek valley. Estimated production by the Riley Investment Company Dredge for 39 seasons in Otter Creek valley totals 4,621 kg (148,598 oz) of refined gold from at least 4,908,152 m³ (6,419,242 yd³) of processed pay (table 11).

In 1916, Union Construction Company (UCC) built a revolving trommel dredge for the Beaton and Donnelly partnership and installed it at the mouth of Black Creek very near the already operating Riley Investment Company dredge. The cover of this report shows both dredges as they approach each other on adjoining Otter Creek claims in 1916. The Beaton and Donnelly dredge discovered rich pay as it moved up Black Creek in 1916, 1917, and 1918; however, horses had to pull the dredge back to the Otter Creek valley after the upper paystreak limit was reached because water could not be retained in impoundment ponds.

The Beaton and Donnelly dredge was renamed the North American Dredging Company in the 1920's and was one of Flat's most prominant mining concerns for many years, especially after the shutdown of the Yukon Gold dredge on Flat Creek. Relocating houses and other structures by moving them on timbers, the North American dredge worked through the Flat townsite in 1929; this house moving took place at least two other times during the duration of dredging. The North American dredge was shut down in 1931 and restarted briefly in 1936 and then more permanently in 1938, after it was also rebuilt by the Washington Iron Works. The North American dredge worked almost continuously for 17 years after 1938, including most of World War II. The dredge's best years were in 1916 and 1941 when 386 kg (12,433 oz) and 297 kg (9,582 oz) of gold, respectively, were recovered near the mouths of Black and Flat Creeks. The lower Flat Creek ground was successfully exploited because the former Yukon Gold company operation did not recognize the existence of a rich left-limit bench (Richard Fullerton, oral commun., 1988). After 1959 the dredge was operated intermittantly until 1963, when it was permanently shut down in Flat townsite (fig. 21). Historical production during 35 seasons of operation is estimated to total 4,459 kg (143,374 oz) of refined gold from about 4,172,854 m^3 (5,457,566 yd^3) of processed pay (table 11).

The three bucket-line dredges that left such prominant herring-bone tailing piles in the valleys of Otter and Flat Creeks collectively recovered 17,261 kg (550,000 oz) of gold or 38 percent of total historical Iditarod district production.

Other mechanized mines worked the lower-grade pay left by the hand miners and the Yukon Gold Company dredge after World War I. In 1935, the first diesel tractors were freighted into the district and used in placer mining. Sunshine Mining Company based in Coeur d'Alene, Idaho, entered the district in 1936 and attempted to develop a large, low-grade placer deposit within a buried terrace level on lower Willow Creek below the present Fullerton placer camp (sheet 1). Their efforts ultimately failed, but a number of large pieces of heavy equipment including a 1.34 m^3 (1.75 yd^3) dragline were later sold to smaller mining companies and used for many years.

Many mechanized mining operations using bulldozers, loaders, and draglines have worked in the Flat district since the 1930's. Machine operations with many years of mining activity include: Northland Development Company on Willow Creek (dragline and washing plants, 1936-44), Uotilla and Ogriz on Slate Creek (dragline, bulldozer, and washing plant, 1936-48), Patrick Savage on Flat Creek (bulldozer and hydraulic operations, 1935-55), Flat Creek Placers Inc. on Chicken, Happy, Willow, and Flat Creeks (various dragline, bulldozer, and hydraulic operations, 1940-present), Miscovich and Sons on Otter and Black Creeks (bulldozer and hydraulic, 1920-50), Andy Miscovich on Otter Creek (bulldozer and dragline, 1951-58), Awe Mining Company on Flat Creek (dragline with washing plant, 1930's to 1950's), Olson and Company on Flat Creek (two draglines and washing plants, 1930's to 1950's), and Harry Agoff on Prince Creek (bulldozer, hydraulic operation, 1920-50). Otter Dredging Company's 1985 operation near Discovery camp remined ground previously dredged by the Riley Creek dredge (fig. 22).

In 1989 and 1990, John and Richard Fullerton worked Flat Creek (bulldozer, dragline); Alvin Agoff worked Prince Creek (bulldozer, dragline); Richard Wilmarth developed pay on lower Chicken Creek (bulldozer); and Otter Dredging Company (Miscovich family) processed pay on Otter Creek and at the Golden Horn lode property (backhoe and sophisticated plant).

LODE DEPOSITS

INTRODUCTION

Metal-bearing hard rock deposits in the area are known principally for their gold and silver values, but elevated or anomalous values of tungsten, tellurium, zirconium, bismuth, tin, antimony, mercury, tantalum, and niobium have also been discovered. All deposits and concentrations are confined to monzonitic stocks and associated sedimentary

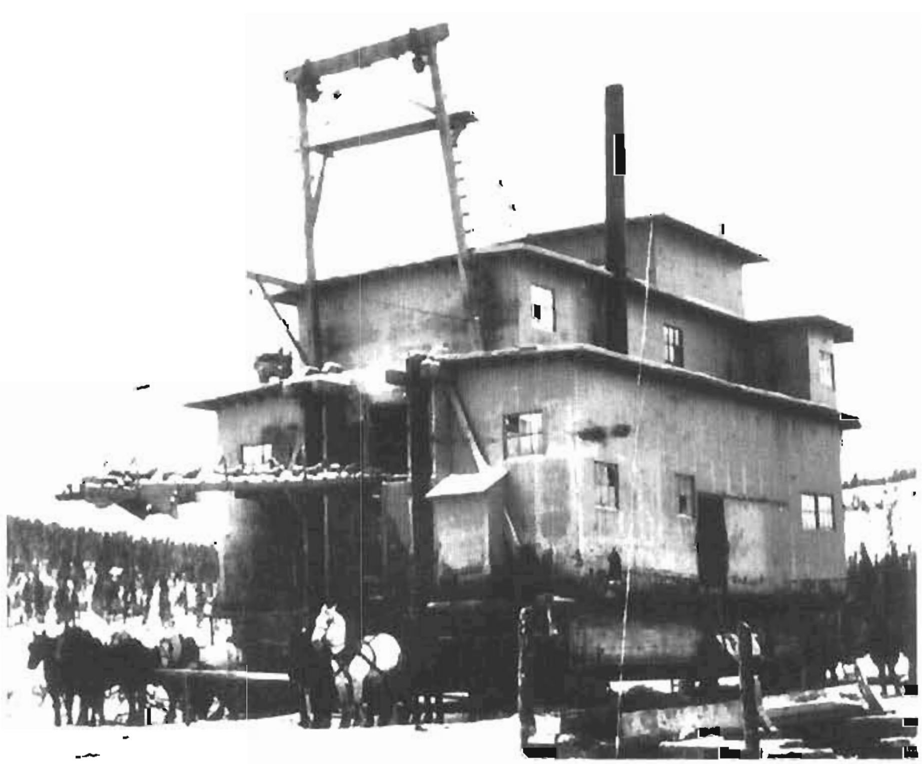

Figure 21. *Beaton and Donnelly dredge (later known as North American Dredging Company operation) being towed down Black Creek by draft horses in the winter of 1918. The dredge moved up the stream as it mined from 1916 to 1918, but was unable to return under its own power due to water impoundment failure. The dredge resumed operations on Otter Creek during 1919. Photo courtesy of Jean Ostnes Collection, University of Alaska Fairbanks archives.*

rocks, hornfels and metavolcanic strata overlying or adjacent to the plutons. Additionally, anomalous concentrations of chromium, cobalt, and nickel have been identified within altered mafic dikes.

GOLDEN HORN DEPOSIT

The Golden Horn deposit is a series of en echelon, steeply dipping, quartz-carbonate-scheelite-arsenopyrite-sulfosalt-cinnabar veins hosted in several phases of the Black Creek stock (sheets 1 and 2). Production history was summarized in the previous chapter. The relationship of the Golden Horn Deposit to the Minnie Gulch and Glenn Gulch prospects is shown on sheet 2. Mineralized veins trend north 10°-25° east for at least 1.5 km (1 mi) before disappearing beneath colluvium to the southwest and valley fill to the northeast. Isolated portions of the vein were reportedly found on bedrock during placer mining activities in upper Otter Creek paystreak (John Miscovich, oral commun., 1988). A N. 25° E. trending vein uncovered by trenching in 1990 near the summit of Chicken Mountain about 4 km (2.5 mi) to the southwest, more-or-less strikes into the known present-day exposures and may be a significant extension of the Golden Horn vein-fault structure. The veins and shears depicted on sheet 2 are found 20-40 m (65-130 ft) from the contact between the Black Creek stock and relatively unaltered siltstone. A distinctive zone of ankerite-sericite alteration about 20 m (65-ft) wide envelops most of the veins in the immediate mine area. The northeast trending veins predominantly dip steeply to the southeast; a few veins dip steeply to the northwest in the northwest corner of the mine cut. Individual veins range in width from nearly 2 cm-1 m (1 in.-3.3 ft); eight to 10 quartz sulfide veins parallel the main Golden Horn vein-fault that was exploited previously by underground mining methods (sheet 2).

Arsenopyrite, scheelite, quartz, and lead-antimony sulfosalts are easily identified during field inspection. Gold assays value at several oz/per-ton (table 10); nevertheless, visible gold is rare.

Polished section and microprobe analyses were completed on several samples from the mine cut. Scheelite-rich vein material (88BT30; 90BT321) collected in the trench near the shaft contained boulangerite, silver-free tetra-

Figure 22. *Originally worked by dredge, this paystreak near Discovery Camp is being remined by the modern equipment of the Otter Dredging Company, circa 1988. Economic pay was found where the Riley Creek dredge had encountered difficult, irregular, and resistant volcanic bedrock.*

hedrite, low-silver owyheeite (AgPbSbS) and rare zoubeckite as inclusions in both arsenopyrite and chalcopyrite (fig. 23). Straw-yellow scheelite contained about 0.6 percent MoO_3 at this locality; molybdenum normally replaces tungsten in scheelite.

Massive arsenopyrite from the caved portal area was analyzed (88BT39; 90BT320). Samples contained quartz, bladed calcite crystals, abundant arsenopyrite, and minor galena and boulangerite. Gold of high fineness (910-920 fine) in the 8-70 micron-size range occurs near the edges of arsenopyrite grains, suggesting a narrow paragenetic position for gold and arsenopyrite (figs. 24a, b).

Concentrates and residium from the Golden Horn mineralized zone were microscopically examined for paragenetic relationships. High-silver electrum and acanthite or stromeyerite infill fractures in arsenopyrite (fig. 25a). Interestingly, grains of gold were found in small fractures of cinnabar nuggets found in the residuum of the Golden Horn vein (fig. 25b). Rare and tiny grains of chalcopyrite and selenite were also found in cinnabar nuggets. In summary, megascopic and microscopic analyses show that silver-antimony-lead sulfosalt, and electrum formed later than arsenopyrite, scheelite and, in some cases, cinnabar.

Detailed mapping of the Golden Horn open cut delineated four plutonic phases. An alkali gabbro-monzodiorite phase is clearly cut by monzonite, but the relationship between the syenite and monzonite is unclear. Granite porphyry dikes cut all other igneous lithologies. Kuskokwim Group sandstone crops out in cuts 15-30 m (50-100 ft) east of the caved portal (sheet 2). Its unaltered nature contrasts with more normal intrusive-hornfels contacts typical in the district and reinforces the contention that the pluton-sediment contact is a fault zone which we refer to as the Granite Creek fault. Most auriferous mineralization appears to be confined to the monzonite phase–especially within zones of ankerite-sericite alteration. Chorite-calcite-quartz veins in joints of gabbro-monzodiorite are apparently devoid of gold and other metallic minerals.

Assays of selected mineral zones are summarized in table 10. These include chip-channel samples from the open cut shown on sheet 2 and grab samples from trenches and cuts southwest of the Golden Horn exposed area. Besides gold, the Golden Horn vein fault contains anomalous amounts of silver, antimony, arsenic, tungsten, yttrium, lead, zirconium, and mercury. Grades of most of these elements–especially arsenic and antimony–are limited by maximum assay values available and interference problems caused by analytical techniques used. We estimate that 1.9 percent arsenic, 1.2 percent antimony, and about 2.0 percent tungsten are reasonable average grades of mineralization, based on eight selected samples where accurate assay values are available (table 10; #28 series). The average values of remaining anomalous elements could not be estimated due to limitations of the data set.

The following inferred reserve estimates and associated discussions follow the "half-square" method advocated by Harding (1923) and Patterson (1959) that assumes that vertical extent of mineralization is at least equal to half the known strike length. Sampling depicted on sheet 2 and reported in table 10 (#28 series) was conducted to determine accurate assay values of gold and silver in the Golden Horn vein-fault deposit. An effort was made to exclude high-grade zones in the vein, and we believe the 29 chip-channel samples are representative of the mineralized zone. We also assume that 0.2 m^3 (8.5 ft^3) of mineralized rock equals 1 short ton (.907 metric tonnes) in mass.

The 29 chip-channel samples average 9.9 g/tonne (0.29 oz/ton) gold and 21.8 g/tonne (0.64 oz/ton) silver over average sample widths of 1.4 m (4.6 ft). Using a total strike length of 225 m (740 ft) for the Golden Horn vein and associated splays, and average vein width of 1.4 m (4.6 ft), and minimum inferred depth of 113 m (370 ft) the Golden Horn deposit and related vein splays contain inferred reserves of 134,390 tonnes (148,000 tons) grading 9.9 g/tonne (0.29 oz/ton) gold, and 21.8 g/tonne (0.64 oz/ton) silver only within the stripped limits of the open cut. We also infer average grades of about 1.9 percent arsenic, 1.2 percent antimony, and 2.0 percent tungsten within the same zone, based on assumptions previously summarized.

A larger but lower grade mineralized zone exposed in the open cut ranges from 10 to 35 m (33 to 115 ft) wide over the narrower quartz-sulfide vein system. The system of ankeritized, sericitzed fractures and joints is believed to average about 1.2 g/tonne (0.035 oz/ton) gold and 3.4 g/tonne (0.1 oz ton) silver over an average width of

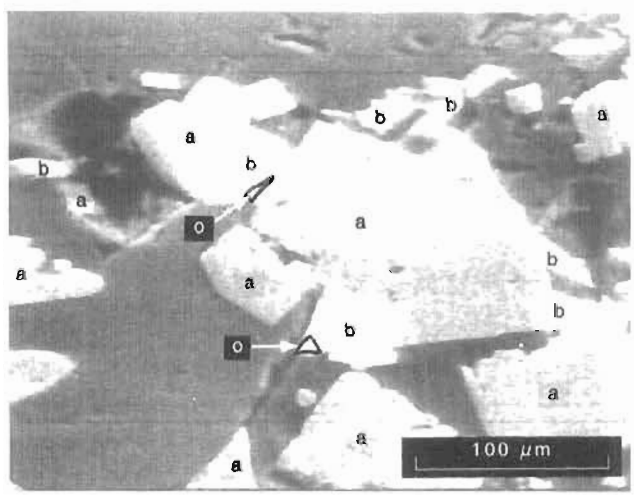

Figure 23. *Photomicrograph of ore minerals from scheelite-rich vein material from sample site 88BT30, Golden Horn (sheet 2) deposit showing owyheeite (o), associated with boulangerite (b) and arsenopyrite (a). Photo by Cannon Microprobe Inc.*

A. B.

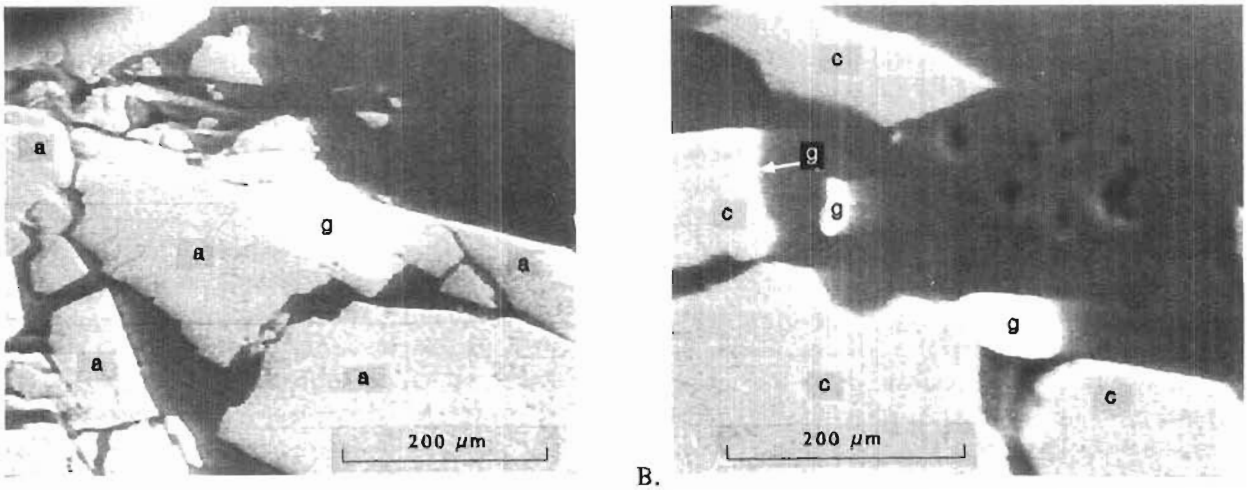

Figure 24. *Photomicrograph of ore minerals found at arsenopyrite-rich zone near portal at sample site 88BT39: (A) 920 fine gold (g) in arsenopyrite (a); (B) 910 fine gold (g) in carbonate (c). Photo by Cannon Microprobe Inc.*

about 30 m (98 ft). Andrews and others (1978) and Adams and Siems (1982) also report that the ankerite-sericite envelope adjacent to the Golden Horn vein-fault contains drill intersections of (1) 9.5 m (31 ft) of 1.9 g/tonne (0.056 oz/ton) gold; (2) 61.6 m (202 ft) of 0.8 g/tonne (0.024 oz/ton) gold, and (3) 33 m (109 ft) of 0.6 g/tonne (0.018 oz/ton) gold--all within 200 m (640 ft) of the Golden Horn shaft. Inferred resources of the larger lower-grade zone within the stripped area, using the half square assumption, are 2.85 million tonnes (3.150 million tons) grading, 1.2 g/tonne (0.035 oz/ton) gold and 3.4 g/tonne (0.1 oz/ton) silver.

Investigations by Andrews and others (1978), Adams and Siems (1982), and Bull (1988) extend the strike length of the Golden Horn vein fault an additional 259 m (850 ft) to the southwest and about 107 m (350 ft) to the northeast of the open cut depicted on sheet 2. The inferred reserve estimates given above should be considered as minimum in scope.

GLENN GULCH OR MOHAWK LODE

The Glenn Gulch gold-antimony-silver lode, originally referred to as the Mohawk deposit (Mertie and Harrington, 1916) lies approximately 650 m (2,130 ft) due west of the main showings at the Golden Horn deposit (sheet 2). Glenn Gulch is perhaps better known for the large gold nuggets--up to 500 g (16 oz)--discovered during early placer mining activities. A stibnite vein up to 1 m thick was discovered on the prospect by placer mining activities

A. B.

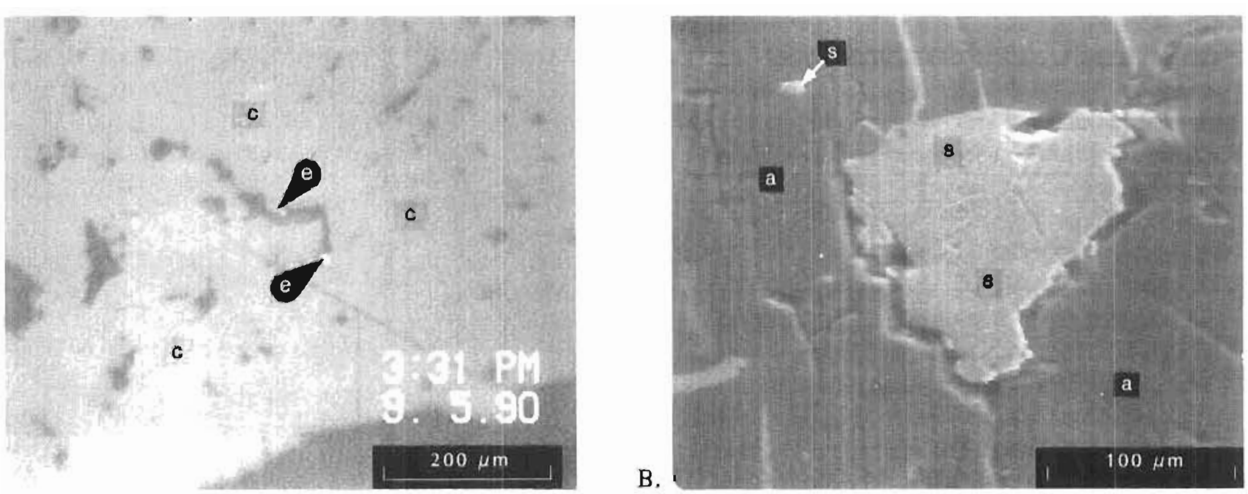

Figure 25. *Photomicrograph of placer nuggets from Golden Horn residual deposit: (A) high silver electrum (e) in cinnabar (c); (B) acanthite or stromeyerite (silver sulfide) (s) in massive arsenopyrite (a) (89BT323). Photo by Cannon Microprobe Inc.*

in 1912 (Brooks, 1916). The Glenn Gulch prospect consists of sulfide-quartz mineralization in a N. 5°-8° E. shear zone 1-2 m (3-6.5 ft) thick that can be traced for about 50 m (164 ft) before it becomes buried on both ends by vegetation and tailings. Andrews and others (1978) show the vein extending norheastward into Otter Creek valley. The shear zone cuts at least two poorly understood phases of the Black Creek stock--a granular felsite and weathered monzonite or monzodiorite. Major stibnite and minor arsenopyrite can be readily identified in the field. According to Brooks (1916) "a little cinnabar is associated with stibnite in Glenn Gulch." We did not identify cinnabar during our work. A distinctive reddish kermesite oxidation covers most rubble and in-place exposures of the mineralization. Polished section and microprobe analysis has identified three sulfide-sulfosalt minerals and shows at least two separate phases of mineralization. Early arsenopyrite is brecciated and intruded by stibnite and a silver-lead-antimony sulfosalt, diaphorite (fig. 26). Assays range from 0.85 to 8.6 g/tonne (0.025-0.251 oz/ton) gold, 8.5 to 1,019 g/tonne (0.16-29.73 oz/ton) silver and 0.16-36.7 percent antimony (sheet 2, map no. 30, table 10).

MINNIE GULCH MINERALIZED AREA

A zone of en echelon quartz veinlets and a barite-bearing shear zone cut monzonite in a 25-m-(80-ft) wide zone about 350 m (1,150 ft) west of the Golden Horn deposit (sheet 2). The quartz veinlets strike N. 45° to N. 60° E. which may relate to more northeasterly striking veins and tensional fractures observed west of the main Golden Horn lode system (fig. 27). Sulfides are rare to absent and mineralization is confined to dessiminated stibnite in quartz and sericite gangue. A 10-m (32-ft) chip channel sample traverse (sheet 2; map no. 29, table 10) yielded 1.36 g/tonne (0.04 oz/ton) gold and 350 ppm antimony. The barite-bearing shear zone contains hydrothermally altered kaolinite gangue in the general absence of quartz; no gold or quartz gangue were detected from the barite-bearing shear zone.

CHICKEN MOUNTAIN LODES

The flat, cryoplanation surface covering the upper part of Chicken Mountain is underlain by a crudely north-south, irregularly defined zone containing thin, stockwork-like, auriferous quartz veins hosted in medium-grained monzonite and syenite. The most conspicuous areas of vein concentration are found in the Idaho Bench at the headward bowl of Flat Creek and about 250 m (820 ft) to the east in the headward drainage of Chicken Creek (figs. 28, 29). Before trenching and reclamation began in 1987, the exposed mineral zone comprised a 110 m² (1,180 ft²) area at Flat Creek and a 272 m² (2,920 ft²) area at Chicken Creek; most of the remaining slopes, including the area in between the two prospects, were buried and overlain by colluvium and vegetation. In both prospect areas thin auriferous veinlets occur in conjugate vein orientations; one vein strikes N. 45°-20° E., and dips 60°-70° NW. whereas a secondary vein strikes of N. 50°-60° W., with dips of 80° NE. Vein density varies widely-as close as 50 cm (20 in.) or separated by as much as 2 m (6.6 ft). The veins, ranging in thickness from 0.5 to 5 cm (0.2 to 2 in.) and averaging 2 cm (0.8 in.), are composed of quartz and ankerite(?) and minor amounts of cinnabar, stibnite, and free gold. Additionally, geochemical analyses of samples (see map nos. 83-85, table 10) show elevated levels of bismuth, beryllium, arsenic, yttrium, lead, and zinc besides anomalous gold, mercury, and antimony. Our best results show 10 m (32 ft) and 7 m (23 ft) chip-channel samples averaging 1.3 g/tonne (.039 oz/ton) gold, and 2.4 g/tonne (.07 oz/ton) gold, respectively.

Exploration financed by Fairbanks Gold Inc. from 1987 to 1990 significantly added to the knowledge of the Chicken Mountain lode system. Extensive trenching and limited diamond drilling-programs corraborate the previously described hypothesis that several plutonic phases fractionated from mafic to felsic compositions. Early monzogabbro is cut by monzonite and quartz monzonite phases of the stock. Evidence for vertical metal zonation was found in drill hole 90-5, where we identified the following successive mineral associations with depth: pyrite-arsenate 36-51 m (119-167 ft); chalcopyrite-molybdenite 51-60 m (167-196 ft); and chalcopyrite-

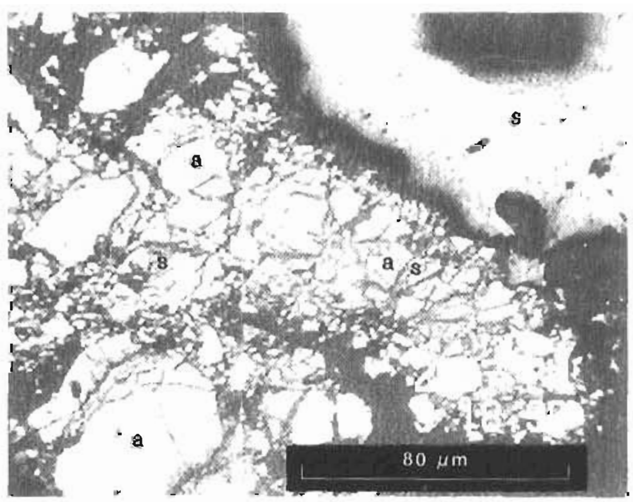

Figure 26. *Photomicrograph of stibnite(s) as cementing agent in arsenopyrite (a), Glenn Gulch lode, Iditarod district, Alaska sample site (89BT10). Photo by Cannon Microprobe Inc.*

arsenopyrite 60-89 m (196-293 ft). Our surface investigations have identified stibnite-cinnabar-pyrite-gold-quartz veinlets on the Idaho Bench about 3 m (10 ft) from the spudded hole previously described. Microprobe analysis of the stibnite-cinnabar-quartz veinlet (sample 88BT50) shows that stibnite contains up to 0.1 percent tellurium; but no gold; cinnabar and quartz gangue were barren of gold. About 40 m (125 ft) of stockwork-rich quartz monzonite in drill hole 90-5 contained 1.2 g/tonne (0.035 oz/ton) gold, 0.035 percent arsenic, and 0.019 percent copper, mainly within a 37-m-(120-ft) long disseminated chalcopyrite rich zone (Richard Gosse, written commun., 1990). This recent industry work confirmed Kimball's (1969) prediction of large tonnages of auriferous mineralization in the upper Chicken Creek drainage.

Anomalous tantalum values were also found in drill hole 90-5. Fractured monzogabbro to monzodiorite contained an average grade of 98 ppm tantalum, 0.062 percent chromium, 0.042 percent nickel, and 55 ppm cobalt to the depth of 17 m (55 ft). One enriched 1.5 m (5 ft) zone contained 302 ppm tantalum. The enriched tantalum-bearing zones are in monzogabbro cut by quartz-sulfide veinlets 0.5 to 1 cm (0.01-0.4) in width. X-ray diffraction analysis of sheared vein material from this interval identified ilmenorutile, a niobium-tantalum titanium oxide. Ilmenorutile enriched with the niobium end-member was previously reported from placer concentrates in the study area-particularly from Otter Creek immediately below monzogabbro exposed at the Golden Horn deposit (Bundtzen and others, 1987). The tantalum mineralization was probably introduced during an early(?) phase of muscovite-quartz-biotite greisen vein development in the Chicken Mountain stock. The elevated chromium, nickel, and cobalt values are believed to mirror the mafic monzogabbro host rock; no gold values of significance were found in the tantalum bearing zone.

PARAGENESIS OF LODE DEPOSITS HOSTED IN BLACK CREEK AND CHICKEN MOUNTAIN STOCKS

Formation of the lodes related to the Black Creek stock are thought to be related to the crystallization of the pluton. Both the Chicken Mountain and Black Creek stocks show: (1) successive rimming of olivine by clinopyroxene then biotite, (2) the replacement of zoned plagioclase by orthoclase, (3) several biotite phases including a later stage biotite alteration throughout the groundmass, and (4) ubiquitous late amphibole rimming other mafic minerals. Thin and polished section and microprobe analyses augmented by field relationships allow us to hypothesize a progressive sequence of mineralization and alteration:

1. "Griesen-like" alteration or muscovite-biotite-quartz ± ilmenorutile, en echelon veinlets cutting early phase monzodiorite and gabbro.

Figure 27. *Auriferous quartz vein in Minnie Gulch pit, circa, 1989. Note decomposed monzonite gruss host rock.*

2. Extensive sericite-ankerite-quartz with minor chrome-phengite mainly as veinlets or massive replacement in all igneous rocks. Additionally, introduction of black sulfide(?)-clast-supported breccias (black material originally thought to be dravite) and minor chalcopyrite, and trace molybdenite in both monzonite and altered monzonite porphyry.

3. Arsenopyrite-scheelite-gold-quartz accompanied by extensive chlorite alteration along fractures and joints. Additionally, introduction of dolomite veining and dolomite-quartz matrix brecciation and associated open space sulfide introduction.

4. Lead sulfosalt-gold ± owyheeite, stromeyerite, and acanthite introduced in shears and faults accompanied by sericite(?) alteration in monzonite.

5. Quartz-stibnite ± cinnabar ± gold in veins in quartz monzonite and quartz syenite sometimes indistinguishable from previous phase.

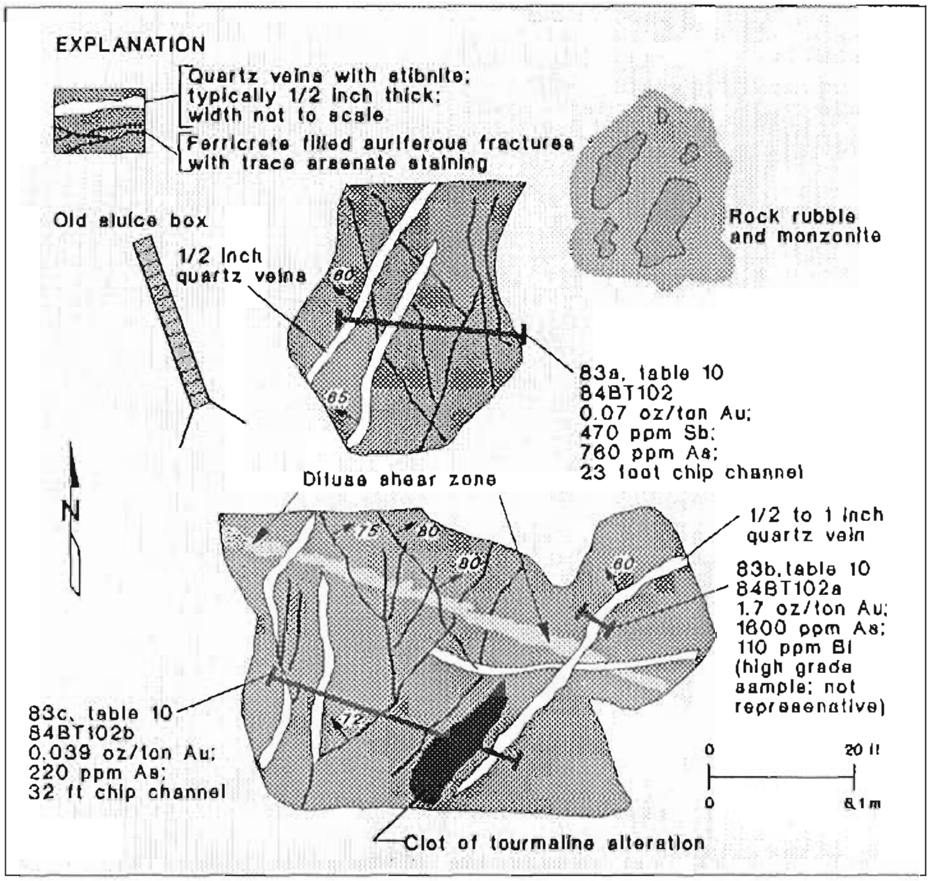

Figure 28. *Sketch of selected exposures of mineralization near upper Flat Creek illustrate structural controls of gold mineralization.*

Bull (1988) examined intact drill core from the Union Carbide consortium exploration efforts of 1978-81 of the Golden Horn lode system and provides additional detailed information concerning the alteration paragenesis.

Fluid inclusion measurements of two samples from the Golden Horn deposit are summarized in table 12. NaCl-poor inclusions in quartz from phase 1 mineralization yield homogenation temperatures averaging 272°C with a maximum decrepitation temperature of 401°C. Inclusions poor in NaCl from milky quartz in phase 4 sulfosalt-rich vein material yield average homogenation temperatures of 143°C.

After plotting arsenopyrite-pyrite mineral compositions on a fS_2-T plot (after Kretshmar and Scott, 1976), Bull (1988) arrived at equilibrium temperatures of 300°-350°C-suggesting the arsenopyrite-scheelite-gold mineralization of the Golden Horn is within the mesothermal range. Our collective (limited) data suggest multiple mineralized pulses spanning the mesothermal and epithermal temperature ranges.

The vein stockworks on Chicken Mountain are conspicuously localized in the cupola phase of the monzonite directly below a thermally altered andesite-basalt roof pendant that forms the mountain summit. The paucity of vein density in the overlying volcanics suggest they served as a cap for the mineralization. Overall, lodes on Chicken Mountain and at Golden Horn appear to be gold-base metal stockwork zones, superficially similar to those found in protore or distal phased porphyry copper systems (Titley and Hicks, 1966). Recent porphyry copper-gold systems within alkaline intrusions have been described at Mt. Milligan in British Columbia (Rebagliati, 1989) and the Pebble Copper prospect near Iliamna, Alaska (Phil St. George, Cominco Alaska Inc., written commun., 1990). However, concentric potassic and phyllic alteration zones normally associated with porphyry systems were not recognized in our study. Bakke (1991) also reports a lack of concentric hydrothermal alteration in intrusive-hosted gold mineralization at the Fort Knox deposit in the Fairbanks district.

Figure 29. *En echelon quartz-free-gold ± cinnabar veins from Idaho Bench, offsite from summit of Chicken Mountain.*

Table 12. *Summary of fluid inclusion data from selected samples, Golden Horn deposit*[a]

Sample number	83BTFlat	81BT5003
Location	Vein (event 4) from "A" trench, Golden Horn	Greisen (event 1) from Union Carbide core, Golden Horn
Host mineral and appearance	milky quartz with parallel extinction	clear quartz intergrown with with muscovite
Quality of phase observation	vapor phase often did not renucleate on cooling; often had to cool to 30°C for reappearance	good with consistent degree of fill
Inclusion Types on	a) liquid rich; b) subordinate solid bearing	a) liquid rich; b) one gas phase behaved critically heating (decrepitated)
Total frozen and average freezing temperature	3; -3.1°C with standard deviation = 0.3	3; -0.9°C with standard deviation = 0.5°C
Total heated and average vaporization temperature	8; 143°C with standard deviation = 26°C	13; 261°C with standard deviation = 53°C
Weight percent NaCl	5.5	1.8
Average volume percent H_2O	70	80
Average homogenization temperature	143°C	272°C with standard deviation = 64
Average decrepitation temperature	NA	401°C

[a]Determinations performed at Univeirsity of Alaska Mineral Industry Research Laboratory heating stage by Kathym Lamal and T.K. Bundtzen, 1983.
NA = not available.

PROSPECTS NORTH OF FLAT (MALEMUTE PUP, GOLDEN GROUND, AND NIELSON PROSPECTS)

Auriferous quartz veins cut monzonite and altered volcanic rocks in the Granite Creek drainage and in Malemute Pup. The Malemute Pup (loc. 46, sheet 1) prospect was staked in 1926 by Fred Lusher, a local Flat prospector. Mine development was reported for the years 1929-34, but production, if any, is unknown. Frank Salen, who placer mined Granite Creek for many years, also worked on the veins prior to World War II. The mine workings were completely overgrown with vegetation at the time of our visit in 1986. The following geological discussion is based on examination of rubble and on the summaries by Mertie (1936) and Meyer (1984). An adit explored a N. 25° E. (striking) 80° SE. (dipping) vein system in the northern edge of the Black Creek monzonite north of Otter Creek valley. Just west of the dump, rubble of mafic volcanic rock forms hillslope scree. The vein system contains thin quartz stringers and shears 1-4 cm (0.4-1.5 inch) thick over a 0.5 m (1.5 ft) width; the veins contain arsenopyrite, minor cinnabar, and carry gold values. A sample of mineralized material that we collected from the dump was analyzed (table 10, no. 31).

Prospects near the head of Granite Creek, referred to as the Golden Ground and Nielson prospects (Holzheimer, 1926), consist of thin, 1-2 cm (< 1 in.), quartz-arsenopyrite veins in olivine-bearing basaltic andesite of the TKvm unit. Two adits, 80 m (262 ft) vertically separated have been driven into the Nielson and Golden Ground prospect. Based on material in the dumps, the tunnels are judged to be approximately 15-20 m (50-66 ft) long and two veins are identified: one vein in outcrop strikes N. 15° E. and dips 80° SE. while the other in outcrop strikes N. 22° E. and dips 70° SE. One sample of ore from the Nielson prospect contained 3.7 g/tonne (0.11 oz/ton) gold and anomalous arsenic. The only ore mineral identified was arsenopyrite. Samples from the upper Golden Ground prospect contain up to 50 g/tonne (1.47 oz/ton) gold, 500 g/tonne (14.7 oz/ton) silver, and anomalous copper, lead, arsenic, antimony, and cadmium (table 10 and sheet 1, map no. 9) from vuggy, ferricrete quartz rubble.

OTHER PROSPECTS

A large iron-stained quartz vein intruding hornfels 2 km (1.3 mi) southwest of the mouth of Black Creek was equipped with an adit and two small trenches (sheet 1). The quartz vein varies from 3-25 cm (1.2-10 in.) thick, strikes N. 41° E., dips 60° SE. and yielded anomalous gold and silver from a selected grab sample.

Gossan zones and thin quartz stockwork are conspicuous in hornfels and igneous rubble on the prominent 857 m (2,840 ft) peak northeast of Flat in the general vicinity of the Golden Ground and Nielson prospects. Bedrock exposures are rare and it is difficult to ascertain the specific parameters of individual mineral deposits; however, chip and grab assays show anomalous beryllium, niobium, arsenic, copper, bismuth, and silver in a 2 km^2 (0.80 mi^2) area at the head of Boulder Creek. The mineralization is localized just above a monzonitic stock that underlies the hornfels; the mineralized cupola and hornfels warrant further exploratory work.

Thin arsenopyrite veins in basaltic andesite were discovered in trenches about 0.5 km (0.3 mi) southwest of the Golden Horn deposit. The veinlets strike N. 15°-20° E. and dip vertically, but have an unknown or small strike length. Besides elevated gold, antimony, and arsenic, one sample (sheet 1, map no. 28) contains 1,400 ppm yttrium.

A quartz-cinnabar vein was discovered in earlier years during gold dredging activities at the west end of the Flat airstrip. According to Ken Dahl (oral commun., 1985), the vein was up to 1 m (3.2 ft) wide and extended in a northerly direction across most of the dredged valley bottom. Several pieces of cinnabar float were found about 50 m (160 ft) south of the west end of Flat airstrip, but it is not clear whether this sporadic material represents in-place mineralization.

MINERALIZED DIKES

Stibnite-quartz stockwork and fracture fillings occur in quartz porphyry (Tkg) along the Iditarod-Nixon Fork fault about 4 km (2.5 mi) northeast of the mouth of Prince Creek (sheet 1, loc. 99-103). Extent of stibnite mineralization is limited to a small stockwork zone 1-2 m (3-7 ft) wide, but a larger zone of silicification some 100 m (330 ft) wide was noted during sampling. Gold anomalies up to 2,900 ppb gold (or 2.62 g/tonne gold) are associated with the antimony occurrence. The quartz porphyry dikes and associated stibnite-gold mineralization are similar to deposits in the Ganes-Yankee Creek mineralized dike swarm (Bundtzen and Laird, 1982) and the Donlin Creek gold-bearing dike swarm (Miller and Bundtzen, 1987, 1992), where substantial lode and placer gold resources occur.

Altered mafic dikes throughout the study area and monzogabbro of the Chicken Mountain stock contain anomalous quantities of chromium, nickel, and cobalt. Average chromium values of 1,250 ppm and nickel values of 600 ppm (N=8) are three times above normal background for mafic rocks (Krauskopf, 1969).

COAL

Thin coal seams found near the old tramway between Flat and Iditarod supplied fuel for local heating systems and blacksmiths in early years (Brooks, 1914). The coal-bearing bed is 0.3 to 0.8 m (1-2.5 ft) thick, strikes N. 60° E., dips 50° SE., and lies in the Kqs unit, a composite lithology deposited in brakish marine and nonmarine environments. Vegetated pits examined during our work show plant-rich quartz, arenite, and shale as dominant bedrock lithologies. Mertie (1936) reported average calorific values of 7,983 and an average Btu value of 14,369 or anthracite by rank. The poor exposures that typify the old coal mine prevented any further examination by the authors.

PLACER DEPOSITS

The gold placers of the study area differ from drainage to drainage and depend on distance from lode sources, stream aspect, and degree of bedrock disintegration. The Iditarod-Flat district is one of Alaska's best examples of a progressive evolution from residual to eluvial to stream heavy-mineral placer concentrations from mineralized source rock. The streams that have yielded commercial amounts of placer gold are confined to a small 50 km^2 (19 mi^2) region centered on Chicken Mountain and in Otter Creek valley. The probable sources of placer gold are the auriferous veins, disseminations, and stockworks in the Chicken Mountain and Black Creek stocks, in the hornfels aureole north of Otter Creek, and in mineralized bedrock within the valley of Otter Creek.

Gold fineness data from placer deposits throughout the study area are summarized by Smith (1941), Metz and Hawkins (1981), and Bundtzen and others (1987). A summary of mineral content and fineness values is shown in table 13. The fineness values districtwide range from 822 to 891 and average about 864, based on 112 weighted determinations. Principal heavy minerals include cinnabar, magnesiochromite, magnetite, radioactive zircon, ilmenite, scheelite, ilmenorutile, garnet, and cassiterite. The overall placer provenance is somewhat puzzling because mineral

Table 13. *Summary of heavy mineral concentrate and gold fineness data, Iditarod district, Alaska*[a]

Placer depositional (stream drainage)	Heavy minerals	Gold fineness range	Average fineness
Prince Creek Bench	Magnetite, ilmenite cinnabar-chrome fluorapatite spinel	NA	886
Prince Creek (modern drainage)	Cinnabar, ilmenite, zircon, scheelite, magnetite, diopside, chromite-magnesio-chromite, cassiterite	NA	834
Willow Bench	NA	856-883	874
Happy Creek	Zircon magnetite, ilmenite, chromite, hyperstene, enstatite, richterite, cinnabar, fluorapatite	862-884	862
Chicken Creek	NA	850-870	861
Flat Creek (Head)	Zircon, black pyroxene, amphibole, scheelite, cinnabar, stibnite	854-901	861
Flat Creek	NA	NA	864
Otter Creek	Arsenopyrite ilmenite, cinnabar, scheelite, pyrite, zircon	822-848	847
Black Creek	Magnetite, zircon, arsenopyrite, ilmenite, cinnabar, chromite, magnesiochromite, scheelite, richterite, enstatite, zircon, cassiterite, diopside, ilmenorutile, argentopyrite	NA	819
Granite Creek	NA	NA	854
Malemute Pup	NA	NA	832
Slate Creek	NA	NA	855

[a]Data mainly summarized from Bundtzen and others (1987) and Smith (1941) and some additions from this study. Heavy mineral percentages progressively decrease in order of appearance.
NA = not available

assemblages range from epithermal to upper mesothermal temperatures of formation and from gold-mercury-antimony to gold-arsenic-tin-niobium-tungsten associations. The existence of magnesiochromite and high nickel values is unusual because very minor amounts of rocks of ultramafic affiliations have been recognized. Our sources for the the following discussion were mineralogical and lab fineness information collected during our investigations, discussions with miners, and previously published information.

CHICKEN MOUNTAIN PLACERS

Prince, Slate, Chicken, Flat, and Happy-Willow Creeks all have their headward sources in a small 2 km^2 (0.8 mi^2) region near the summit of Chicken Mountain (fig. 30). These second-order streams range from 6-12 km (4-8 mi) in length and have asymmetrical profiles that show steepest sides on their southern or western limits (fig. 30). Stream gradiants range from 200 m/km (405 ft/mi) near their heads, slowly decreasing to 80 m/km (165 ft/mi) at midstream to 40 m/km (80 ft/mi) where they enter major trunk streams off the flank of Chicken Mountain. On modern flood plains, the overburden, which is covered by vegetation and overlain by decomposed rock-rich regolith, averages 3-6 m (10-20 ft) in thickness mid-stream and 5-8 m (16-25 ft) near stream heads. The thickened overburden occurs near the tops of the drainage basins in the steep ($\geq$15° gradient) drop-off zones and bowl-shaped depressions that characterize Flat, Happy, and Slate Creeks. In these areas the overburden consists of large slide rock slabs which have moved downslope from the summit area of Chicken Mountain. Older terrace levels have significantly thicker overburden than active flood plains. For instance, the overburden in mine cuts on Prince and Willow Creeks ranges from 6 to 9 m (20 to 30 ft) in thickness and consists of varved frozen silt that contains up to 50 percent ice.

Mineralized monzonitic bedrock on Chicken Mountain and Black Creek, the presumed sources of placer gold, is hosted in deeply weathered, sandy gruss that ranges in depth from 1 to 6 m (3.3 to 20 ft) and averages 4 m (13 ft) in many areas. We believe that the transformation from fresh pluton to gruss can be explained through a sequence involving: (1) freeze-thaw expansion along joint sets and opening or rotation of joint planes; (2) formation of scaly aggregate or exfoliation sheets along enlarging joint faces through groundwater-induced mechanical and physical weathering; (3) progressive rounding of original square blocks; and (4) grussification of original plutonic rock leaving remanent knocker blocks (fig. 31). The depth to weathering varys according to specific environmental factors. On Chicken Mountain, fresh plutonic rocks were encountered within 10 m (33 ft) of the surface (Jim Prey, oral commun., 1990), but weathering depths of up to 50 m (164 ft) were documented in drill programs on Black Creek (Andrews and others, 1978).

The physical and chemical disintegration of the monzonite into sand-sized particles released free gold and other heavy minerals from vein and other deposits; these heavy minerals then sank into the rock debris. Low specific-gravity rock-forming minerals and gangue material has been continually removed by wastewater and mechanical disintegration. This process produces an enrichment in gold and, in favorable areas, an economically exploitable deposit. These classic residual placers are best observed in the headward slopes of the Happy, Chicken, and Flat Creek drainages such as the Idaho Bench, and the Mohawk and Upgrade claim groups. Much of the original residual gold-heavy mineral accumulations later moved downslope because of frost action, gravity, and in part, water transport. These modified hillslope or eluvial placers are found on steep slopes at the headward bowl of Flat Creek and in the sloped cryoplanation terraces of the Chicken Creek drainage. With continuing influence of stream hydraulics, the hillslope deposits are eventually worked into the auriferous stream placer deposits that have been the major source of placer gold production in past years.

A general westward migration of streams during assymetrical valley formation played an important role in the evolution of stream placer deposits around Chicken Mountain. Solifluction due to daytime thawing activity is more pronounced on south- or west-facing slopes and causes stream drainages to migrate toward north- or east-facing abrupt slope walls (fig. 30) Through this process, older, eastern bench deposits or strath terraces formed on Prince, Slate, Flat, Willow, and Chicken Creeks. Aerial photographic interpretation augmented with field observations have shown that, in one case, stream pyracy has resulted from the westerly migration process. Remnants of high level (380 m; 1,250 ft) bench deposits at the divide between Prince and Chicken Creeks indicate that the upper portion of Prince Creek was captured by Chicken Creek. Consequently, it seems probable that the original lode sources of both streams lie in the cupola-stockwork area of

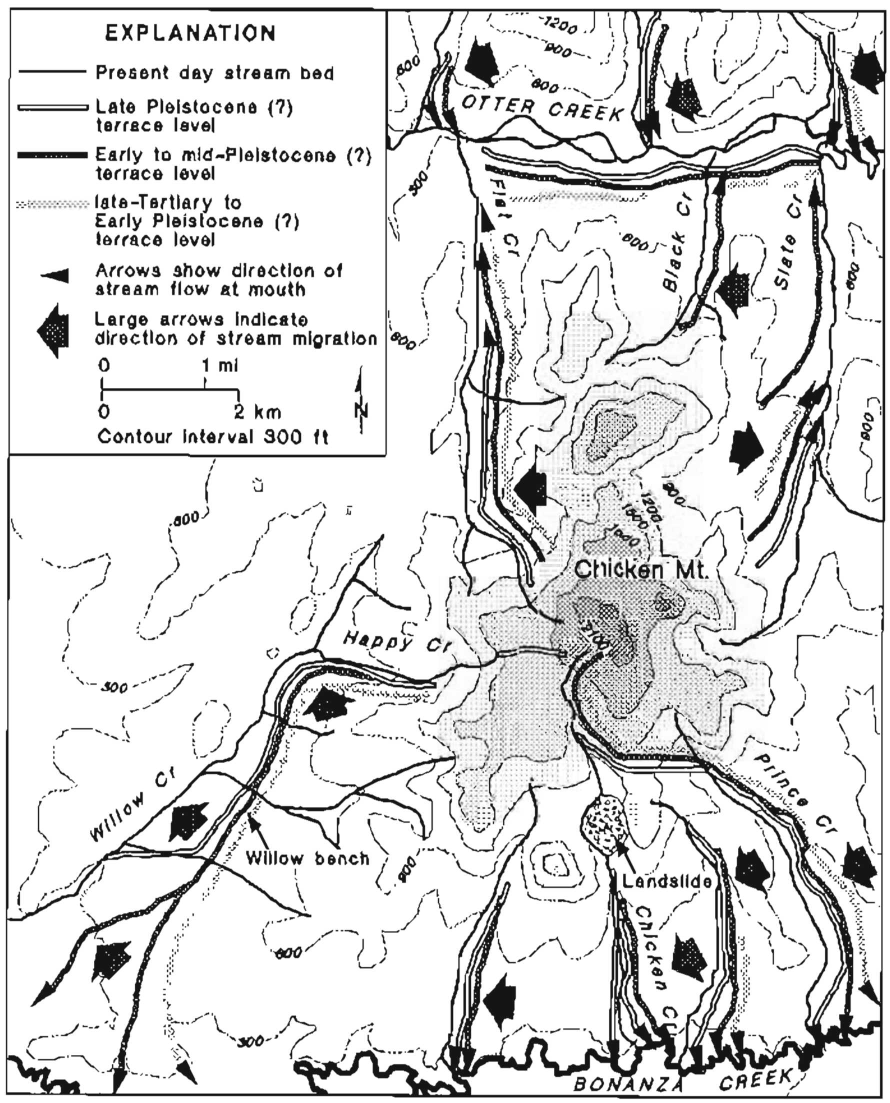

Figure 30. *Aerial photograph interpretation illustrating Chicken Mountain stream drainage evolution.*

the general Idaho and Mohawk bench area, and that present headward reaches of Prince Creek are not eroding this lode source. Further down Prince Creek, evidence exists for at least three bench levels. The two oldest bifurcate a low bedrock rib 1-2 km (0.7-1.4 mi) east of the present confluence with Bonanza Creek while the youngest terrace level closely parallels the present stream (figs. 30, 32).

Westerly or southwesterly stream migration can best explain the present configurations of Willow and Happy Creeks. The paleo-stream bed of Happy Creek is now preserved as a series of prominent terrace or bench levels on the eastern or northeastern valley limits. The ancestral Happy Creek moved westward leaving various terrace levels on Willow Creek. The terrace levels indicate an ancestral stream course that is markedly to the east of the current position of Willow Creek. In similar fashion Chicken, Flat, and Slate Creeks migrated in a westerly direction leaving bench levels on the eastern limits. Midway in Chicken Creek valley, a landslide has buried an earlier channel of the stream forcing a sharp curvilenear stream diversion around the obstruction.

Gold in bench terrace or bench deposits on Willow Flat and Prince Creeks generally show higher fineness values when compared to that from active flood plains of the modern stream. Our two fineness tests of gold from benches on Prince Creek average 886 and gold from the modern stream yields a fineness of 838. Gold bullion from the Willow Bench, the presumed ancestral course of Happy Creek, averages 874, whereas down the course of the modern stream valley of Happy Creek gold fineness averages 862. The same relationship is apparently true on Flat Creek, because Mertie and Harrington, (1924, p. 113) report that the gold of Flat Creek has two grades; the gold taken from the bench gravel is coarser and of higher fineness than that taken from the creek gravel.

On Flat Creek gold that progressively worked downstream increases some 25-35 points in fineness (854-881), probably as a result of silver and base metals leaching out of the placer bullion leaving the geochemically stable gold. Gold from near in-place sources on the Idaho claim yielded fineness value of 854-901 and averaging 861 ($N=6$), which is consistent with our theory that fineness values increase downstream from the gold source areas.

Available data shows that bench placers contain more gold than modern stream placers. On Prince Creek the bench levels contain about twice the gold grade (1.2-1.6 g/m^3; 0.03-0.04 oz gold yd^3) of the average of modern stream gravels or 0.61-0.81 g/m^3 (0.015-0.20 oz gold yd^3) (Alvin Agoff, oral commun., 1986). In the upper bowl of Flat Creek, much of the extremely rich ground was found on the eastern benches. This ground was worked first by the dredge of Yukon Gold Co. and later by smaller operators. Some 3.59 million m^3 (4.7 million yd^3) processed by the dredge during the seven years of operation in the basin averaged 2.2 g/m^3 (0.055 oz/yd^3) (table 9). On the western limit, modern stream gravels yielded grades one-quarter to one-half as high.

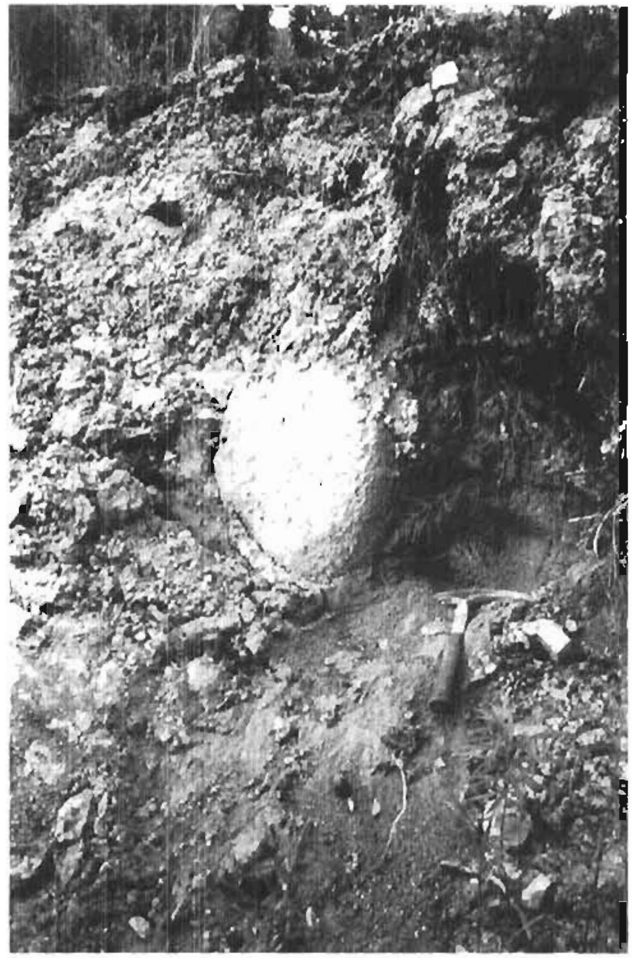

Figure 31. *Resistant monzonite "knocker" in sandy gruss near Black Creek illustrates final grussification in the study area.*

Placer gold concentrations on various terrace levels of the Willow Bench have been further modified from crosscutting by east-west tributaries entering Willow Creek (fig. 30). Gold concentrations appear to be enriched at the intersection of each pup with the older terrace levels (Richard Fullerton, oral commun., 1988). Furthermore, fineness values also appear enriched by 10- to 25 points at these points of intersection.

On Prince Creek analyses of heavy mineral concentrate from bench and stream gravels differ significantly. Bench deposits contain a major component of cinnabar, garnet (below garnet-bearing granite porphyry sills in the lower stream) chrome spinel, stibnite, diopside, tremolite, ilmenite, and zircon. However, modern stream gravels have a somewhat lower amount of chrome spinel, ilmenite, and diopside, but instead contain scheelite, and cassiterite.

Figure 32. *Prince Creek drainage looking north shows older terrace or bench levels on the eastern limit and modern stream on the western limit. Ancestral channels, oldest to youngest numbered 1 through 3; present-day stream shown on far left of photo.*

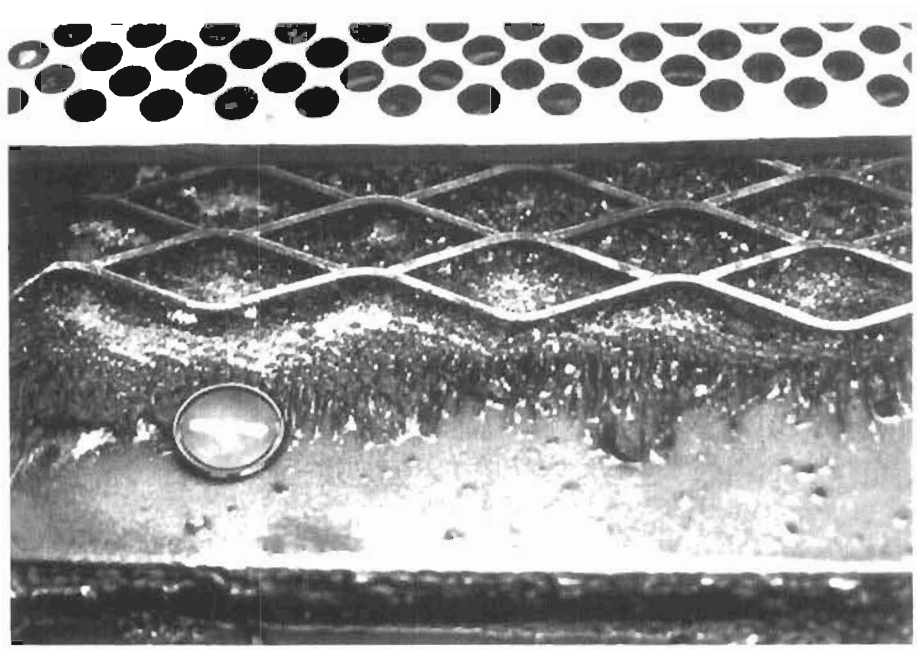

Figure 33. *Placer gold from Happy Creek, 1983, Fullerton family operation. (Flat Creek Placers Inc.). Note uniform fine-grained, "oat meal" gold grains.*

Assuming the chrome spinel, ilmenite, diopside, and zircon present in both deposit types are accessory minerals of the pluton, the ore minerals represented in the modern stream deposits could be interpreted as being mesothermal in origin, whereas ore minerals of the bench deposits appear to be an epithermal assemblage. If these assumptions are correct, then mineralization on Chicken Mountain has been progressively stripped away by erosion.

Placer gold from different streams draining Chicken Mountain are remarkably similar in grain size and physical dimension. Nearly 90 percent of the gold consists of small, equant grains in the -80 to -20 mesh range; flake gold is uncommon to rare (fig. 33). The largest nuggets average 25 g (0.88 oz). The largest nugget from the Chicken Mountain area reported by Mertie (1936) was a 57 g (1.33 oz) piece recovered from the Willow Bench. Fineness values in bench deposits are 862 (Chicken Creek), 871 (Willow), 862 (Happy Creek), 876 (Prince Creek), 855 (Slate Creek), and 878 (Flat Creek). The remarkably similar fineness values for all the streams (range = 23 points for all the placer deposits), strongly indicates a similar, if not identical, lode source. Additionally, heavy minerals identified in concentrates by White and Killeen (1953) and Bundtzen and others (1987) all contain mineral species common to all-scheelite, chrome spinel, zircon, amphiboles, cinnabar, and diopside. The specific known lode sources are thin (0.5-2 cm; 2-0.8 in.), auriferous quartz veinlets in the Chicken Mountain pluton; the thin veinlets help explain the uniform sized distribution of the placer gold present in the streams.

PLACER DEPOSITS OF OTTER CREEK DRAINAGE

Placer gold deposits in the Otter Creek drainage differ in morphology, gold fineness, uniform size distribution, and heavy mineral content from those formed around Chicken Mountain. The westerly flowing Otter Creek heads at a major stream divide with the Dishna River 25 km (15 mi) northeast of Flat. Unlike the streams radially draining Chicken Mountain, valley asymmetry is reversed and exhibits steepened northwall and a gradual southern rim underlain by bench gravels. The older benches gradually merge with modern stream alluvium. Auriferous gravels are confined to (1) Otter Creek from its confluence with Granite Creek and extending 8 km (5 mi) to a poorly defined area about 3 km (2 mi) downstream from Flat townsite, (2) the last 3 km (2 mi) of Granite Creek, (3) 4 km (2.5 mi) of Black Creek and its nearby tributary Glenn Gulch, and (4) Boulder Creek (where production of gold was modest). Placers on both Otter and Black Creeks begin on the upstream end of the Black Creek monzonite-monzogabbro body, which hosts the Golden Horn gold-tungsten shear zone. Placers on Granite and Boulder Creeks, and Malemute Gulch are also immediately below a mineralized monzonite pluton, exposed north of Otter Creek. Prior to exploitation, the overburden thickness varied from 3 to 6 m (10 to 20 ft) with 1 to 2 m (3 to 6 ft) being stream gravel and the remainder organic muck-silt deposits.

Reproducible platinum anomalies (0.8 to 1.3 ppm) were discovered while analyzing gold bullion from Black Creek. This reinforces earlier accounts by Andrews and others (1978) and Miscovich (written commun., 1981) of platinum in the Otter Creek drainage. Although not of economic concentrations, its presence suggests further platinum analytical work with bullion and concentrates might be warranted. Otter Creek drainage also contains the highest amount of other economic heavy minerals such as scheelite, cinnabar, and zircon (fig. 34).

In Otter Creek, gold fineness decreases downstream from an average of 854 near the Golden Horn deposit, to

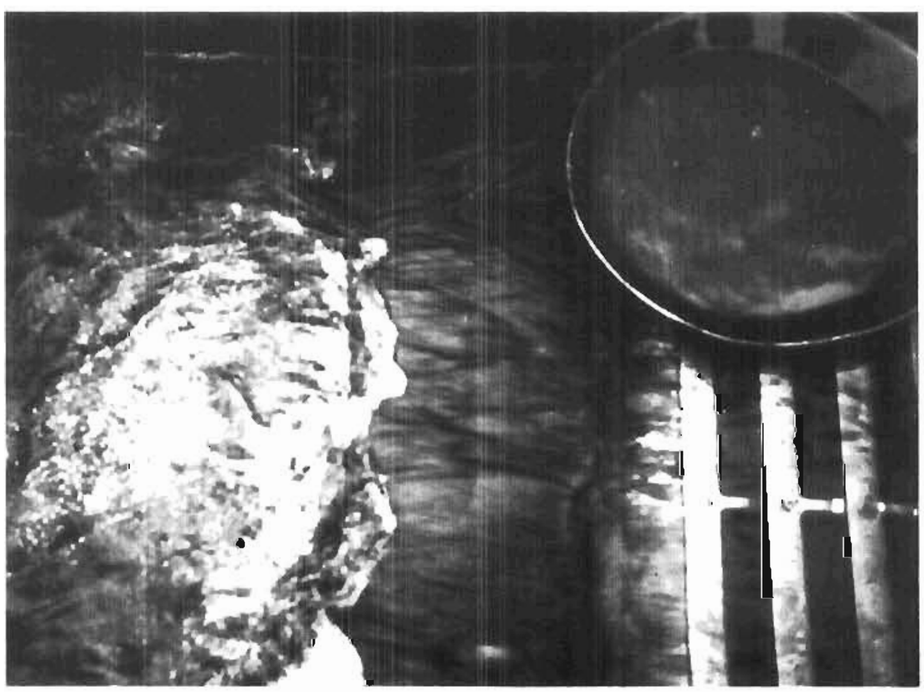

Figure 34. *Cleanup of payzone from semiresidual placer deposit, Golden Horn mineralized area, upper Otter Creek drainage. Note scheelite (white) concentrations in arsenopyrite-gold bullion.*

838 near the Flat airstrip, to about 824 below the town of Flat (Mertie, 1936). The decreasing fineness values in a downstream direction is the opposite of what would be expected by silver-base metal leaching effects and might suggest multiple lodes sources in the valley of Otter Creek. We hypothesize that the high-fineness gold is derived from veins and shears in the Black Creek monzonite (which we refer collectively to as the Golden Horn deposits) and the lower fineness bullion emanates downstream from undiscovered deposits beneath placer cuts.

Otter Creek placer gold is significantly coarser than that found in streams draining Chicken Mountain. Two distinctive types of placer gold from the Otter Creek drainage have been noted over the years: (1) angular fine gold in abundant quartz gangue, and (2) rounded nugget gold lacking quartz or gangue mineralogy. A 548 g (16 oz) nugget was recovered in Glenn Gulch in 1933 (Mertie, 1936) and in 1987, John Miscovich found the largest gold nugget in the district's history along the rim of Minnie Gulch--a rounded 870 g (28 oz) piece virtually free of gangue impurities (fig. 35). The larger veins averaging 0.5 m (1.6 ft) in thickness that are found in the Golden Horn, Minnie Gulch, and Glenn Gulch mineralized area are the logical sources for coarse gold found in the Black and Otter Creek drainages.

CLASSIFICATION OF LODE AND PLACER DEPOSITS

The Golden Horn, Glenn Gulch, Chicken Mountain, and Malemute Pup deposits in the Iditarod district are classified as intrusive-hosted, gold-polymetallic deposits that have characteristics of alkaline related, precious metal systems of the western United States such as those described by Wilson and Kyser (1988), Thompson and others (1985), and Mutscher and others (1985). All four deposits and other occurrences in the study area consist of shallow, cupola-hosted, vein-fault, and quartz stockwork concentrations of gold, silver, arsenic, antimony, ± mercury, and ± tungsten; the deposits also contain elevated levels of bismuth, uranium, zirconium, and yttrium. Principal gangue minerals are quartz, tourmaline, and very minor fluorite, but tourmaline is notably absent in the Golden Horn deposit. Dolomite breccias and open space fillings are peculiar to the Golden Horn deposit. Virtually all other volcanic-plutonic rocks of the Kuskokwim igneous belt contain tourmaline and locally axinite in breccia pipes, veins, and as abundant accessory mineral concentrations (Bundtzen and Swanson, 1984).

Host plutons at Flat belong to the metaluminous and peraluminous, alkali-calcic to quartz-alkalic suite. Locally mafic phases of both the Black Creek and Chicken Mountain stocks are slightly alkaline or quartz alkalic and have Peacock indexes of about 51.

Detailed geology, trace element geochemistry, ore mineralogy, and mineral paragenesis indicate that lodes in the study area formed during several events that spanned the mesothermal and epithermal temperature ranges. Our detailed work coupled with recent exploration drilling programs make a strong case for vertical and lateral metal hydrothermal

Figure 35. *Nugget weighing 869 g (28 oz) recovered in Minnie Gulch area, Otter Creek drainage, from semiresidual colluvium. Photo courtesy of John Miscovich.*

mineral zonation. Highest temperatures and pressure conditions occur at deepest structural levels, and lowest temperature-pressure mineral assemblages at or near surface conditions are exhumed by erosion. We believe that all mineral deposits in the Flat area represent the same Late Cretaceous zoned system now exposed in several erosional levels.

The metal zonation scheme of the Flat area shown in table 14 is based on existing data and our best collective judgements. Shallow, epithermal mineralization in the more deeply eroded Black Creek stock has been largely removed by stream dissection, whereas the partially unroofed Chicken Mountain lode system still has much of the shallow, low-temperature, mercury-gold-antimony association intact.

Heavy mineral placer deposits downslope and downstream from the known lode sources in the study area reflect the overall hard rock style of mineralization. The grain size, fineness, trace element geochemistry, and distribution of placer gold of all streams draining the Chicken Mountain stock are remarkably similar suggesting a near-identical lode source for placers in Prince, Happy, Chicken, Slate, Willow, and Flat Creeks. Microscopic examination of placer and lode gold shows cinnabar attached to gold grains, which suggests epithermal conditions of lode formation at the Idaho Bench and Golden Horn deposits. Likewise, the coarse placer gold in Otter and Black Creeks reflects the large shear-veins present in the presumed lode sources at the Golden Horn property. Alkali amphiboles and pyroxenes including edenite, richterite, and hastingsite in placer concentrates in the streams also reflect the alkaline compositions of source plutonic rocks. Platinum, niobium, uranium-rich zircon, and bismuth values (in placer

Table 14. *Schematic summary illustrating mineralogical zonation in metalliferous lodes of Flat-Iditarod district, Alaska*

Mineral deposits	Alteration	Mineral assembledge	Geothermometry estimates	Generalized T/P conditions
1. Chicken Mountain (event 4) 2. Flat airstrip 3. Golden Horn (event 5)	Dickite, weakly silicic	1. Cinnabar + stibnite + gold + quartz 2. Cinnabar + quartz + stibnite + quartz 3. Auriferous cinnabar + stibnite + quartz	NA	Epithermal
1. Glenn Gulch (event 2) 2. Golden Horn (event 4) 3. Chicken Mountain (event 3)	Weakly argillic	1. Stibnite + boulangerite + silver + sulfosalts 2. Boulangerite + arsenopyrite + owyheeite + stromeyerite 3. Pyrite arsenate + silver sulfosalts	Homogeneration temperature in quartz of 148° at Golden Horn	Lowest mesothermal or epithermal
1. Golden Horn (event 3) 2. Minnie Gulch	Chloritic; dolomitic; weakly ankeritic	1. Arsenopyrite + scheelite + tetrahedrite + gold + quartz; trace chalcopyrite 2. Barite + boulangerite + gold	NA NA	Lower mesothermal
1. Chicken Mountain (event 2) 2. Golden Horn (event 2) 3. Glenn Gulch (event 1)	Strong ankerite, alteration + fluorite	1. Chalcopyrite + molybdenite + chalcopyrite + arseno-pyrite 2. Chalcopyrite + galena + arsenopyrite 3. Arsenopyrite	Atomic weight percent arsenic >330°C	Mesothermal
1. Golden Horn (event 1) 2. Deepest zone, Chicken Mountain (event 1)	Greisenization	1. Muscovite + biotite + ilmenorutile 2. muscovite + biotite + ilmenorutile + cassiterite(?)	Decripitate temperature of >401°C at Golden Horn	Upper mesothermal

NA = not available.

concentrates) also occur in mineral deposits associated with other alkali-calcic to quartz alkalic plutons in the Kuskokwim mineral belt (Bundtzen and Laird, 1991).

Several inconsistencies between placer and lode mineral content remain. The trace amounts of cinnabar found in lodes within the Black Creek stock do not account for the abundance of cinnabar found in the nearby placer deposits on Otter and Black Creeks. Perhaps the shallowest or lowest temperature portions of the mineral deposits have been removed by erosion. Bull (1988) could not find appreciable magnetite and found only trace ilmenite in igneous rocks of the area; however, magnetite and ilmenite are abundant in most of the placer concentrates. Like the cinnabar question, either magnetite-rich lode or rock unit sources remain undiscovered or magnetite-rich mineral deposits or igneous rocks have been removed by erosion.

The Late Cretaceous-early Tertiary volcanic-plutonic complex and associated mineral deposits of the study area can be compared and contrasted with other similar alkalic-to-subalkalic intrusive hosted, gold-polymetallic deposits in Alaska and the North American Cordillera (table 15).

Although similar mineralization style and alteration exists in the Kensington, Fort Knox, and Gold Hill and Timberlines lode systems in Alaska, telluride mineralogy, low sulfide content, plutonic chemistry, and crystallization ages of the stocks (Jurassic to mid-Cretaceous) clearly contrast with deposits we have studied in the Flat area.

Deposits in the Rocky Mountain alkalic province, including the productive Zortman-Landusky lodes in central Montana, are also similar to those of the study area. Lodes in both the Flat and Zortman-Landusky areas contain fluorite-ankerite alteration halos, stockwork-type mineralization in host monzonite and syenite, and have comparable Late Cretaceous-early Tertiary (Laramide) plutonic and mineral crystallization ages. The Zortman-Landusky and other related mineral deposits in Montana lack significant mercury and tungsten, but contain tellurides, which apparently contrast with the major elemental content of mineral deposits found in the Flat area.

We also note some similarities with newly discovered alkalic porphyry and copper-gold deposits at Mt. Milligan, British Columbia (Rebgliati, 1989) or at Pebble Copper near Iliamna, Alaska (St. George, 1991). However, the concentric potasssic, phyllic, and argillic alteration halos that are usually found in gold porphyries (Sillitoe, 1991; Vila and Sillitoe, 1991) are not yet recognized in the Flat district.

In summary, mineralization in the study area shares many similarities with alkaline instrusions of Laramide age found throughout western North America. However, enough differences exist with better known deposits to suggest that polymetallic-gold deposits in the Flat district and other plutonic-hosted mineral deposits in the Kuskokwim mineral belt might deserve a separate classification.

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We dedicate this report to the late Richard Fullerton, longtime Iditarod district miner and Alaskan resident, who passed away in late July 1990.

Table 15. *Generalized comparison between Iditarod-Flat gold district and selected examples of alkalic-plutonic hosted gold deposits in Alaska and North American cordillera*

Characteristics	Deposit examples					
	Flat district (this study)	Fort Knox Fairbanks district (Bakke, 1991)	Kensington, Juneau district (Kirkhan, 1989)	Gold-Hill-Timberline Valdez Creek (Smith, 1981)	Mt. Milligan British Columbia (Rebgliati, 1989)	Zortman-Landusky, Montana (Wilson and Keyser, 1990; Mutscher and others, 1985)
General geology	Volcanic pile (andesite flows) intruded by multiphase stock	Multiphase pluton intrudes schist of Yukon-Tanana terrane	Intermediate stock intrudes coast range plutonic complex	Small plugs and stocks intrude Mesozoic Kahiltna terrane	Andesite/latite flows by intermediate porphyritic stock	Latite flows intruded by alkalic stock
Plutonic compositions	Highly fractionated monzonite and monzodiorite dominate	Granodiorite, quartz monzonite	Diorite, quartz, diorite	Alkali gabbro and granodiorite	Monzonite	Syenite and monzonite
Plutonic and mineral deposit ages	68-70 Ma (probably the same for lodes)	89-92 Ma (lodes may be younger)	120 Ma (lodes are early Tertiary)	140 Ma (lodes uncertain)	Jurassic	52-43 Ma (same for lodes)
Alteration	Variable; strong ankerite; also fluorite dolomite, chlorite in veins	Silicic; lacks concentric alteration of gold porphyries	Ankerite	Ankerite	Central potassic; distal phyllic (concentrically zoned)	Ankerite-sericite-fluorite
Deposit paragenesis	At least five events spanning mesothermal-epithermal range	Several events in mesothermal range	Several events in mesothermal range	Mesothermal depositional range	Several events in mesothermal range	Several events in epithermal- to mesothermal range
Deposit type	Alkali-calcic to quartz alkalic, pluton-hosted stockwork polymetallic gold deposit	Telluride, bismuth, gold-bearing sulfide-poor intrusive stockwork; somewhat uncertain deposit type	Telluride-bearing gold sulfide-poor alkalic stockwork; "mother lode"; mesothermal type	Telluride-gold-bearing, sulfide-poor stockwork; "mother lode"; mesothermal type	Copper-gold-alkalic porphyry	Polymetallic alkalic gold stockwork

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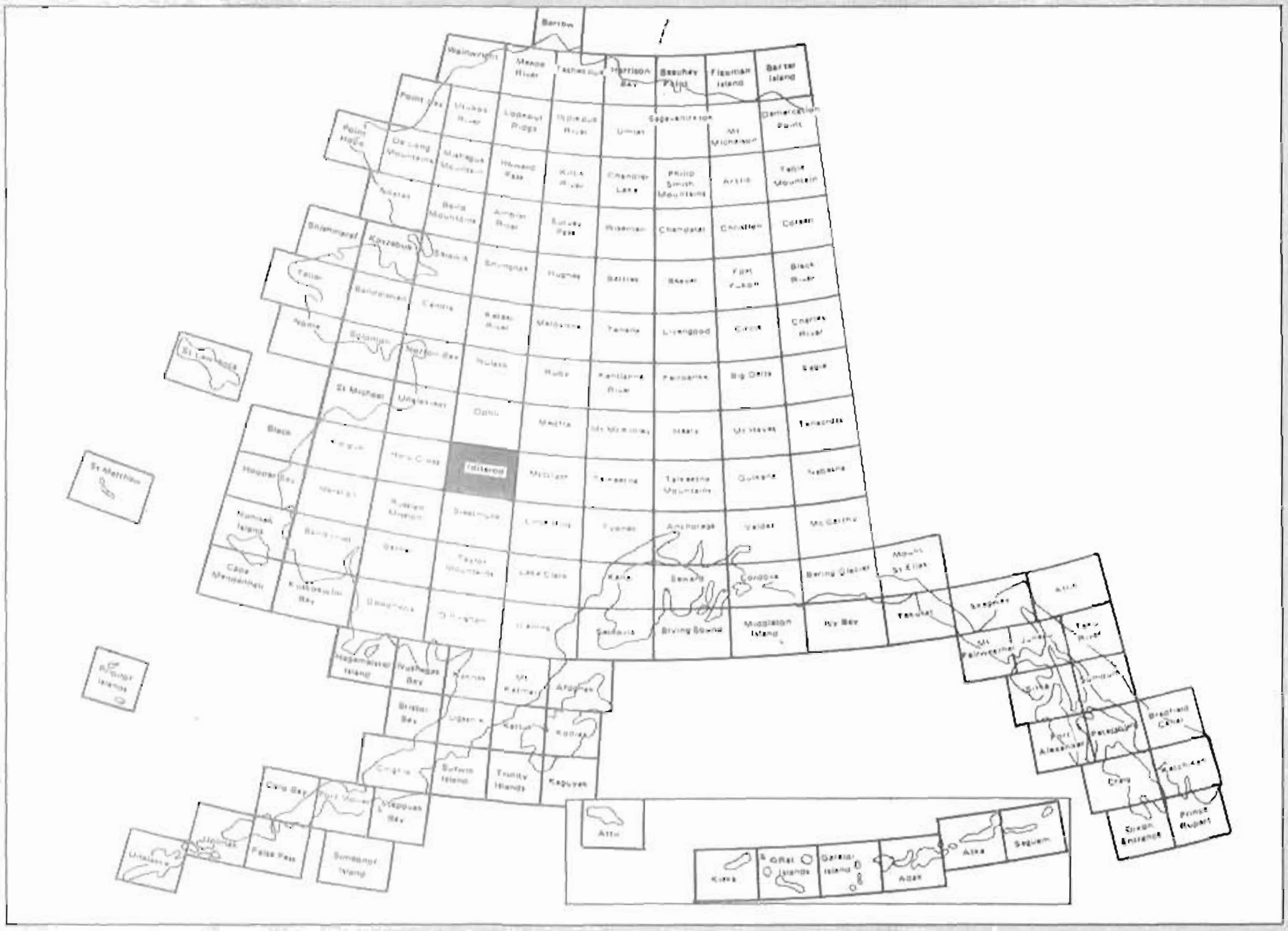
Barrow
Wainwright
Meade River
Teshekpuk
Harrison Bay
Beechey Point
Flaxman Island
Barter Island
Point Lay
Utukok River
Lookout Ridge
Ikpikpuk River
Umiat
Sagavanirktok
Mt Michelson
Demarcation Point
Point Hope
De Long Mountains
Misheguk Mountain
Howard Pass
Killik River
Chandler Lake
Philip Smith Mountains
Arctic
Table Mountain
Noatak
Baird Mountains
Ambler River
Survey Pass
Wiseman
Chandalar
Christian
Coleen
Shishmaref
Kotzebue
Selawik
Shungnak
Hughes
Bettles
Beaver
Fort Yukon
Black River
Teller
Bendeleben
Candle
Kateel River
Melozitna
Tanana
Livengood
Circle
Charley River
St Lawrence
Nome
Solomon
Norton Bay
Nulato
Ruby
Kantishna River
Fairbanks
Big Delta
Eagle
St Michael
Unalakleet
Ophir
Medfra
Mt McKinley
Healy
Mt Hayes
Tanacross
Black
Holy Cross
Iditarod
McGrath
Talkeetna
Talkeetna Mountains
Gulkana
Nabesna
St Matthew
Hooper Bay
Russian Mission
Sleetmute
Lime Hills
Tyonek
Anchorage
Valdez
McCarthy
Nunivak Island
Bethel
Taylor Mountains
Lake Clark
Kenai
Seward
Cordova
Bering Glacier
Mount St Elias
Cape Mendenhall
Kuskokwim Bay
Dillingham
Iliamna
Seldovia
Blying Sound
Middleton Island
Icy Bay
Yakutat
Skagway
Atlin
Pribilof Islands
Hagemeister Island
Nushagak Bay
Naknek
Mt Katmai
Afognak
Taku River
Mt Fairweather
Juneau
Sitka
Sumdum
Bristol Bay
Ugashik
Karluk
Kodiak
Bradfield Canal
Port Alexander
Petersburg
Ketchikan
Chignik
Sutwik Island
Trinity Islands
Kaguyak
Craig
Cold Bay
Port Moller
Stepovak Bay
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Adak
Atka
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