DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PRE-FIELD STUDY AND MINERAL RESOURCE ASSESSMENT OF THE SLEETMUTE QUADRANGLE, SOUTHWESTERN ALASKA

by

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Open-File Report 89-363

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1989

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ABSTRACT

This document represents a comprehensive summary of all presently existing geologic, geochemical, and geophysical data pertaining to the Sleetmute quadrangle, southwestern Alaska. Most of this data has been previously published by Federal or State agencies, however, some unpublished data is also included. The purpose of this report is to present a preliminary mineral resource assessment based solely on existing data, and to make recommendations for future work should this quadrangle be designated for examination under the Alaska Mineral Resource Assessment Program (AMRAP).

The Sleetmute quadrangle encompasses parts of the low rolling Kuskokwim Mountains and the Holitna Lowland. The Kuskokwim River, Alaska's second largest, crosses the northern half of the quadrangle. Access is primarily by air, although the Kuskokwim River is navigable by small boats and shallow-draft commercial vessels. Over half of the quadrangle is State owned; ownership of the remaining land is about equally divided between Native interests and the Federal Government.

Alaska's largest mercury mine, the Red Devil deposit, is located in the Sleetmute quadrangle. Although now closed, this mine produced over 36,000 flasks of mercury (1 flask is 76 lbs) from cinnabar-stibnite-quartz veins hosted in Cretaceous flysch and altered dikes. The quadrangle has also yielded about 4,000 troy ounces of gold from several small stream placer deposits and an undetermined but minor amount of placer scheelite (tungsten ore).

The oldest rocks, a Paleozoic carbonate sequence, are poorly exposed in the southeast part of the Sleetmute quadrangle, in the broad sloping plain of the Holitna Lowland. Triassic and Early Cretaceous sedimentary and volcanic rocks that are interpreted to be part of an accreted volcanic-arc complex, occur in the southwest part of the quadrangle, but are volumetrically minor. The majority of the Sleetmute quadrangle is underlain by Cretaceous interbedded sandstone, shale, and conglomerate, which comprise a post-accretionary basin-fill flysch sequence. Late Cretaceous to early Tertiary plutonic rocks and associated volcanic rocks intrude and overlie this sequence. Peraluminous hypabyssal rhyolite and altered felsic to intermediate dikes, also of Late Cretaceous to early Tertiary age, cut the sedimentary rocks as well. Two major northeast-trending strike-slip faults cross the quadrangle, each having a minimum of 90 km (56 mi) right-lateral offset.

Geochemical data coverage exists for only about 10% of the Sleetmute quadrangle. Although limited in scope, the data indicate anomalous concentrations of mercury, antimony, silver, gold, tin, tungsten, molybdenum, and arsenic (and lesser chromium, copper, lead, and zinc). These data suggest the possible existence of previously unreported mineral occurrences and deposits.

Geophysical data is so sparse that only a preliminary interpretation is possible. Gravity data indicate the likely presence of a Tertiary or Quaternary basin in the central eastern Sleetmute quadrangle. Magnetic data suggest that several previously undetected plutons lie beneath the Cretaceous flysch. Mineralization associated with the upper contact zones of these plutons may lie at shallow depths.

Known and potential lode mineral deposits of the Sleetmute quadrangle are described in terms of six deposit models listed below:

1 - Red Devil type mercury-antimony,
2 - alkalic epithermal gold-silver,

3 - gold-tungsten-quartz vein,
4 - tin-silver-boron enriched,
5 - Mississippi Valley type lead-zinc, and
6 - zinc-lead-silver, copper, or iron skarn.

Both mines and prospects of deposit model types 1 and 3 occur within Sleetmute quadrangle. Mines, prospects, or mineral occurrences of model types 2, 4, and 6 occur in neighboring quadrangles. Similar geology, supported by geochemical anomalies, leads us to propose that deposits of these latter three types may also occur in Sleetmute quadrangle. Although no deposits or occurrences of the Mississippi Valley type have been documented in this region, permissive host rocks are present, leading us to consider this model also.

We have not considered deposit models for oil or coal resources in the Sleetmute quadrangle. Although Smith and others (1985) reported that rocks of the Holitna Basin have shale maturation values within the oil window, these rocks have probably experienced temperatures high enough to preclude them as a source rock. Based on this assumption, we estimate the potential for oil resources is low. We also estimate the potential for coal resources is low. Northeast of the Sleetmute quadrangle, Bundtzen and Gilbert (1983) reported coal seams in Tertiary sediments in several localities adjacent to the Denali-Farewell fault. However, no coal has been reported from Sleetmute quadrangle and the potential host rocks, if present, are buried.

To assess the mineral resource potential, we divided the quadrangle into six tracts (plate 3), each characterized by a factor or combination of factors indicative of a particular deposit type. Tract 1, an area permissive for Red Devil type mercury-antimony deposits, is defined on the basis of geologic, geochemical, and geophysical information, as well as by the presence of known mines, prospects, and occurrences. Tract 2, areas permissive for alkalic epithermal gold-silver deposits, is defined primarily on the basis of favorable geology (in this case the presence of granitic to monzonitic plutons), but is supported by geochemical and geophysical data. Tract 3, areas permissive for gold-tungsten-quartz vein deposits, is defined by the presence of a mine, a prospect, and, to a lesser degree, by geochemical anomalies. Tract 4, possibly related to tin-silver-boron enriched deposits, is defined on the basis of geochemical anomalies. Tract 5, permissive for tin-silver-boron enriched or alkalic-epithermal gold-silver deposits, is defined on the basis of geophysics alone, which suggests the presence of buried plutons. Finally, Tract 6 outlines an area underlain by carbonate rocks, the potential hosts for either Mississippi Valley type lead-zinc, or skarn deposits. No geochemical data is available to support this tract designation, so it is defined solely on the basis of geology, but skarn deposits are known to be present to the east.

We conclude that the Sleetmute quadrangle has a moderate to high potential for discovery of additional deposits of the Red Devil mercury-antimony type (Tract 1). The potential for occurrence of alkalic epithermal gold-silver and gold-tungsten-quartz vein deposits (Tracts 2 and 3, respectively) is considered to be moderate, but acquisition of additional data may lead to a higher rating. The potential for tin-silver-boron enriched deposits and mineralization associated with buried plutons (Tracts 4 and 5, respectively) is difficult to determine because little data are available, but is considered to be low and unknown, respectively. Similarly, the potential for Mississippi Valley type or skarn deposits (both in Tract 6) is difficult to evaluate because of a lack of data. However, based on existing data, the potential is low for discovery of Mississippi Valley type deposits and moderate for discovery of skarn deposits. Clearly, additional information, particularly geochemical data, is needed before a thorough assessment can be accomplished.

CHAPTER 1. LOCATION, ACCESS, CLIMATE, AND LAND STATUS

The Sleetmute 1° x 3° quadrangle (scale 1:250,000) is located in southwest Alaska, 210 miles west of Anchorage (fig. 1). The area comprises nearly 18,000 km^2 (7000 mi^2) of variable terrain encompassing portions of two physiographic provinces: the Kuskokwim Mountains and the Holitna Lowland (Wahrhaftig, 1965). The Kuskokwim Mountains, a succession of rounded ridges and broad lowlands, lie along a northeast-trending axis; the southeastern range boundary diagonally bisects the quadrangle. The average elevation is 370 to 760 m (1,200 to 2,500 ft) but some of the more rugged terrain rises to between 900 and 1,250 m (3,000 and 4,100 ft) and has been glaciated. The intervening well-drained lowlands have an elevation of 90 to 180 m (300 to 600 ft). Timberline occurs at an elevation of about 370 m (1,200 ft). The broad, northwest-sloping plain of the Holitna Lowland lies east of the mountains, is 90 to 240 m (300 to 800 ft) in elevation, and drains part of the west side of the Alaska Range. The Kuskokwim River, the second largest in Alaska, roughly bisects the northern half of the quadrangle and several of its tributaries -- the Holitna, Stony, and Swift Rivers -- flow across the Holitna Lowland.

Access to the quadrangle is essentially by aircraft since no roads or summer trails exist. Commercial air service from Aniak, 20 miles west of the quadrangle, is available to the villages of Sleetmute, Crooked Creek, Red Devil, and Stony River. Several other native villages along the Kuskokwim River have gravel airstrips suitable for small aircraft. During the summer months, the Kuskokwim River is navigable for small craft and suitable for float plane landings. Petroleum and heavy supplies are brought to the riverside villages by shallow-draft barge from Bethel. Although much of the quadrangle is heavily vegetated, ridgetops above timberline can be traversed on foot.

The climate of the region is subarctic, characterized by short, typically wet summers, and by dry, cold, windy winters (Cady and others, 1955). Average summer temperatures are approximately 55° F, and the quadrangle has discontinuous permafrost.

Land jurisdiction in the quadrangle is divisible into three categories (fig. 2). About 55% of the land is owned by the State of Alaska; 25% is Native land (5% of which is under multiple ownership); and about 20% of the land is Federally owned and administered by the Bureau of Land Management (BLM). The area contains no Federal or State designated park or wilderness lands.

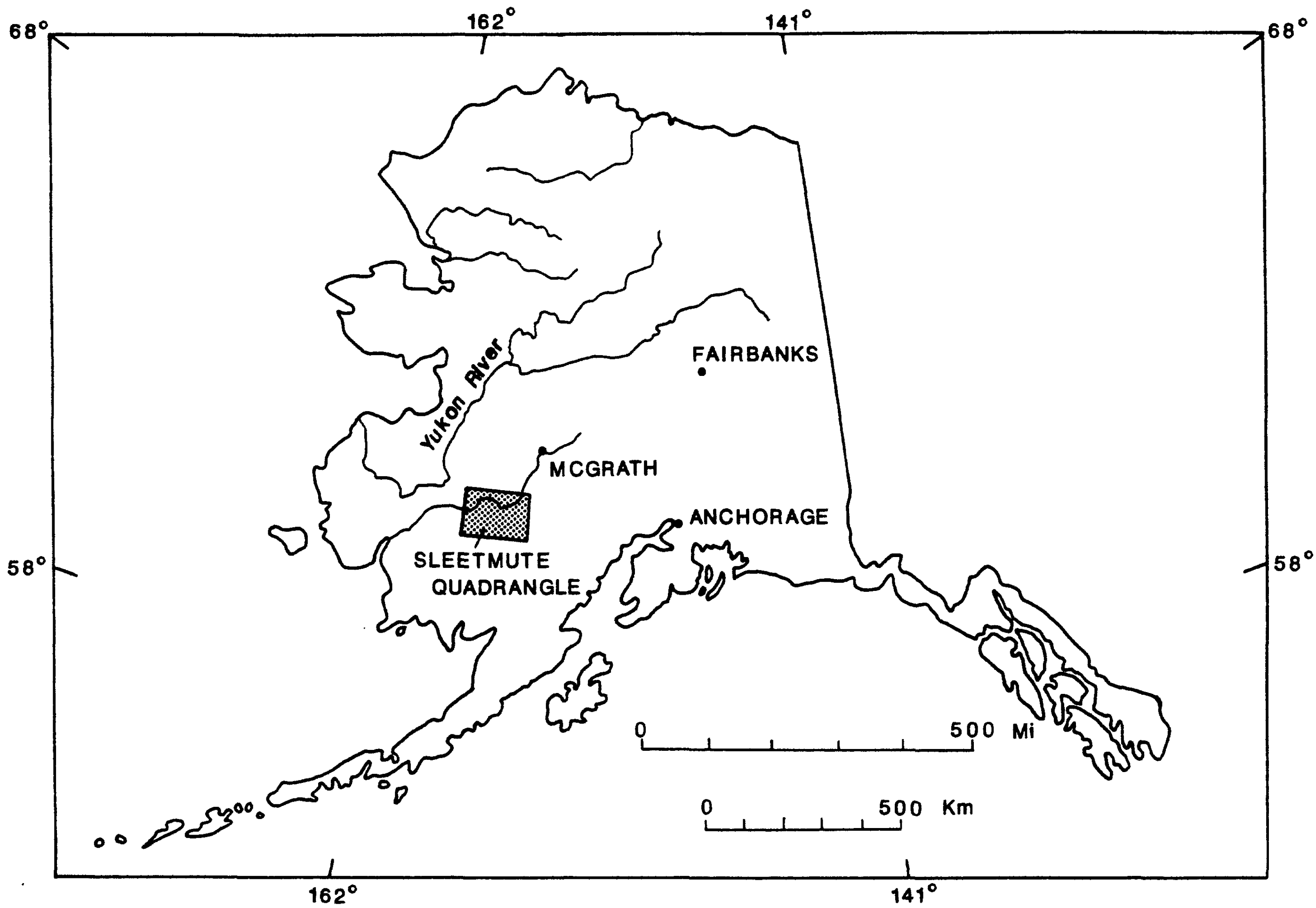


Figure 1. Map showing location of the Sleetmute quadrangle, Alaska.

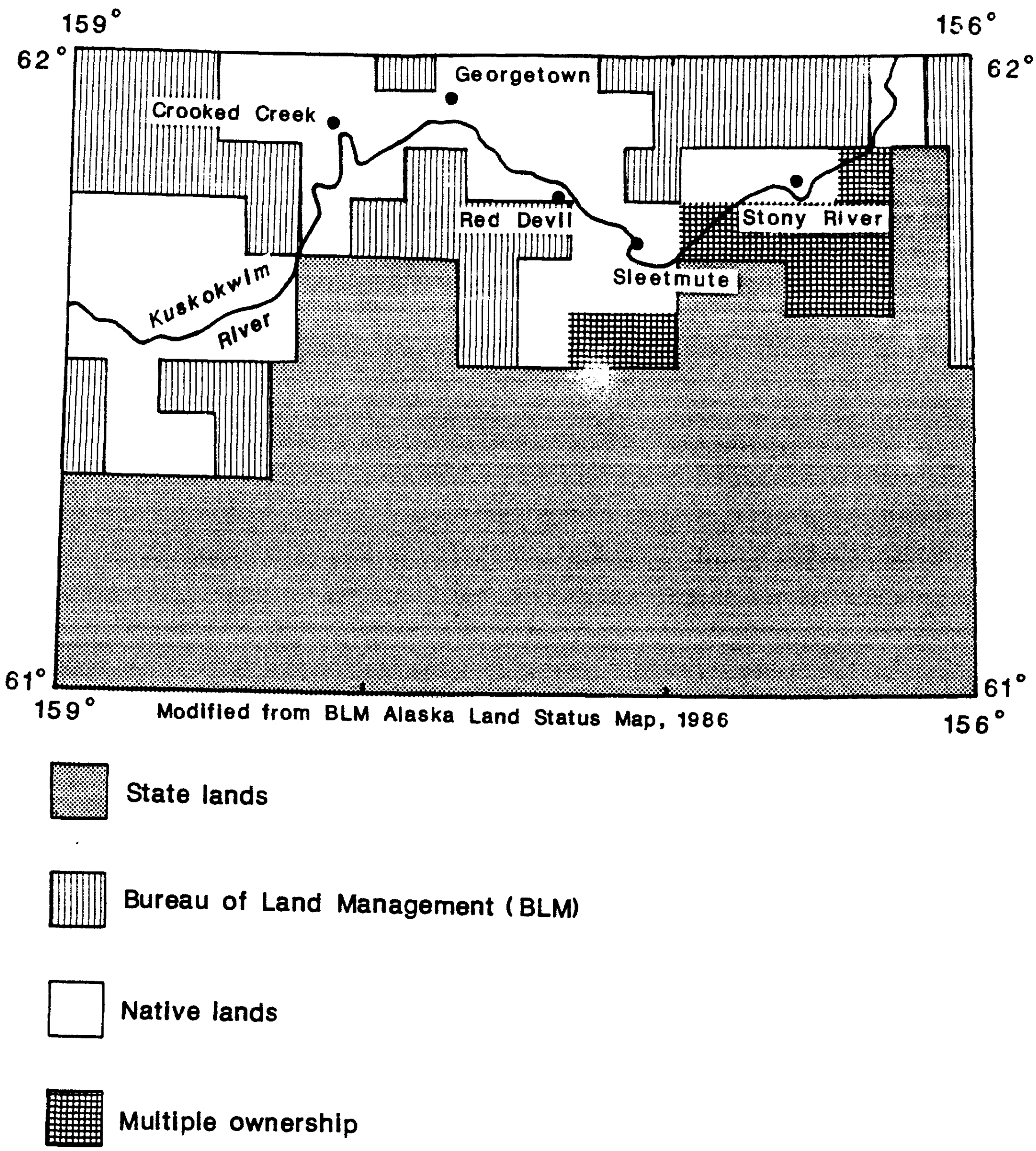


Figure 2. Map showing land status in the Sleetmute quadrangle, Alaska.

CHAPTER 2. GEOLOGY

DATA COVERAGE

PREVIOUS WORK

Except for a few well studied mineral properties, the geology of the Sleetmute quadrangle is known only on a reconnaissance scale. The first systematic geologic observations of the area were made by J. E. Spurr of the U. S. Geological Survey (USGS) in 1898 while descending the Kuskokwim River by canoe (Spurr, 1900). From 1902 to 1903, in conjunction with his search for valuable minerals, prospector William R. Buckman prepared a map of the Holitna River basin and later forwarded it to the Geological Survey (Cady and others, 1955). In 1914, USGS geologists, A. G. Maddren and P. S. Smith, both worked in the Sleetmute quadrangle; Maddren investigated mineral occurrences and Smith concentrated on regional geology (Maddren, 1915; Smith and Maddren, 1915; Smith, 1917).

With the advent of World War II, the presence of mercury deposits drew interest to the Kuskokwim region. Between 1941 and 1945 a team from the USGS led by W. M. Cady performed field studies of the central Kuskokwim region by foot and boat. Cady and others (1955) summarized the geography, geology, and mineral resources of the entire region, and provided more detailed geologic maps of selected mining areas. Their report remains the most comprehensive study of the region published to date. Between 1942 and 1944, while the USGS was conducting geologic mapping, the U. S. Bureau of Mines (USBM) trenched and sampled ten known mercury deposits in southwest Alaska, six of which were in the Sleetmute quadrangle (Webber and others, 1947). The Alaska Territorial Department of Mines also reported on the important mercury deposits of the area, primarily by summarizing published information and reports from miners (Joesting, 1942).

After the flurry of activity in the early to mid 1940's, no new geologic field work was undertaken by public investigators until the mid 1950's when the USBM, Alaska Territorial Department of Mines, and the USGS resumed work, focusing almost exclusively on mineral resources. The USBM performed further trenching and sampling of mercury prospects within the Sleetmute quadrangle in various years between 1954 and 1970 (for example see Maloney, 1962, 1968; Merrill and Maloney, 1974). The USBM also conducted a reconnaissance geochemical sampling of river bars along the Kuskokwim River in search of gold anomalies (Maloney, 1969). The Alaska Territorial Department of Mines (which became the Alaska Division of Mines and Minerals in 1961) examined and reported on several mercury mines and prospects within the Sleetmute quadrangle (Jasper, 1955a, b, 1956, 1961, 1963). The USGS performed a detailed investigation of the Red Devil mercury deposit in 1957 and 1958 (MacKevett and Berg, 1963). Sainsbury and MacKevett (1960, 1965) discussed several other mercury deposits of the Sleetmute quadrangle in addition to that at Red Devil. However, the most comprehensive study of the Red Devil mine was a company report written by Gordon Herreid, mine geologist for Alaska Mines and Minerals (Herreid, 1960). Herreid's report formed the basis of the account later published by Malone (1962, p. 13-20). Another mercury deposit in the Sleetmute quadrangle, the Mountain Top mine, was drilled by the Bureau of Mines in 1970 and mapped in detail (scale 1:600) by the USGS (Sorg and Estlund, 1972).

Ten years passed before work resumed in the Sleetmute quadrangle. In 1983 the USBM performed ten days of reconnaissance geochemical sampling in parts of the Holy Cross, Iditarod, Russian Mission, and Sleetmute quadrangles (Meyer, 1985). The most detailed geologic mapping and geochemical sampling within the Sleetmute quadrangle to date was conducted by the Alaska Division of Geological and Geophysical Surveys (ADGGS) in 1983 and

1984. Their reconnaissance work resulted in publication of geologic maps at a scale of 1:40,000 for the Sleetmute A-6, B-5, and B-6 quadrangles (Decker and others, 1984b; Robinson and others, 1984; Reifenstuhl and others, 1984, respectively) and accompanying geochemical sample location and data compilations (Robinson, 1984a, b, c, respectively). The ADGGS also published geologic compilations of data for Sleetmute A-5 and A-7 which combine locality and sample descriptions from work performed by the USGS from 1943 to 1945 with new data collected by ADGGS in 1983 (Decker and others, 1984a; Decker and others, 1985, respectively). The ADGGS mapped unconsolidated and bedrock deposits along the Kuskokwim River, in response to local concerns regarding economic extraction of sand, gravel, and riprap (Krause, 1984; Bundtzen and others, 1989).

Geologists from several private companies and universities have pursued topical studies in the Sleetmute quadrangle. Carbonate rocks of the Holitna Basin, exposed in southeast Sleetmute quadrangle, were discussed by Blodgett (1983), Blodgett and others (1984), Blodgett and Clough (1985), Clough and others (1984), Clough and Blodgett (1985, 1989), Palmer and others (1985), and Smith and others (1984, 1985). Volcanic and plutonic rocks exposed in the Horn Mountains (northwest Sleetmute quadrangle), were briefly examined by Bergman and Doherty (1986), Bergman and others (1987), and Doherty and Bergman (1987).

BASE MATERIAL AVAILABLE

Adequate base materials suitable for geologic work are currently available. The 17,850 km^2 (6,890 mi^2) Sleetmute quadrangle is covered by thirty-two USGS 1:63,360-scale topographic base maps having contour intervals of 50 or 100 feet. Eleven east-west U-2 flight lines across the quadrangle were flown between 1978 and 1984 yielding 280 color-infrared aerial photos. These particular air photos are the most useful for field mapping because the scale is comparable to the 1:63,360 topographic maps and the contrast and detail is sufficient to allow recognition of a bedrock or rubble exposure as small as 9 m^2 (100 ft^2).

SUMMARY OF GEOLOGIC INFORMATION

OVERVIEW

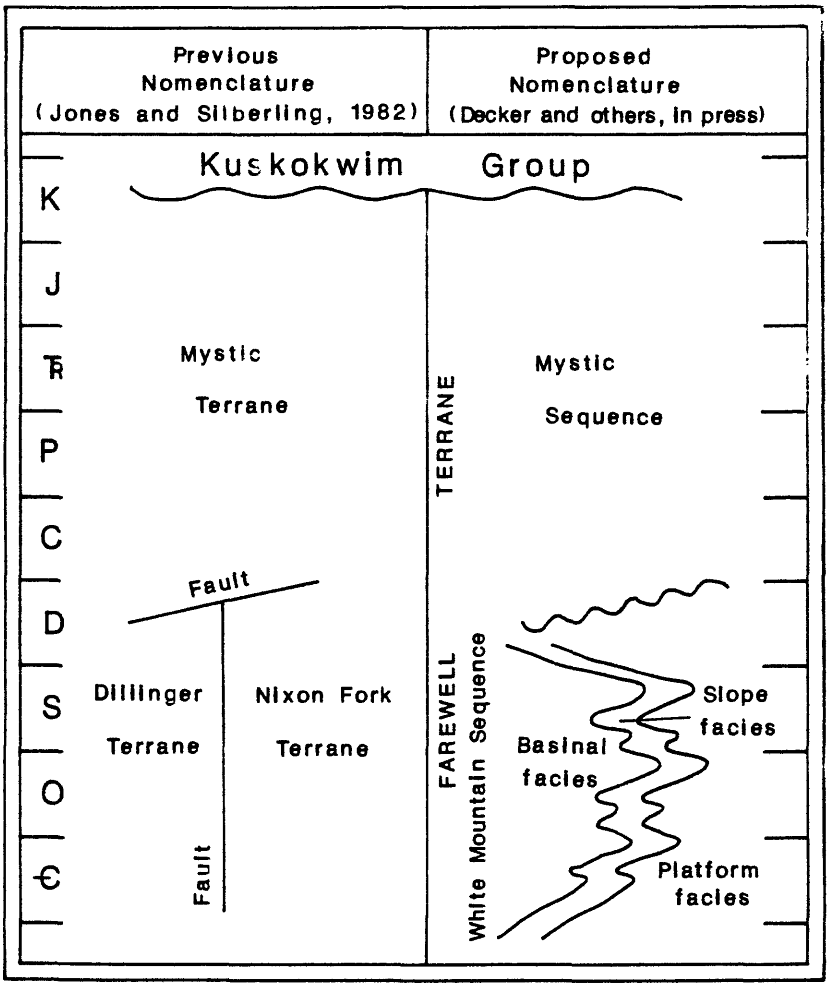
The rocks of the Sleetmute quadrangle can be broadly subdivided into three packages: 1) Paleozoic sedimentary rocks of continental margin origin, 2) Mesozoic sedimentary and volcanic rocks of accretionary origin, and 3) post-accretionary sedimentary and igneous rocks. The Cambrian to Devonian Holitna Group (Cady and others, 1955), exposed in the low hills of the southeast part of the quadrangle, consists of both platform-carbonate and deep-marine basin deposits. The Triassic and Lower Cretaceous Gemuk Group (Cady and others, 1955), exposed in the southwest part of the quadrangle, consists of mixed sedimentary and volcanic rocks interpreted to be part of a volcanic-arc complex that was accreted to the North American continent during late Early Cretaceous time (Box, 1983, 1985). Post-accretionary rocks form by far the most abundant rock lithologies exposed in the study area. Dominant among these is the upper Lower to Upper Cretaceous Kuskokwim Group (Cady and others, 1955), a sequence largely composed of marine turbidite facies rocks (flysch). Intruding and overlying the pre- and post-accretionary rocks are Late Cretaceous to early Tertiary plutonic and volcanic rocks. The volcanic rocks are usually associated with plutons of intermediate composition in volcano-plutonic complexes. Sheets, sills, and dikes of felsic and mafic compositions, most of which are probably unrelated to the plutons, are ubiquitous throughout the region. Finally, surficial deposits of Quaternary age cover over 70% of the quadrangle (plate 1).

Two major northeast-trending strike-slip faults cut post-accretionary rocks in the Sleetmute quadrangle. The more northerly of the two, the Iditarod-Nixon Fork fault, barely clips the northwest corner, while the Denali-Farewell fault system almost bisects the remainder of the quadrangle. An offset of at least 90 km (56 mi), since Late Cretaceous to early Tertiary time, has been documented for the Iditarod-Nixon Fork fault (Miller and Bundtzen, 1988). Mid Paleozoic carbonate rocks are offset by about 150 km (93 mi) along the Denali-Farewell fault (Decker and others, in press). The Boss Creek fault, in the south-central part of the quadrangle, is considered to be a splay of the Denali-Farewell fault system. Southwest of the Denali-Farewell fault, the Kulukbuk thrust places carbonate rocks of the Holitna Group over Kuskokwim Group flysch.

As defined by Jones and others (1981), the Sleetmute quadrangle includes parts of the Paleozoic Nixon Fork and Dillinger terranes, and part of the Mesozoic Togiak terrane. Within this framework, the Holitna Group is part of both the Nixon Fork and Dillinger terranes, whereas the Gemuk Group is part of the Togiak terrane. Jones and Silberling (1982) distinguished the first two terranes by stratigraphy, but more recent stratigraphic information indicates that the Nixon Fork and Dillinger terranes represent contrasting facies within a single depositional basin (Bundtzen and Gilbert, 1983; Blodgett, 1983; Blodgett and others, 1984; Blodgett and Clough, 1985). Recognition of this genetic relationship led Decker and others (in press) to combine the Nixon Fork, Dillinger, and Mystic terranes (rocks of the Mystic terrane do not crop out in the Sleetmute quadrangle) into one -- the Farewell terrane -- that includes lower Paleozoic through Lower Cretaceous continental margin deposits (fig. 3). Decker and others (in press) further subdivided the Farewell terrane into two distinct sequences, 1) the Middle Cambrian through Middle Devonian White Mountain sequence, and 2) the Late Devonian through Early Cretaceous Mystic sequence. Gilbert and Bundtzen (1984) presented evidence that rocks of the Mystic terrane (Mystic sequence of Decker and others, in press) are in depositional rather than structural contact with rocks of the Dillinger terrane. Relations between the old and new terranes in the Sleetmute quadrangle are summarized in figure 4. The White Mountain sequence is composed of three facies: a shallow-marine platform facies, a transitional or slope facies, and a deep-marine basinal facies (Decker and others, in press). We adopt the new terrane designation of Decker and others (in press), because it corresponds better with the known geology of the Holitna Basin. In the Sleetmute quadrangle then, rocks of the Holitna Group belong to the White Mountain sequence of the Farewell terrane. An unnamed curvilinear fault divides the Holitna Group into two lithostratigraphic units. The more westerly unit, composed of shallow-marine platform facies rocks, lies outboard of deep-marine basinal (and possibly transitional) facies rocks of the remaining unit. Although the facies boundary is locally a fault, it is lithologically gradational nearby.

The Gemuk Group, exposed in the southwest part of Sleetmute quadrangle, is part of the Togiak terrane of Jones and others (1981). Box (1983, 1985) refined and further subdivided the terranes of the Bristol Bay region which include the Togiak terrane. Box (1985) envisioned the Togiak terrane as part of an intra-ocean volcanic arc complex that later collided with the continental margin.

The following sections of this geology summary describe each of the three rock packages (Paleozoic rocks of continental margin origin, Mesozoic rocks of accretionary origin, and post-accretionary rocks) in more detail, and in a final section on tectonic history, relate them to one another. For the most part we will use stratigraphic ("Holitna Group" and "Gemuk Group") rather than tectonostratigraphic terminology in describing rocks of the Sleetmute quadrangle. However, the latter terminology ("Farewell terrane" and "Togiak terrane") will be used for regional correlations.



Modified from Decker and others (in press)

Figure 3. Terminology and relationships of the Farewell terrane.

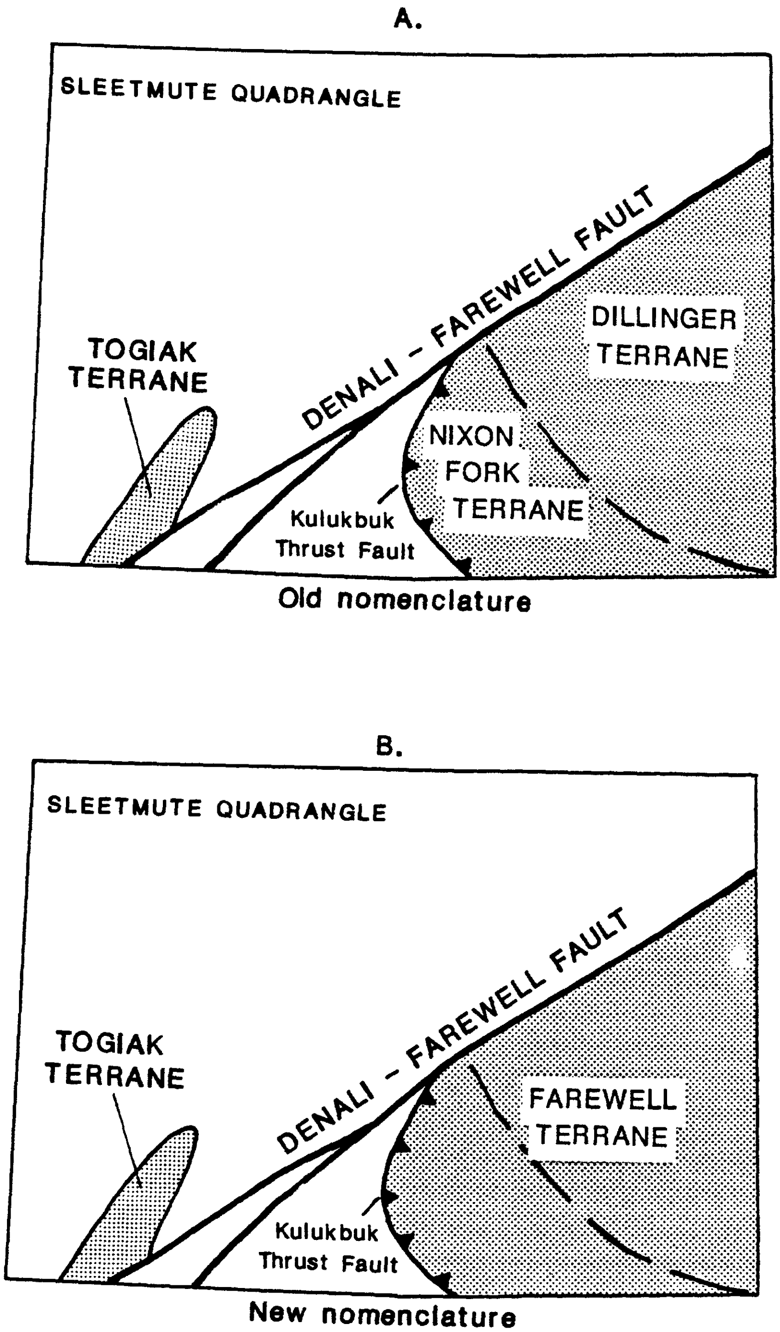


Figure 4. Tectonostratigraphic terranes of the Sleetmute quadrangle, Alaska. Nomenclature of Jones and others (1981) is shown in A. Nomenclature of Decker and others (in press) is shown in B.

PALEOZOIC ROCKS OF CONTINENTAL MARGIN ORIGIN

The Paleozoic rocks exposed in the southeast part of Sleetmute quadrangle are part of the Holitna Group mapped by Cady and others (1955). The actual extent of these rocks is undetermined because they are thickly mantled by surficial deposits. Cady and others (1955) described a sequence of partly dolomitic, massive to thinner bedded limestone and minor local intraformational conglomerate, which they estimated to be at least 1,500 m (5,000 ft) and probably closer to 3,000 m (10,000 ft) thick. They recognized Silurian and Devonian fossils in the upper part of the sequence and postulated the undated lower part to be as old as Ordovician.

Subsequent work has both refined the paleontologic ages and defined depositional facies for these rocks. Fossil collections made in the early 1980's established the presence of Ordovician faunas (Blodgett and others, 1984). Subsequently, even older rocks were identified in the southwest corner of the Sleetmute A-2 quadrangle where a Middle Cambrian trilobite was collected (Palmer and others, 1985; Decker and others, in press). The youngest fossils collected so far are of early Middle Devonian (Eifelian) age from the Sleetmute A-4 quadrangle (R.B. Blodgett, unpub. data, 1983).

Recent workers agree that depositional facies can be defined for the Paleozoic rocks of the Holitna Group. It is generally agreed that in the Sleetmute quadrangle, rocks located east of the unnamed curvilinear fault (the dotted fault that lies southeast of the Denali-Farewell fault and east of the Kulukbuk thrust fault, plate 1), are of deep-water basinal character as suggested by the presence of platy limestone, graptolitic shale, bedded chert, and minor interbeds of limestone turbidites (Smith and others, 1985; Decker and others, in press). The Paleozoic rocks exposed in the belt that lies between the Kulukbuk thrust and the unnamed curvilinear fault, are considered by recent workers (Blodgett and others, 1984; Smith and others, 1985; Decker and others, in press) to represent deposition on a Middle Ordovician to Middle Devonian shallow-water carbonate platform. These strata are underlain by deeper-water, basinal strata of Middle Cambrian to Early Ordovician age. A Late Silurian-Early Devonian algal reef complex that developed along the outer edge of the carbonate platform, described by Blodgett and others (1984), Blodgett and Clough (1985), and Clough and Blodgett (1985, 1989), is exposed in the Kulukbuk Hills and to the southeast along the southwest side of the Hoholitna River in the Sleetmute A-2 and A-3 quadrangles. Coeval lagoonal, oolitic shoal, and tidal channel deposits developed shoreward of the reef-complex (Clough and others, 1984; Smith and others, 1985; Decker and others, in press). Decker and others (in press) noted that along the Hoholitna River and in the vicinity of the "Door Mountains"[1] in southeast Sleetmute quadrangle, platform carbonate rocks appear to grade into coeval deeper-water basinal rocks. These workers suggested that two factors indicate a transitional or slope facies: 1) the presence of limestone debris flows with clasts from the algal reef complex, and 2) the close interdigitation of both shallow-water and deep-water facies.

The Paleozoic carbonate rocks clearly represent a continental margin sequence. Deposition apparently took place in a warm, tropical latitude based on sedimentologic and paleontologic evidence summarized by Decker and others (in press). The sedimentologic evidence comes primarily from rocks of the shallow-water platform facies, including the thick algal barrier reef complex. Paleontologic evidence is derived from the fossil fauna and flora which are of presumed warm, tropical affinity, most notable being the abundance of calcareous green algae (dasycladaceans and udoteaceans) in the platform facies (Poncet and Blodgett, 1987).

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[1] The "Door Mountains" shown on the Sleetmute 1:250,000-scale topographic map are incorrectly labeled; the real Door Mountains lie to the south in the Taylor Mountains quadrangle (Nick Mellick, Mellick's Trading Post, Sleetmute, Alaska, oral commun., 1988).

MESOZOIC ROCKS OF ACCRETIONARY ORIGIN

Rocks of the Triassic and Lower Cretaceous Gemuk Group, first mapped and described by Cady and others (1955), crop out in the southwest part of Sleetmute quadrangle. The descriptions provided by Cady and others (1955) remain the most detailed to date and have been extensively relied upon for this summary. The type locality of the Gemuk Group lies about 25 km (15 mi) south of the Sleetmute quadrangle near Cinnabar Creek (Taylor Mountains D-8 quadrangle). This mixed unit is largely composed of dark, dense, massive siltstone interbedded with lesser amounts of chert and volcanic rock (including tuff), but also contains thin interbeds of limestone and graywacke. The siltstone is composed of very fine-grained angular lithic and mineral fragments derived in part from volcanic rocks. The dense fabric and dark color of the siltstone make it resemble basalt. The unsorted and angular nature of the clasts led Cady and others (1955) to liken the siltstone to a very fine-grained breccia, closely allied to a graywacke. Chert (usually gray or black, but locally red or green) forms thin distinct beds that in some places grade into other lithologies. Remnants of radiolaria and foraminifera are commonly observed in silty varieties of the chert. Volcanic interlayers are primarily composed of andesitic lava flows and subordinate tuff layers of similar composition. Locally, the lava flows are as much as 60 m (200 ft) thick and vitric tuff layers are 60-90 m (200-300 ft) thick. Alteration of pyroxene to chlorite + antigorite, and plagioclase to chlorite + fine-grained mica is common in the volcanic rocks. The minor amount of limestone occurs as isolated lenticular beds, some of which are silicious and resemble chert. Most of the limestone is fine grained, but coquinas, composed of coarse fossil shell fragments in a fine-grained limestone matrix, also occur. Cady and others (1955) estimated the Gemuk Group to be 4,500-7,500 m thick (15,000-25,000 ft) in the type section area (near Cinnabar Creek, Taylor Mountains D-8 quadrangle). The base of the Gemuk Group is not exposed. The contact between the Gemuk Group and the overlying Kuskokwim Group is exposed in the southwest corner of the Sleetmute quadrangle where it is mapped as a transition from siltstone, chert, and volcanic rocks (below) to graywacke (above). Beds of the Gemuk and Kuskokwim Groups are widely concordant, but Cady and others (1955, p. 30) concluded that the "...contact marks a regional unconformity although there is no local evidence for such a break".

Cady and others (1955) collected pelecypods of Late Triassic age from discontinuous limestone beds in the type section area of the Gemuk Group. They postulated that rocks below this strata might be older than Late Triassic, because they are lithologically different. The youngest fossils (Early Cretaceous and Cretaceous in age) were found by Cady and others (1955) in siltstone and silty limestone along the Holokuk River (Sleetmute A-7). No fossils of Jurassic age have been found.

Only a very minor amount of additional work has been done on the Gemuk Group of Sleetmute quadrangle. Reifenstuhl and others (1984) mapped two exposures in the southwest corner of Sleetmute B-6 quadrangle as Gemuk Group and described them as medium-grained calc-arenite sandstone and dark-gray slate. Cady and others (1955) clearly stated that the Gemuk Group, particularly in the uppermost zones, is composed of mixed siltstone, chert, and volcanic rocks. We question whether the exposures mapped by Reifenstuhl and others (1984) are indeed Gemuk Group; they may be Kuskokwim Group. If they are the latter, then the Gemuk Group only extends to the northeast corner of Sleetmute A-7 quadrangle.

The Gemuk Group is part of the Hagemeister subterrane of the Togiak terrane (Box, 1985). Based on his work in the northern Bristol Bay region, Box (1985) divided the Hagemeister subterrane into three stratigraphic sequences separated by unconformities (fig. 5). The lowest sequence (#1) grades upward from an ophiolitic base through a thick volcanic breccia sequence into shallow-marine volcanogenic sandstones. Sequence #1 ranges in age from Late Triassic to Early Jurassic. The middle sequence (#2) is composed of Middle and Upper Jurassic marine to non-marine volcanic and volcaniclastic strata. The uppermost sequence (#3) is comprised of

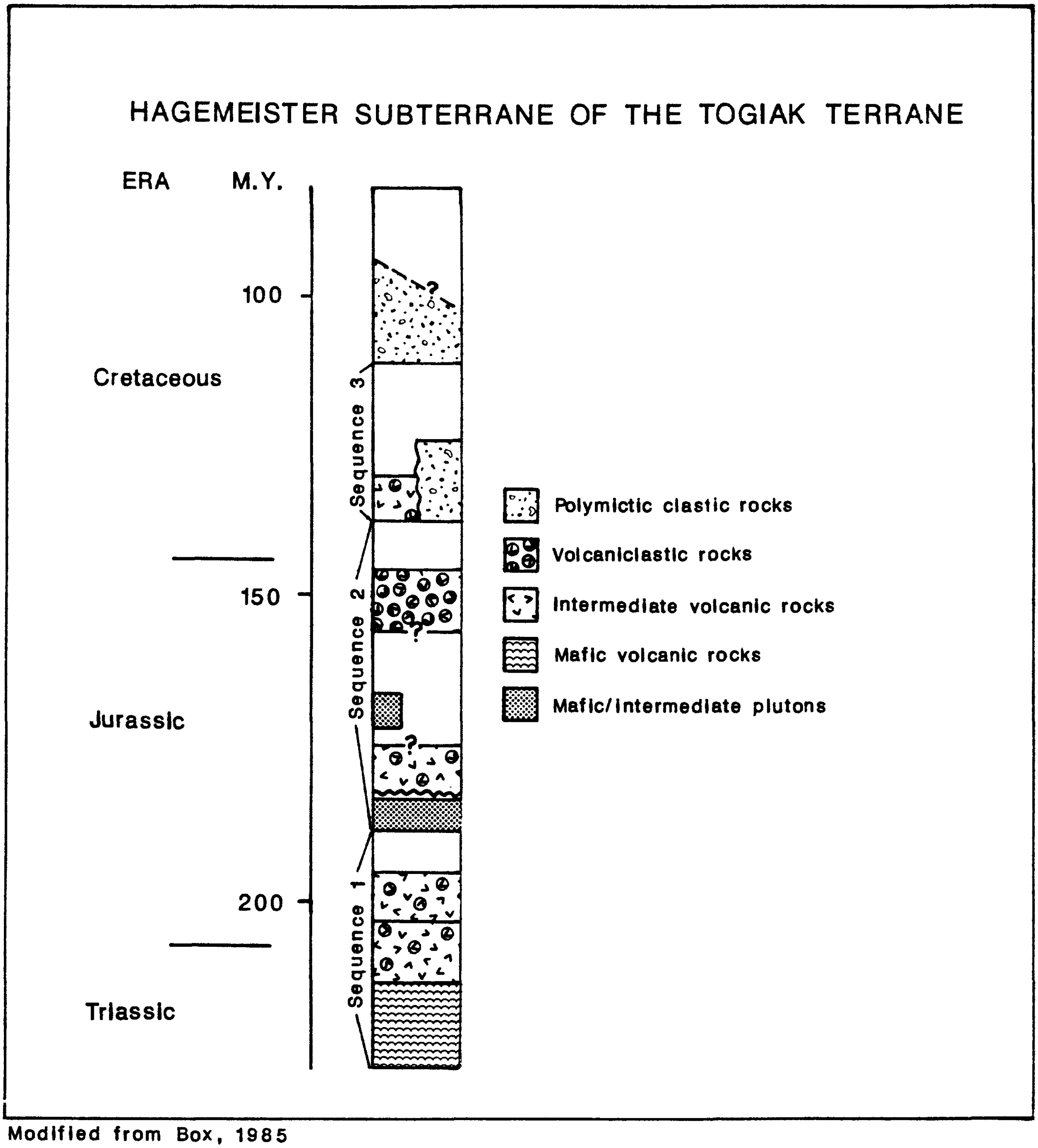

Figure 5. Stratigraphic section of the Hagemeister subterrane of the Togiak terrane showing the three sequences defined by Box (1985, fig. 2-3).

locally derived Lower Cretaceous volcanic and sedimentary rocks deposited in shallow- to deep-marine settings. In these terms, the Gemuk Group described by Cady and others (1955) shows parts of sequences #1 and #3; the ophiolitic rocks at the base of sequence #1 and all of sequence #2 are missing from the Gemuk Group. Assuming that we are correct in including the Gemuk Group in the Togiak terrane, where are the missing pieces? Are detailed correlations precluded by distance from the Bristol Bay region? Has the middle sequence (#2) been faulted away? Will additional mapping reveal the missing parts? In spite of these unanswered questions, Box's work gives us a framework upon which to build our understanding of the Gemuk Group. The Gemuk Group appears to have formed in an oceanic island-arc environment where Upper Triassic through Lower Cretaceous volcanic and volcaniclastic rocks were deposited. By Early Jurassic time, the volcanic pile had reached sea level. A complex distribution of interfingering deep- and shallow-marine to subaerial facies resulted from complex volcanic island topography (Decker and others, in press). The volcanic arc (Togiak terrane) and its associated subduction complex (Goodnews terrane) accreted to the North American continent during late Early Cretaceous time (Box, 1983, 1985).

POST-ACCRETIONARY ROCKS

Kuskokwim Group

Rocks of the upper Lower to Upper Cretaceous (Albian to Coniacian) Kuskokwim Group are, by far, the dominant bedrock in the Sleetmute quadrangle (plate 1). Rocks of the Kuskokwim Group are found in parts of a dozen 1:250,000-scale quadrangles, encompassing over 70,000 km^2 (27,000 mi^2) of southwest Alaska (fig. 6). The Kuskokwim Group consists primarily of marine turbidites deposited into a northeast-trending, elongate, fault-controlled basin; subordinate shallow-marine and fluvial strata were deposited along the margins of the basin (Bundtzen and Gilbert, 1983; Pacht and Wallace, 1984). The Kuskokwim Group unconformably overlies pre-amalgamation terranes, indicating accretion was complete by Albian time. Kuskokwim Group rocks typically are poorly exposed and form low, rolling hills with rounded ridges at maximum elevations of about 800 m (2,600 ft). They are regionally deformed into broad open folds, and locally into tight chevron folds. Cady and others (1955) were the first to describe and name the Kuskokwim Group. Others since have studied these rocks in various areas (Decker and Hoare, 1982; Bundtzen and Gilbert, 1983; Pacht and Wallace, 1984; Crowder and Decker, 1985; Moore and Wallace, 1985; Murphy and Decker, 1985; Miller and Bundtzen, 1987), but a detailed sedimentologic analysis of the basin is still lacking.

The Kuskokwim Group is composed of interbedded sandstone, siltstone, shale, minor conglomerate, and rare thin coal seams. Cady and others (1955) estimated graywacke to comprise as much as 65% of the Kuskokwim Group. Typified by poor sorting and angular grains, the graywacke is composed of siltstone, chert, quartz, quartzite, phyllite, lathwork volcanic, limestone, feldspar, white mica, and chlorite clasts in varying abundances, thus indicating local sources. Although fragments of fossil shells (*Inoceramus* prisms) and fossil land plants are not uncommon, collections of diagnostic fossils are rare for the Kuskokwim Group. An age range of Albian to Coniacian (Wallace, 1983) is given although only Cenomanian ages have been identified from the Sleetmute quadrangle itself (*Inoceramus* fossils). Fossils of Turonian age dominate the Kuskokwim Group in the Iditarod, Ophir, and McGrath quadrangles.

Rocks of the Kuskokwim Group have not been regionally metamorphosed, but contact metamorphic aureoles are present around even small intrusive bodies, and extend several kilometers away from larger plutons. The hornfels grades outward from dense, hard, completely recrystallized rock near the contact to only slightly recrystallized sandstone or shale distally. Biotite is the most common metamorphic mineral, but locally fibrous sillimanite has been reported (Reifenstuhl and others, 1984).

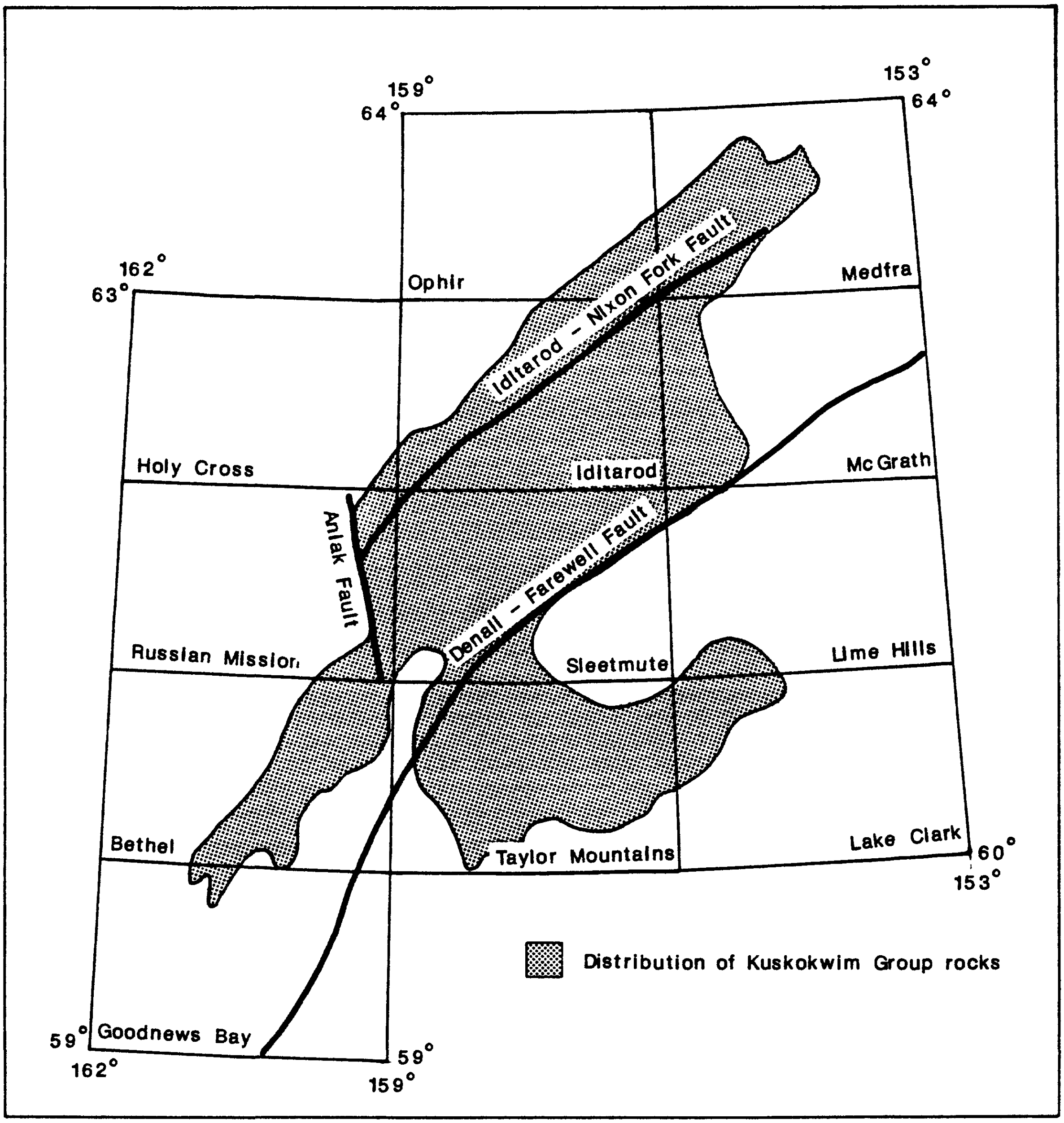

Figure 6. Distribution of rocks of the Cretaceous Kuskokwim Group in west-central and southwestern Alaska.

The central part of the relict basin lies within the Sleetmute quadrangle boundary and contains not only the thickest sections, but also the deepest-water facies. Cady and others (1955) estimated a thickness of over 12,000 m (40,000 ft) for a section exposed along the Kuskokwim River near the village of Sleetmute. Near the basin margins, where mixed shallow-marine and non-marine facies occur, the sections are much thinner (less than 3,000 m or 10,000 ft thick); these are best exposed in the western Iditarod and southwestern McGrath quadrangles (Bundtzen and Gilbert, 1983).

The Denali-Farewell fault cuts the Kuskokwim Group in the Sleetmute quadrangle, but we consider it unlikely that this post-depositional fault divides the unit into sub-basins. Some evidence does indicate a difference across the boundary. Sandstone petrography by Crowder and Decker (1985) of rocks that lie southeast of the Denali-Farewell fault (in Lime Hills A-7 and A-8 quadrangles) revealed that unmetamorphosed sedimentary rock fragments are the dominant clasts. In contrast, petrographic studies by Cady and others (1955) of rocks that lie northwest of the fault indicated they were noticeably poor in sedimentary rock fragments. This difference may be due to variation in local sources rather than the presence of sub-basins. Indeed, local sources probably have been important, based on the fact that the Kuskokwim Group unconformably overlies different pre-amalgamation rocks on either side of the fault; on the northwest it overlies Mesozoic Gemuk Group and on the southeast, Paleozoic carbonate rocks. Even this difference does not necessitate the presence of sub-basins, but we cannot entirely rule out the possibility.

Igneous rocks

The post-accretionary igneous rocks of the Sleetmute quadrangle range from Late Cretaceous to early Tertiary age. They are divided by genetic relationships into five main groups: 1) Late Cretaceous-early Tertiary volcano-plutonic complexes consisting of volcanic fields, plutons, and isolated stocks; 2) Late Cretaceous-early Tertiary sheets, dikes, and sills of peraluminous rhyolite; 3) Late Cretaceous-early Tertiary altered intermediate to mafic dikes and sills; 4) Tertiary granite, and 5) Tertiary basalt. Rocks of the volcano-plutonic association are the most volumetrically significant, followed next by the peraluminous rhyolite. Rocks of the remaining three groups are volumetrically minor.

Rocks of the volcano-plutonic association, which are exposed in the northwest and central-southwest parts of the Sleetmute quadrangle, are part of a belt containing at least a dozen such complexes that strikes roughly northeast and stretches for approximately 275 km (170 miles) (fig. 7). In the classic association, volcanic rocks either overlie or are in fault contact with coeval plutons; locally the plutons intrude and partially assimilate the volcanic rocks (Bundtzen and Gilbert, 1983; Miller and Bundtzen, 1987). However, rocks of the volcano-plutonic association also occur as isolated stocks and dikes, or as volcanic fields (Moll and Patton, 1982). Compositions range widely among both the volcanic and plutonic rocks. In the northern part of the belt the volcanic rocks are primarily basalt and andesite (Moll and others, 1981; Bundtzen and Laird, 1982; Bundtzen and others, 1988a), whereas the southern part of the belt has rhyolite in addition to basalt and andesite (Decker and others, 1984b; Robinson and others, 1984). The plutonic rocks range from diorite or gabbro to syenite, but monzonite, quartz monzonite, granodiorite, and granite compositions dominate (for example, Moll and others, 1981; Bundtzen and Laird, 1982; Reifenstuhl and others, 1984). In the Sleetmute quadrangle, the classic spatial association of volcanic and plutonic rocks occurs in the Horn Mountains and the Kiokluk Mountains. Isolated plutons and dikes (but still of the volcano-plutonic association by age and composition) are exposed in the Chuilnuk Mountains, at Henderson and Red Mountains, and in other scattered localities in the quadrangle. The volcanic field that lies north of Chineekluk Creek is also part of the volcano-plutonic association and displays many similarities with the volcanic fields exposed in the Horn and Kiokluk Mountains.

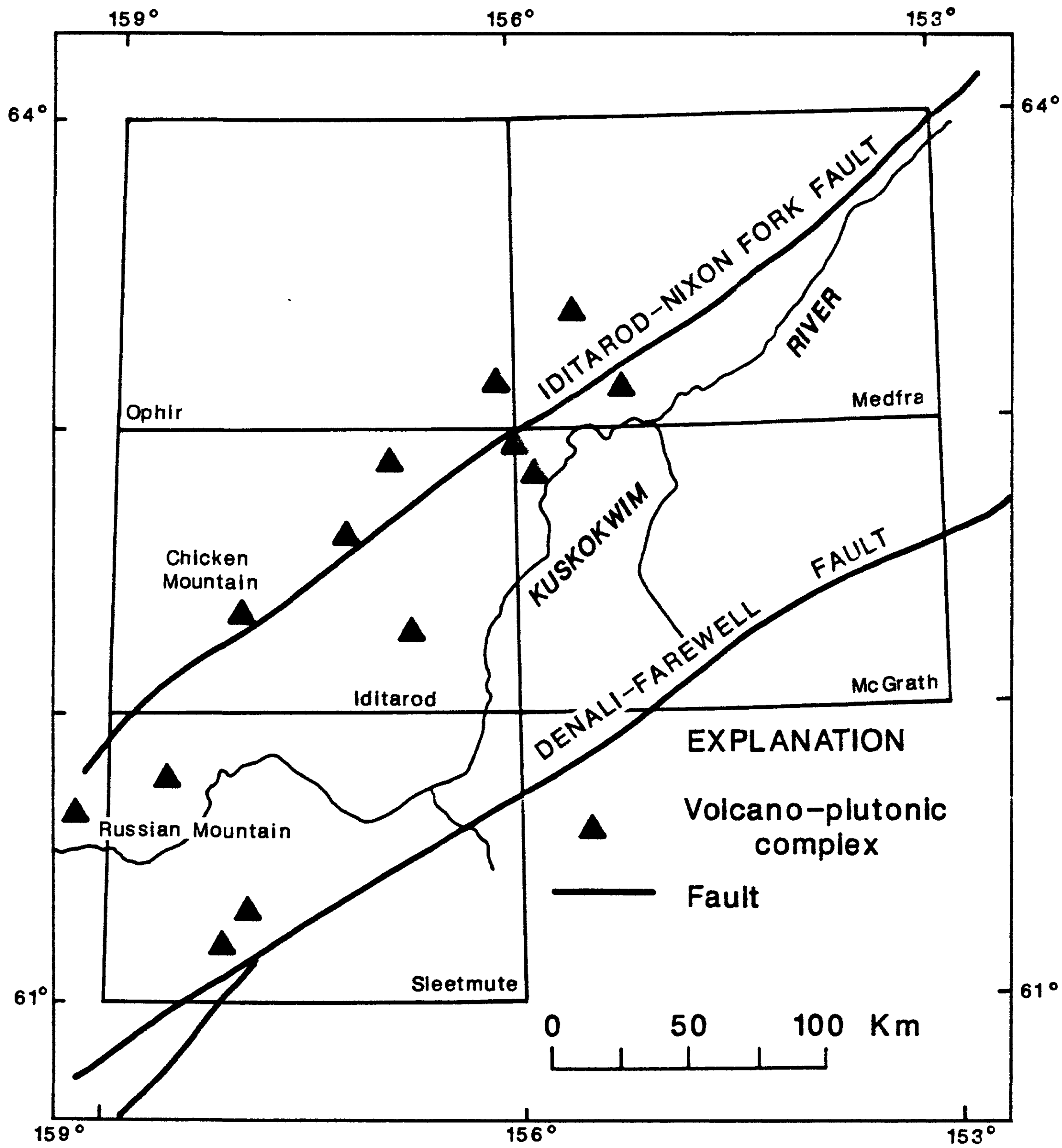

Figure 7. Locations of volcano-plutonic complexes in west-central and southwestern Alaska.

Volcanic rocks of the volcano-plutonic association include units first mapped and described by Cady and others (1955) as the Holokuk Basalt, the Getmuna Rhyolite Group, and the Iditarod Basalt. Cady and others (1955) originally described the Holokuk Basalt as a volcanic unit composed primarily of subaerial basalt flows exposed both in the Horn Mountains and in the area northwest of the Kiokluk and Chuilnuk Mountains. More detailed work in the latter area (Decker and others, 1984b; Reifenstuhl and others, 1984; Robinson and others, 1984) demonstrated the Holokuk Basalt was in fact more varied, containing significant amounts of rhyolite flows, tuff, and tuff breccia as well as andesitic to basaltic flows, agglomerate, tuff, and even a lahar deposit. In the Horn Mountains, Cady and others (1955) mapped rhyolite tuff and flows at the northern end of the Holokuk Basalt. They described these undated rocks as the Getmuna Rhyolite Group and judged them to be the extrusive equivalent of the hypabyssal rhyolite exposed on nearby Juninggulra Mountain. We interpret the Getmuna Rhyolite Group instead to be part of the Holokuk Basalt of the Horn Mountains area, and therefore very similar to the section of Holokuk Basalt exposed in the area northwest of the combined Kiokluk and Chuilnuk Mountains. The Holokuk Basalt is at least 1 km (3,200 ft) thick and unconformably overlies the Kuskokwim Group (Decker and others, 1984b; Reifenstuhl and others, 1984; and Robinson and others, 1984). Finally, we also include with rocks of the volcano-plutonic association, those exposed in the northeast Russian Mission, northwest Sleetmute, and southwest Iditarod quadrangles, which were originally named the Iditarod Basalt. Cady and others, (1955) described the Iditarod Basalt as a sequence of basaltic flows overlying a basal breccia. Noting that andesitic compositions were as common as basaltic compositions in the Iditarod quadrangle, Miller and Bundtzen (1988) renamed the Iditarod Basalt the Iditarod Volcanics, which they described as consisting of a basal unit of tuff, lava, and lahar overlain by mafic to intermediate flows. The Iditarod Volcanics represent an off-set equivalent of the Beaver Mountains volcanic field, part of a volcano-plutonic complex (Miller and Bundtzen, 1988). For this report, we choose to lump the volcanic rocks exposed in the very northwest part of Sleetmute quadrangle (Iditarod Volcanics) with those mapped as Holokuk Basalt for two reasons: 1) the Iditarod Volcanics are clearly associated with a volcano-plutonic complex, and 2) they are not only lithologically similar to the Holokuk Basalt but also show a similar age range based on K-Ar radiometric data. The Iditarod Volcanics range from about 77 Ma to 63 Ma (Miller and Bundtzen, 1988). The Holokuk Basalt generally ranges from about 74 Ma (minimum age) to 64 Ma (Reifenstuhl and others, 1984; Robinson and others, 1984), although one rhyolite whole rock sample yielded 44 Ma (Robinson and Decker, 1986). However, the volcanic stratigraphy is very complex and not well exposed, and several rhyolite flows of varying age apparently exist (B.D. Hickok, oral commun., 1989).

Plutonic rocks of the volcano-plutonic association were originally mapped and described by Cady and others (1955) (without benefit of radiometric age dating) as Tertiary stocks, sills, and dikes primarily composed of quartz monzonite and quartz diabase, but having a range of compositions including minor mafic phases. Later workers established a Late Cretaceous to early Tertiary age for these intrusive rocks based on five samples, collected in the Chuilnuk and Kiokluk Mountains, that yielded a range in K/Ar radiometric ages of 68.9 Ma to 63.8 Ma (the latter is a minimum age)(Decker and others, 1984b; Reifenstuhl and others, 1984; Robinson and others, 1984; Robinson and Decker, 1986). The plutons consist of biotite ± hornblende-bearing granodiorite, granite, lesser quartz monzonite, and minor clinopyroxene gabbro. Quartz + tourmaline veins and tourmaline altered zones occur locally in the plutons. Hydrothermal alteration is also common and produced white mica, chlorite, minor calcite, and locally epidote (Decker and others, 1984b; Reifenstuhl and others, 1984; Robinson and others, 1984). Hornfels aureoles of up to several kilometers in width surround the larger stocks and plutons. Doherty and Bergman (1987) proposed that the volcano-plutonic rocks of the Horn Mountains area form a caldera complex that is surrounded by a ring fracture zone and exhibits densely welded ash-flow tuffs. This hypothesis remains untested, but serves as a focus for further mapping.

The second, less voluminous, group of post-accretionary igneous rocks is composed of sheets, dikes, and sills of hypabyssal peraluminous rhyolite exposed in a broad belt that lies north of the Denali-Farewell fault. The sheets tend to form an en echelon pattern that generally is parallel to regional fold axes. Cady and others (1955), who first mapped and described these rocks, assigned them an earliest Tertiary age. However, Late Cretaceous to early Tertiary age is indicated by six K/Ar radiometric ages ranging from 70.5 Ma to 61.5 Ma (Reifenstuhl and others, 1984; Robinson and Decker, 1986). The rhyolite is locally porphyritic and has quartz, albite, biotite, and/or muscovite phenocrysts; local accessory minerals include garnet and tourmaline. Alteration of feldspar to secondary white mica or clay is common; quartz phenocrysts typically exhibit partial resorption features. At one locality, on the west flank of Holokuk Mountain, Reifenstuhl and others (1984) reported the occurrence of brecciated and tourmalinized rhyolite cemented by quartz + tourmaline. We have designated the rhyolite as peraluminous based on two criteria. First, 12 of the 14 major oxide analyses published by Decker and others (1984b), Reifenstuhl and others (1984), and Robinson and others (1984) can be classified as peraluminous using the definition of Shand (1947) that $Al_2O_3 > Na_2O + K_2O + Ca_2O$ for peraluminous rocks. Second, garnet is present locally.

Although volumetrically minor, igneous rocks of the third group are ubiquitous throughout the Kuskokwim Group. These consist of intermediate to mafic dikes and thin sills, most of which are altered to carbonate, chalcedony, quartz, sericite, and clay. Cady and others (1955) who first noted this alteration assemblage, called the dikes "silica-carbonate" rock. Many of these are spatially associated with the cinnabar-stibnite bearing lodes discussed in Chapter 5 of this report.

The fourth and fifth groups of igneous rocks are volumetrically minor, but are spatially and temporally distinct from the other igneous rocks. The fourth group consists of several small quartz monzonite stocks that intrude rocks of the Holitna Group in the southeastern part of the quadrangle. Biotite from the most northern of these stocks yielded a K-Ar radiometric age of 41.7 Ma (Robinson and Decker, 1986). The fifth group consists of one small exposure located south of the Denali-Farewell fault in the Sleetmute A-6 quadrangle. Decker and others (1984b) described rubble of fresh-looking olivine basalt from which they obtained one K/Ar radiometric age of 38.2 Ma (whole rock). No other information is available, but based on age alone, this rock is distinct from other mafic volcanic rocks of the Sleetmute quadrangle. Interestingly, Bundtzen and Laird (1982) reported a 35.1 Ma K-Ar radiometric age from olivine basalt overlying other volcanic units in the Beaver Mountains complex about 200 km (120 mi) to the north.

Clearly additional work is needed to define the Tertiary intrusive and volcanic rocks, but also to refine our knowledge of the Late Cretaceous-early Tertiary igneous rocks of Sleetmute quadrangle. Further field mapping, accompanied by petrographic studies, additional chemical analyses, and more age determinations, is necessary as a first step in these studies.

Unconsolidated deposits

Most of the bedrock in the Sleetmute quadrangle is covered by surficial deposits consisting of colluvium, loess, glacial till and outwash gravel, fluvial terrace and bench gravels, and floodplain deposits (Cady and others, 1955). The highest upland areas are covered by colluvium comprising residual material that generally reflects the character of the underlying bedrock; the lower mountains are mostly mantled with a thick layer of loess. Intermontane lowlands are generally covered with loess and a thick vegetation mat. The boundary between residual colluvium and other surficial deposits is often difficult to determine and consequently bedrock contacts on the geologic map are largely approximate.

The broad plain of the Holitna Lowland is covered by till and outwash from glaciers originating in the western Alaska Range; end moraines form conspicuous arcuate ridges (plate 1). At least four glacial episodes are represented by the deposits. The Chuilnuk, Kiokluk, and Horn Mountains, the highest and most rugged mountains of the Kuskokwim Range in the Sleetmute quadrangle, supported small alpine glaciers during the last major glaciation and are characterized by cirques, tarns, and elongate U-shaped valleys containing morainal deposits (Waythomas, 1984).

Terrace gravels and floodplain deposits of silt, sand, and gravel occur along the Kuskokwim River and its main tributaries (Krause, 1984). The Kuskokwim River flows over a relatively narrow floodplain in the northeastern part of the quadrangle, confined to the junction of the Holitna Lowland and the eastern front of the Kuskokwim Mountains. The river is restricted to a narrow gorge having sparse floodplain deposits as it abruptly cuts across the mountain range near the village of Sleetmute.

TECTONIC HISTORY

The framework for discussion of the geology of the Sleetmute quadrangle has been established by stratigraphic subdivision based on genetic relationships: Paleozoic rocks of continental margin origin (the Holitna Group, Farewell terrane), Mesozoic rocks of accretionary origin (the Gemuk Group, Togiak terrane), and post-accretionary rocks. The post-accretionary rocks were further subdivided into the Kuskokwim Group (a post-accretionary basin fill sequence), igneous rocks, and unconsolidated deposits. In this final section we draw from regional studies to relate these genetically distinct units and discuss their tectonic history.

The Farewell terrane represents deposition of shallow-water carbonate platform facies and coeval deep-water outer shelf and slope facies during Cambrian to Late Devonian time (Bundtzen and Gilbert, 1983; Blodgett and Clough, 1985). Rocks of the platform carbonate facies prograded over rocks of the deep-water facies during mid-Paleozoic time (Bundtzen and Gilbert, 1983). This continental margin sequence was connected to the Paleozoic North American continent (Blodgett and Clough, 1985), and probably has moved little with respect to it since, at least, early Mesozoic time (Wallace, 1983).

The Togiak terrane and the closely associated Goodnews terrane, formed as an intra-oceanic arc-trench complex during Late Triassic to Early Cretaceous time. The Hagemeister subterrane of the Togiak terrane represents a volcanic arc that built upward, reaching sea level by Early Jurassic time (Box, 1983). The presence of a particular faunal assemblage (characterized by the pelecypod *Weyla* sp.) well north of its usual range suggests post-Early Jurassic poleward displacement for rocks of the Hagemeister subterrane (D.L. Jones, oral commun., in Box, 1985; Decker and others, in press). Convergence of the combined Togiak and Goodnews terranes culminated with an arc-continent collision in late Early Cretaceous time (Box, 1983; and Wallace, 1983). The Farewell terrane was likely a significant part of the North American continental backstop to which the Togiak and Goodnews terranes were accreted (Decker and others, in press).

Following accretion (in mid Cretaceous time), an extensional tectonic regime formed a subsiding basin into which the Kuskokwim Group sediments were deposited. The Kuskokwim Group unconformably overlies rocks of both the Farewell and Togiak terranes indicating that amalgamation was complete by Albian time. The suture between these terranes (now buried beneath the Kuskokwim Group) may have been the focus of considerable northward translation by right-lateral strike-slip motion (Decker and others, in press). A rapid progression from deep-marine turbidite facies to shallow-marine, and finally to non-marine deposits in the upper part of the Kuskokwim Group indicates cessation of basin infilling occurred in Late Cretaceous time (Bundtzen and Gilbert, 1983). Volcanism, localized along extensional high angle faults, began during the last stages of basin filling (Bundtzen and Gilbert, 1983; Gemuts and others, 1983). These high angle faults became the sites of repeated igneous activity in the form of mafic to felsic dike swarms, subaerial volcanic flows and volcano-plutonic complexes, and peraluminous rhyolite sills and dikes. The work of Bergman and Doherty (1986) and Bergman and others (1987) suggests calc-alkalic to alkali-calcic magmatism of the volcano-plutonic association is related to northward-directed subduction of the gently dipping Kula plate, and occurred over a 400-600-km-wide belt from 60-80 m.y. ago. Bergman and others (1987) further suggested that post-subduction processes accompanied by crustal lithospheric melting, resulted in a younger magmatic event (45-60 m.y. ago). The peraluminous rhyolite sills and dikes of the Sleetmute quadrangle indicate involvement of crustal material in the magma, but show a wider age range (61-70 m.y.) than that indicated by Bergman and others (1987) for post-subduction crustal melting.

The region is deformed by folds and faults. Pre-Tertiary rocks have undergone at least two periods of folding, the latest of which has resulted in formation of a series of northeast-trending anticlines and synclines. The dominantly open fold style becomes isoclinal where strata are further compressed between major faults. High-angle faults (of which the Iditarod-Nixon Fork and Denali-Farewell systems are examples) parallel the fold structure. The Iditarod-Nixon Fork fault has had a minimum of 88-94 km (55-58 mi) right-lateral movement since Late Cretaceous-early Tertiary time (Miller and Bundtzen, 1988). A right-lateral displacement of 145-153 km (90-95 mi) is indicated for the Denali-Farewell fault based on the offset of a Late Silurian to Early Devonian algal barrier reef complex (Blodgett and Clough, 1985). A prominent escarpment cuts Quaternary deposits along the Iditarod-Nixon Fork fault suggesting activity in Pleistocene and possibly Holocene time (Bundtzen and others, 1988a). The Denali-Farewell fault system also shows evidence of Quaternary to Holocene movement and is probably still active (Bundtzen and others, 1986). Although considerable fault displacement has occurred since latest Cretaceous time, the basin into which the Kuskokwim Group was deposited is still recognizable (fig. 6), indicating that the amount of post-accretionary displacement is insignificant when compared to that of pre-amalgamation (Decker and others, in press).

CHAPTER 3. GEOCHEMISTRY

DATA COVERAGE

Only a small portion of the Sleetmute 1:250,000-scale quadrangle has been evaluated by geochemical assessment techniques. Unlike many other 1° x 3° quadrangles in Alaska, no geochemical data was collected for the Sleetmute quadrangle under the National Uranium Resource Evaluation (NURE) program. The Alaska Division of Geological and Geophysical Surveys (ADGGS) conducted a geochemical survey of three of the 1:63,360-scale Sleetmute quadrangles (Robinson 1984a-c), but this amounts to only 9% of the quadrangle. A minor amount of additional geochemical data is available for selected mines and prospects. These include studies conducted by the USGS (Mertie, 1936; MacKevett and Berg, 1963; Sainsbury and MacKevett, 1965) and by the U.S. Bureau of Mines (Webber and others, 1947; Malone, 1962; Maloney, 1962, 1968; Merrill and Maloney, 1974; Meyer, 1985). The data is too scattered and incomplete to serve as an adequate data base for evaluation of the quadrangle as a whole.

SUMMARY OF GEOCHEMICAL SURVEYS

ROCK GEOCHEMISTRY

Geochemical analyses of rock samples collected from mines, prospects, and occurrences are among the most useful data for identifying pathfinder element suites in the Sleetmute quadrangle. Studies such as Sainsbury and MacKevett (1965), Sorg and Estlund (1972), and Webber and others (1947) showed that cinnabar-stibnite lode deposits in the Sleetmute quadrangle are consistently characterized by anomalous concentrations of Hg, Sb, and As. This geochemical association is particularly characteristic of ore samples from the Red Devil mine (plate 2, #22) and adjacent prospects, including the Alice and Bessie, Ammeline, Barometer, Fairview, McCally Creek, Mercury, Two Genevieves, and Willis properties (Sainsbury and MacKevett, 1965; Cady and others, 1955; Cobb, 1972, 1976). Mineralized rock samples collected from other lodes in the quadrangle, such as Harvison, Rhyolite, Egnaty Creek, Landru, Mellick's, Kolmakof, and Mountain Top (plate 2, #3, #4, #6, #24, #26, #27, and #34, respectively), also exhibit a similar geochemical signature (Joesting, 1942; Cady and others, 1955; Malone, 1962; Maloney, 1962, 1968; Jasper, 1963; Sainsbury and MacKevett, 1965; Merrill and Maloney, 1974). The association of Hg-Sb-As is by far the most common type of anomalous geochemical signature to be found in Sleetmute quadrangle, but other anomalous metal suites are also expected. Mineralized rocks from the Red Devil area contain 15 to 300 ppm Cu and 30 to 150 ppm Pb, and 700 ppm Zn; and cinnabar-bearing rock samples collected from the Rhyolite prospect contain 70 ppm Cu and 700 ppm Zn (Sainsbury and MacKevett, 1965). This suggests elevated base metal values may also characterize some of the cinnabar-stibnite rich systems.

Although placer gold has been discovered on several drainages in Sleetmute quadrangle, relatively few precious-metal lode deposits have been identified. Cady and others (1955) described vein quartz containing free gold and scheelite above the placer gold mine at Fortyseven Creek (plate 2, #40 and #41), and a cinnabar-bearing ore sample from the Rhyolite prospect (plate 2, #4) contains 15 ppm Ag (Sainsbury and MacKevett, 1965). However, most lodes in the Sleetmute quadrangle do not appear to contain appreciable precious metals. Numerous placer gold deposits to the north in the Iditarod quadrangle, for example the Donlin Creek and Iditarod-Flat areas, are associated with metal-bearing lode sources. These precious-metal-bearing lode occurrences are commonly spatially associated with rhyolite or monzonite intrusions (Miller and Bundtzen, 1987). The similarity in geologic setting between the two quadrangles makes it possible that additional precious-metal lode occurrences will be found in the Sleetmute quadrangle. Ag, Au, or W may be important geochemical pathfinder elements for such lodes.

No significant base-metal lode occurrences are known from the Sleetmute quadrangle. However, in the Beaver Mountains of the Iditarod quadrangle, Cu, Pb, Zn, and Sn anomalies, associated with chalcopyrite-, galena-, and cassiterite-bearing mineral occurrences, have been identified (Bundtzen and Laird, 1982). These mineral occurrences are hosted by monzonitic intrusions and associated hornfels. The Konechney and Cobalt Creek copper-rich prospects to the west in the Russian Mountain area (Russian Mission quadrangle) are also spatially associated with the occurrence of monzonite and contain anomalous Au, Ag, Co, U, and locally Sn in addition to Cu (Cady and others, 1955; Bundtzen and Laird, 1989). The presence of similar rock types in the Sleetmute quadrangle suggests that base-metal anomalies are possible for geochemical samples from this quadrangle.

Robinson (1984a-c) reported geochemical results for over 100 rock samples collected in Sleetmute A-6, B-5, and B-6 quadrangles during geologic mapping by the ADGGS. Areas having anomalous geochemical values in rock samples commonly also have anomalous values in stream sediment and heavy-mineral-concentrate samples. These areas are discussed in more detail below and are outlined on figure 8.

STREAM SEDIMENT AND HEAVY-MINERAL-CONCENTRATE DATA

As as result of a funding cut prior to completion of the Alaskan surveys, no NURE stream sediment or hydrogeochemistry data exist in the Sleetmute quadrangle. The U.S. Bureau of Mines (USBM) collected 67 stream sediment samples from tributaries along the Kuskokwim River in the Sleetmute quadrangle (Meyer, 1985). Rock, stream sediment, and heavy-mineral-concentrate sampling was conducted by the ADGGS in the Sleetmute A-6, B-5, and B-6 quadrangles (Robinson, 1984a-c). In these three quadrangles geochemical results are reported for a total of 544 stream sediment and 306 heavy-mineral-concentrate samples. Although the USBM and ADGGS geochemical results are too sparse for a complete resource evaluation of the Sleetmute quadrangle, they indicate that several areas are anomalous in Hg, Sb, and(or) As. Additional areas that show anomalous concentrations of Au, Ag, Cr, W, Cu, Pb, Zn, Sn, or Mo are also delineated. Evaluation of the published geochemical data leads us to tentatively define anomalous values for different elements and for different sample media (table 1). As mentioned previously, in Robinson's studies (1984a-c) mineralized areas are generally defined by geochemical anomalies in all three sample media (rock, stream sediment, and heavy-mineral-concentrate samples). Thus, in the following section, all geochemical results are used collectively when defining an anomalous area.

GEOCHEMICAL ANOMALIES

ANOMALOUS AREAS INDICATED BY ADGGS DATA

A number of anomalous areas have been identified by evaluating the geochemical data collected by the ADGGS (Robinson, 1984a-c). In the ADGGS studies rock, stream sediment and heavy-mineral-concentrate samples were analyzed for Ag, As, Au, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, and Zn. In addition, all of the heavy-mineral-concentrate and a selected number of the rock samples were analyzed for Hg, Sn, and W. Anomalous areas (fig. 8) are defined by several samples (rock, stream sediment, or heavy-mineral-concentrate) that show elemental concentrations well above those listed in table 1.

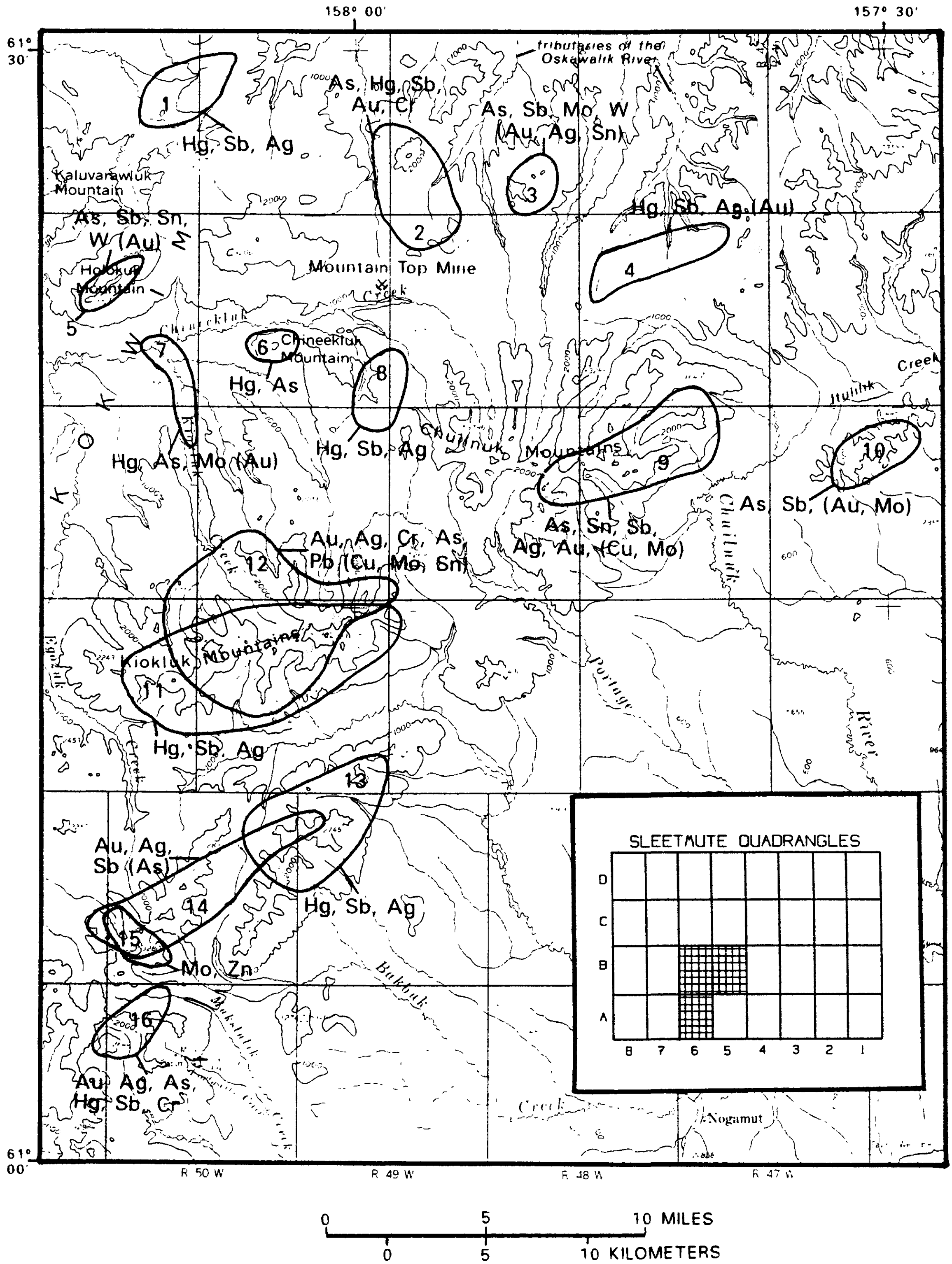

Figure 8. Geochemically anomalous elements in the Sleetmute A-6, B-5, and B-6 quadrangles from the data of Robinson (1984a-c). Elements that are either less consistently or only slightly anomalous are shown in parentheses.

Table 1. Anomalous concentrations of stream sediment, rock, and heavy-mineral-concentrate samples for the Sleetmute quadrangle.

Element	Stream Sediments and Rocks	Heavy-mineral-concentrates
Ag	0.5	1.0
As	25	50
Au	0.1	0.1
Cr	100	150
Cu	75	100
Hg	0.25 ppm	1.0 ppm
Mo	4	5
Pb	50	75
Sb	5	10
Sn	3	5
W	3	5
Zn	150	200

In several of the mine and prospect evaluations previously mentioned (for example, Sainsbury and MacKevett, 1965; Sorg and Estlund, 1972), Hg, Sb, and As appear to be the most significant pathfinders for cinnabar-stibnite mineralization in the Sleetmute quadrangle. An area with anomalous concentrations of Hg, Sb, and Ag in stream sediment and heavy-mineral concentrate samples occurs to the northeast of Kaluvarawluk Mountain (fig. 8, area #1). These anomalies are spatially associated with outcrops of peraluminous rhyolite, intermediate intrusive rock, and minor Kuskokwim Group sandstone (plate 1; Reifenstuhl and others, 1984). Although no mineral occurrences have been reported in this vicinity, the geochemical anomalies suggest the possibility of cinnabar-stibnite mineralization.

Stream sediment, heavy-mineral-concentrate, and rock (mineralized basalt and felsic volcanic) samples collected northeast of the Mountain Top mercury mine exhibit anomalous concentrations of As, Hg, Sb, Au, and Cr (Robinson, 1984c). This area (fig. 8, area #2), is underlain by Holukuk Basalt, Kuskokwim Group sedimentary rock, and peraluminous rhyolite (plate 1; Reifenstuhl and others, 1984). The As-Hg-Sb geochemical association suggests the possibility of cinnabar-stibnite mineralization similar to that identified at the Mountain Top property (Sorg and Estlund, 1972). Four rock samples (two iron-stained basalt, a felsic volcanic, and a rhyolite breccia) contain 0.3 ppm Au, and two heavy-mineral-concentrate samples contain 0.1 ppm Au. These values suggest that gold mineralization may also occur in area #2. The presence of stream sediment samples having up to 210 ppm Cr is probably a reflection of the background geochemical signature of the mafic rocks in this area.

Cady and others (1955) reported evidence of gold placer prospecting on the Oskawalik River, but did not report the exact location of this activity. Geochemical results from rock (altered felsic igneous), stream sediment, and heavy-mineral-concentrate samples collected from tributaries of the Oskawalik River (Robinson, 1984b), reveal two anomalous areas (fig. 8, areas #3 and #4). The easternmost of these areas (#4), anomalous in Hg, Sb, Ag, and possibly Au, is primarily underlain by Kuskokwim Group sedimentary rock, but altered dikes of intermediate composition occur nearby (plate 1; Robinson and others, 1984). One altered felsic dike sample from area #4 contains 0.2 ppm Au. The more western of these two areas (#3), is underlain by felsic volcanic rocks (plate 1; Robinson and others, 1984), and is anomalous in As, Sb, Mo, and W; less consistently, samples are anomalous in Au, Ag, and Sn. Two porphyritic rhyolite samples contain 0.2 ppm Au; two stream sediment samples contain 0.6-0.7 ppm Ag and one heavy-mineral-concentrate sample contains 0.9 ppm Ag; and three rhyolite samples contain 5-20 ppm Sn (Robinson, 1984b). In both areas #3 and #4, the source of the anomalies is uncertain; no lode mineral occurrences are known from this general region.

Anomalous As, Sb, Sn, and W occur in rhyolite, stream sediment, and/or heavy-mineral-concentrate samples collected from Holokuk Mountain (fig. 8, area #5). Two samples (one heavy-mineral-concentrate and one quartz-veined rhyolite), also contain 0.1 ppm Au. Holokuk Mountain is underlain by Tertiary-Cretaceous rhyolite porphyry (plate 1; Reifenstuhl and others, 1984) and has no known mineral occurrences. The geochemical anomaly suite at Holokuk Mountain could be indicative of mineralization similar to that found at the Rhyolite prospect (plate 2, #4) where rhyolite hosts the cinnabar-stibnite mineralization; however, Hg was not found to be anomalous in the samples collected from Holokuk Mountain. The Holokuk Mountain area could also host occurrences similar to the Donlin Creek area of the Iditarod quadrangle where peraluminous rhyolite intrusions are spatially associated with gold-stibnite mineralization (Miller and Bundtzen, 1987).

Stream sediment and heavy-mineral-concentrate samples collected around Chineekluk Mountain are anomalous in Hg and As (fig. 8, area #6). Chineekluk Mountain is underlain by hornfels Kuskokwim Group sedimentary rock and sheeted intrusive rock of felsic to intermediate composition (plate 1; Reifenstuhl and others, 1984). Although no mineral occurrences are known from Chineekluk Mountain, the geochemical anomalies may be related to undiscovered mercury mineralization.

To the southwest and southeast of Chineekluk Mountain, two small areas are defined by geochemical anomalies in samples collected from tributaries of Kiokluk Creek and Chineekluk Creek (fig. 8, areas #7 and #8). Stream sediment and heavy-mineral-concentrate samples collected from Kiokluk Creek (area #7) are anomalous in Hg, As, and Mo; three rock samples (quartz vein in sandstone, quartz vein breccia, and iron-stained siltstone) each contain 0.2 ppm Au. Stream sediment and heavy-mineral-concentrate samples collected from Chineekluk Creek (area #8), are anomalous in Hg, Sb, and Ag (Robinson, 1984c). The bedrock geology in both of these areas consists primarily of Kuskokwim Group sedimentary rocks and lesser mafic volcanic rocks (plate 1; Reifenstuhl and others, 1984). No mineral occurrences are known from either of these areas, but the geochemical results suggest the possibility of mercury or precious-metal mineralization.

Stream sediment, heavy-mineral-concentrate, and rock (altered dike, sandstone, and quartz-tourmaline altered intrusive) samples collected in or near the headwaters of streams that drain the Chuilnuk and Kiokluk Mountains (fig. 8, areas #9, #11, and #12), are anomalous in Hg, Sb, As, Au, Ag, Pb, Sn, and(or) Cr (Robinson, 1984a-c). Less consistently, anomalous concentrations of Cu and Mo are also present in some samples. Both the Chuilnuk and Kiokluk Mountains are underlain by volcano-plutonic complexes that intrude or overlie Kuskokwim Group sedimentary rocks (plate 1; Reifenstuhl and others, 1984). The geochemical anomalies are somewhat analogous to precious-metal related element suites at occurrences such as those in the Iditarod quadrangle near Flat or Moore Creek, where volcano-plutonic complexes are present.

Several stream sediment, heavy-mineral-concentrate, and rock (sandstone, shale, or conglomerate, some of which are iron-stained) samples collected from the prominent ridge at the headwaters of Itulilik Creek (fig. 8, area #10) are anomalous in As and Sb (Robinson, 1984b) and less consistently in Au and Mo. One rock sample of a pyrite + hematite-bearing black shale contains 0.3 ppm Au and three heavy-mineral-concentrate samples contain 0.1 ppm Au; a number of the stream sediment and heavy-mineral-concentrate samples contain 5-6 ppm Mo. No mineral occurrences are known from this area and only Kuskokwim Group sedimentary rocks have been mapped in the vicinity (plate 1; Robinson and others, 1984). This area lies just south of the Denali-Farewell fault and the anomalies could indicate the presence of stibnite or precious-metal mineralization related to this major structure.

Anomalous concentrations of Hg, Sb, and Ag occur in several stream sediment and heavy-mineral-concentrate samples collected near the headwaters of Bakbuk Creek (fig. 8, area #13). Only Kuskokwim Group sedimentary rocks have been mapped here, but the area lies between traces of the Denali-Farewell and Boss Creek faults. No mineral occurrences are known in this area.

Robinson (1984a) reported geochemical results for several rocks (primarily quartz-veined sandstone and shale, and some rhyolite samples), and a few stream sediment and heavy-mineral-concentrate samples collected from the divide area drained by Bakbuk Creek and Egozuk Creek (fig. 8, area #14). Samples collected in this area are anomalous in Au, Ag, and Sb. Less consistent As anomalies (up to 37 ppm) are found in a few rock (silicified sandstone) and stream sediment samples. Area #14 is underlain by Kuskokwim Group sedimentary rock, intruded locally by small hypabyssal rhyolite dikes (plate 1; Decker and others, 1984b). Although no mineral occurrences are found in this area, the lode and placer gold-tungsten deposits of Fortyseven Creek lie immediately to the south (appendix, #40 and #41). No anomalous W values are reported for any of the samples collected, but occurrences similar to those at Fortyseven Creek may also be found in area #14.

Area #15 outlines a geochemical anomaly based on 12 stream sediment samples collected from tributaries of Boss and Bakbuk Creeks which contain 4-6 ppm Mo and 152-166 ppm Zn (Robinson, 1984a). The bedrock geology consists of Kuskokwim Group sedimentary rock intruded by hypabyssal rhyolite dikes (plate 1; Decker and others, 1984b). The anomalies may reflect only lithogeochemical enrichment in shaley rocks, rather than mineralization.

Anomalous values of Au, Ag, As, Hg, Sb, and Cr, occur for several rock (quartz-veined sandstone), stream sediment, and heavy-mineral-concentrate samples in area #16. The rock and stream sediment samples were not analyzed for W values. The bedrock geology in this area consists primarily of Kuskokwim Group sedimentary rocks, but small hypabyssal rhyolite dikes locally intrude the sedimentary rocks (plate 1; Decker and others 1984b). Cady and others (1955) speculated that the mineralization of Fortyseven Creek, which is localized along a shear zone in Kuskokwim Group sedimentary rocks, was genetically related to albite rhyolite at depth.

ANOMALOUS AREAS INDICATED BY USBM DATA

The U.S. Bureau of Mines (USBM) collected stream sediment samples from several creeks and tributaries of the Kuskokwim River between the villages of Sleetmute and Georgetown (Meyer, 1985). This data shows locally anomalous concentrations of Hg, Sb, As, W, Cr, Zn, Pb, and/or Cu. The Hg, Sb, and As anomalies are consistent with the Red Devil type of mineralization (MacKevett and Berg, 1963), the W may be related to felsic intrusive rocks, and the Cr and Zn may be reflecting the geochemical signature of mafic dikes known to locally intrude Kuskokwim Group rocks. The USBM also collected sediment samples from streams that drain the Horn Mountains (Meyer, 1985). These samples contain Cr values of 150-200 ppm, which are probably related to the occurrence of mafic igneous rocks rather than any significant Cr-mineralization. Although some individual stream sediment geochemical anomalies can be identified in the data from Meyer (1985), this information is too widespread to make substantive conclusions regarding geochemical favorability for specific types of mineralization.

CONCLUSIONS

Although the existing geochemical data cover only a small part of the Sleetmute quadrangle, the observed anomalies suggest the following geochemical suites:

1) Anomalous Hg-Sb-As (± Cr) associated with cinnabar-stibnite mineralization similar to the Red Devil type mercury deposit. Mineralization is typically hosted in Kuskokwim Group sedimentary rock or altered dikes.

2) Anomalous Sb-Au-Ag (± Hg, As, Sn, and W) associated with stibnite-dominated mineralization in quartz veins; lesser amounts of cinnabar may be present. This mineralization type is commonly hosted in, or proximal to, hypabyssal rhyolite or felsic intrusions such as those in the Donlin Creek area of the Iditarod quadrangle.

3) Anomalous Au-Ag-W-As-Sb (± Hg, Sn, Cr, Pb, Cu, and Mo) spatially associated with, or hosted in, volcano-plutonic complexes. Quartz veins hosting scheelite, arsenopyrite, and gold, associated with minor stibnite and cinnabar, may result in this anomaly signature.

4) Anomalous Au-Ag-Sb-As (± W, Hg, and Cr), associated with Kuskokwim Group sedimentary rock, but not clearly with the occurrence of igneous rocks. At Fortyseven Creek, such an occurrence appears to be controlled by structures within Kuskokwim Group rocks. Mineralization could be hosted in quartz veins that may contain scheelite, wolframite, arsenopyrite, jamesonite, stibnite, argentite, tellurides, and(or) native gold.

Using the data of Robinson (1984a-c) we have outlined areas that are geochemically favorable for undiscovered mineral deposits. The usefulness of this limited data demonstrates the need for a regional study of the entire quadrangle. Furthermore, the high potential for mercury and gold mineralization in the quadrangle indicates that even routine samples should be analyzed for low concentrations of both Hg (at 20 ppb[2]) and Au (at 50 ppb), perhaps using atomic absorption methods.

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2 ppb = parts per billion

CHAPTER 4. GEOPHYSICS

REMOTE SENSING

DATA COVERAGE

Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM)

Since 1972, a succession of five Landsat satellites have recorded spectral information from the surface of the Earth in the visible and near infrared parts of the electromagnetic spectrum. The recorded information is returned to the earth as electronic signals that are converted to magnetic tape. The magnetic tape for each Landsat scene covers a ground area of 185 km^2 (71 mi^2). The Multispectral scanner (MSS) aboard all five satellites records in four spectral bands, from 0.5 to 1.1 micrometers, with a spatial resolution of 80 m (260 ft). In addition to the MSS, Landsats 4 and 5 have a Thematic Mapper (TM) instrument, which acquires data in a wider spectral range of seven bands, from 0.45 to 2.34 micrometers, at a spatial resolution of 30 m (98 ft).

Landsat satellite digital tape coverage of the Sleetmute quadrangle was acquired from the National Mapping Division field office in Anchorage, Alaska through a tape exchange agreement with the Federally-Owned Landsat Data (FOLD) base. The two scenes cover most of the Sleetmute quadrangle, except for a small triangular area on the north border, as well as areas in the Lime Hills, Russian Mission, Bethel, and Taylor Mountains quadrangles. The MSS data were digitally combined into a mosaic that provided a 1:250,000-scale image base useful for plotting and comparing to other types of data. The complete mosaic image, registered to a Universal Transverse Mercator grid, can be used to provide a regional framework (fig. 9), such that faults and other features mapped in surrounding quadrangles can easily be traced into the Sleetmute quadrangle.

TM data for Alaska is acquired by request through the EROS Data Center, Sioux Falls, South Dakota. The data center has charts that show dates of satellite passes over the quadrangle. Data may be requested for a specific time range (by month), an advantage because a charge is only made for the first coverage that meets the allowable maximum cloud cover. The range of dates should be chosen to minimize both the snow and vegetation cover, and to provide optimum sun angles for spectral studies (about 40°-50°). The period of time to consider would be approximately the last week in March through the first week in July. Three data accessions are presently available providing TM scenes for the Sleetmute quadrangle. One scene for path 74 row 17 covers 95% of the quadrangle; only the southeast corner is missing. Landsat 4 is being scheduled for Alaska and at this time, the satellite is collecting high quality data.

NOAA Advanced Very High Resolution Radiometer (AVHRR)

The National Oceanographic and Atmospheric Administration (NOAA) routinely collects weather data by satellite. The NOAA sensor, AVHRR, provides multispectral data in the visible, near-infrared, and thermal-infrared wavelengths. The USGS, Branch of Geophysics in Denver has digital data for two relatively cloud-free scenes covering the Sleetmute quadrangle, which were acquired by the NOAA-12 satellite on March 4 and 5, 1987. Application of AVHRR data to resource studies is still in the research stage.

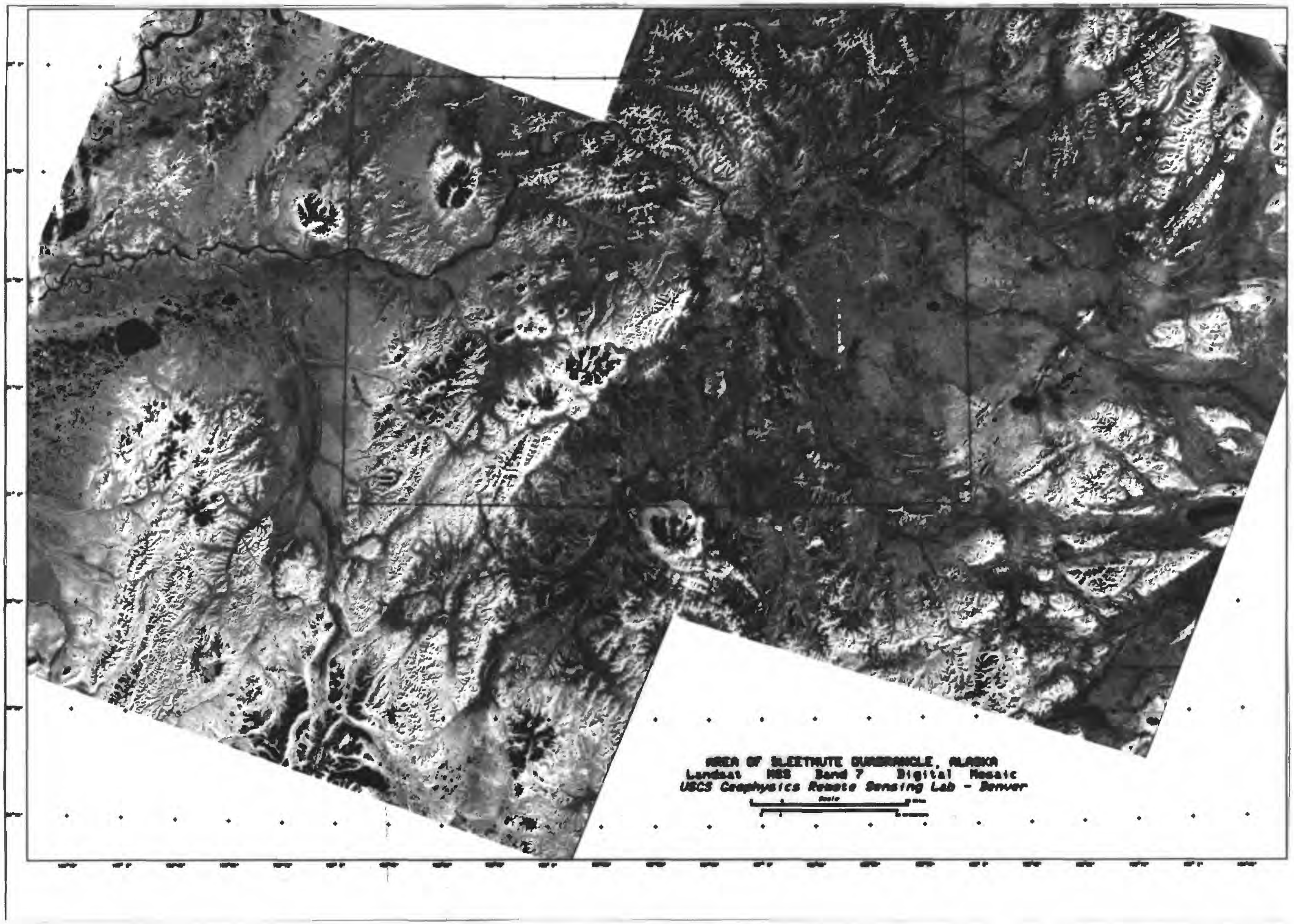

Figure 9. Landsat Multispectral Scanner (MSS) Digital Mosaic of the Sleetmute quadrangle and some of the surrounding area; quadrangle boundary indicated by box.

Synthetic Aperture Radar (STAR-1) mosaic and image strips

Radar is an active sensor that produces microwave radiation to illuminate the topography. The amount of reflected radiation recorded by the system is determined by topography, vegetation, surface roughness, and moisture content. Radar generally emphasizes anomalous features and in the Sleetmute quadrangle it enhances the subtle topography of the eastern part of the quadrangle. The relatively high relief of the southwest part of the quadrangle produces heavy shadowing created by the 600 to 1,200 m (2,000 to 4,000 ft) topographic highs that block out the radiation from the steep back slopes.

Radar for the Sleetmute quadrangle was flown October 1987 by INTERA Technologies, Inc., of Austin, Texas, using the digital high resolution STAR-1 system from a flight altitude of about 9,800 m (32,000 ft) with a west-look direction. Image strips were flown on 20 km (12.5 mi) line spacings. The image mosaic was prepared for, and reconciled to, the USGS 1:250,000 scale topographic base map by Simulation Systems, Inc., a division of MARS Associates, Inc., Phoenix, Arizona. The image strips and mosaic can be purchased as paper prints or as positive or negative transparencies from the EROS Data Center, Sioux Falls, South Dakota.

Aerial photography

There is fairly extensive coverage of the Sleetmute quadrangle by aerial photography. A computer search by EROS Data Center lists 302 cloud-free accessions. The majority of the missions were flown by the U.S. Air Force prior to 1961 at the scale of approximately 1:40,000. Additional missions were flown by NASA in late 1970's and early 1980's to acquire color-infrared air photos at approximately 1:60,000 scale; these are particularly useful for geologic mapping.

SUMMARY

Landsat MSS data have proven useful in preparing maps of the regional distribution of limonitic materials in arid or semi-arid regions (Knepper, 1988; S.L. Simpson, unpub. data). These same image-processing techniques were attempted with the MSS data for Sleetmute quadrangle, but spectral information was obscured by vegetation that presents special problems for spectral studies in Alaska. The higher spatial resolution and additional spectral bands of TM data may provide a better means of looking through the vegetation cover. Special image processing of TM data identifies limonite and clay minerals in a highly vegetated area in Bangladesh (D.K. Knepper, Jr., oral commun., 1988). New methods need to be developed for Alaskan terrain such as processing TM data as ratios of spectral bands which are specifically designed to identify alteration minerals by their unique spectral characteristics. To visually enhance the image, the band ratios are combined into color-ratio composite images by assigning red, green, and blue colors to various combinations of ratios. Another technique that may prove useful in Alaska is to evaluate the images for possible geobotanical correlations. TM images are also useful in mapping regional linear features such as fracture patterns. Finally, TM data would be useful as an image base for displaying regional geological, geophysical, and geochemical data sets. Image processing may be simplified with the help of the Geographic Information System (GIS), which allows rapid, video display of various combinations of data sets that may show significant interrelationships.

Linear features that extend northeast from the southwest border of the quadrangle are apparent on the Landsat image (fig. 9). From west to east, these lines coincide with the mapped traces of the Atsaksovluk, Boss Creek, and Denali-Farewell faults. The Denali-Farewell fault is also well expressed on radar image strips. A complete linear features analysis was not made because of the excessive shadowing on the radar image and the low spatial resolution of the MSS image.

GRAVITY

DATA COVERAGE

Gravity data are sparse for the Sleetmute quadrangle. The 290 gravity stations taken within the Sleetmute quadrangle (D.F. Barnes, unpub. data) were collected by boat along the Kuskokwim, Holitna, Hoholitna, Stony, and Swift Rivers. Portions of these data were published by Meyer and Krouskop (1984). A contour map of the data (terrain corrected by computer to a radius of 167 km or 104 mi) is shown as figure 10. Additional stations (average spacing of 10 km or 6.2 mi) are scattered throughout the eastern half of the quadrangle. In the western half of the quadrangle, the data are too sparse to resolve any gravity anomalies.

INTERPRETATION

On the Bouguer gravity map of Alaska (Barnes, 1977), the Sleetmute quadrangle lies mainly within a relative gravity low of 20 to 30 mGal associated with the Kuskokwim Mountains. On the isostatic residual gravity map of Alaska (Barnes and others, in press), the Sleetmute quadrangle is characterized by neutral isostatic gravity values (+15 to -10 mGal) associated with the Kuskokwim tectonic basin of King (1969). Higher Bouguer and isostatic anomalies occur in the southeastern corner of the map, coincident with exposed and buried rocks of the Holitna Group. The isostatic anomaly highs are part of a northeast-trending belt that shows maxima between +30 and +65 mGal, and that follows the Denali-Farewell fault. Slightly higher Bouguer and isostatic anomalies also occur north and west of the Sleetmute quadrangle. Although this area is covered by post-accretionary basin-fill deposits, the higher Bouguer anomalies may be associated with buried mafic and intermediate volcanic rocks possibly associated with tectonostratigraphic terranes that are not exposed in the Sleetmute quadrangle.

The only well-defined gravity anomaly in the data for the Sleetmute quadrangle is a low that lies southeast of the Kuskokwim River and is labeled GL1-GL2 on figure 10. This gravity low coincides with an area of anomalously low relief; Basket Creek and the Denali-Farewell fault run down the center of the lowland. The cause of this gravity low is most likely a basin containing Quaternary and(or) Tertiary sediments. The steep gradients bounding the low are an indication that the basin is steep sided, possibly fault bounded, and extends to a depth of 1 to 4 km (0.6 to 2.5 mi).

MAGNETICS

DATA COVERAGE

Reconnaissance aeromagnetic data were acquired in the Sleetmute quadrangle as part of the National Uranium Resource Evaluation (NURE) (Aero Service Division, 1980). Figure 11 shows a contour map produced from those data. Flight lines were flown 122 m (400 feet) above ground along an east-west path, spaced 10 km (6 mi) apart. North-south tie lines were spaced about 38 km (24 mi) apart. Data were gridded for contouring at an interval of 3 km (1.87 mi).

INTERPRETATION

On a composite magnetic map of Alaska (Godson, 1984), the Sleetmute quadrangle appears featureless. A broad, but weak (< 200 nT), magnetic high correlates with rocks of the Holitna Group, in contrast to a weak magnetic low correlative with rocks of the Kuskokwim Group. The gradient between the high and the low trends coincides with the northeast-trending Denali-Farewell fault.

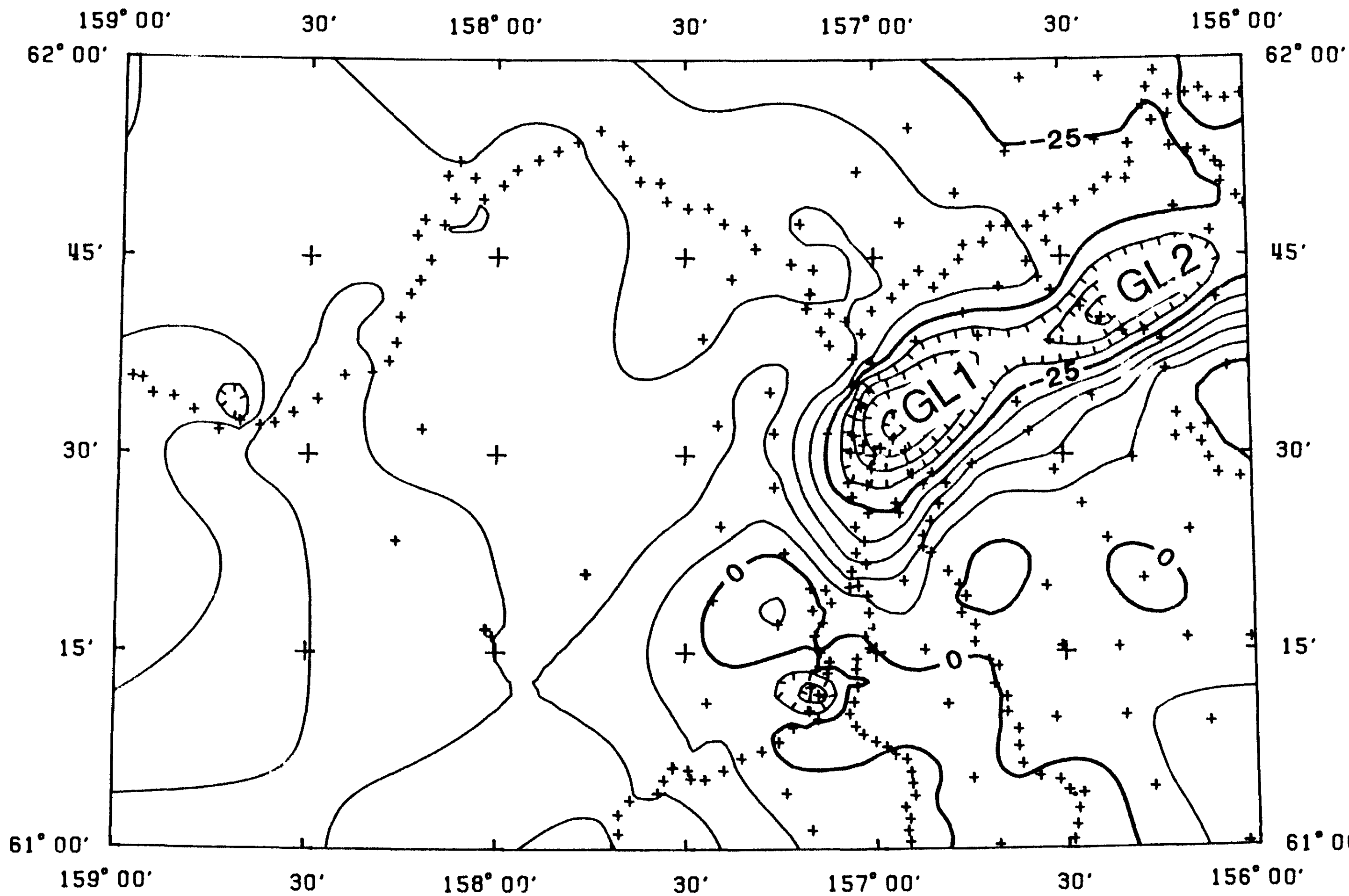

Figure 10. Complete Bouguer gravity anomaly map, Sleetmute quadrangle. Contour interval 5 milligals. Gravity station indicated by + symbol.

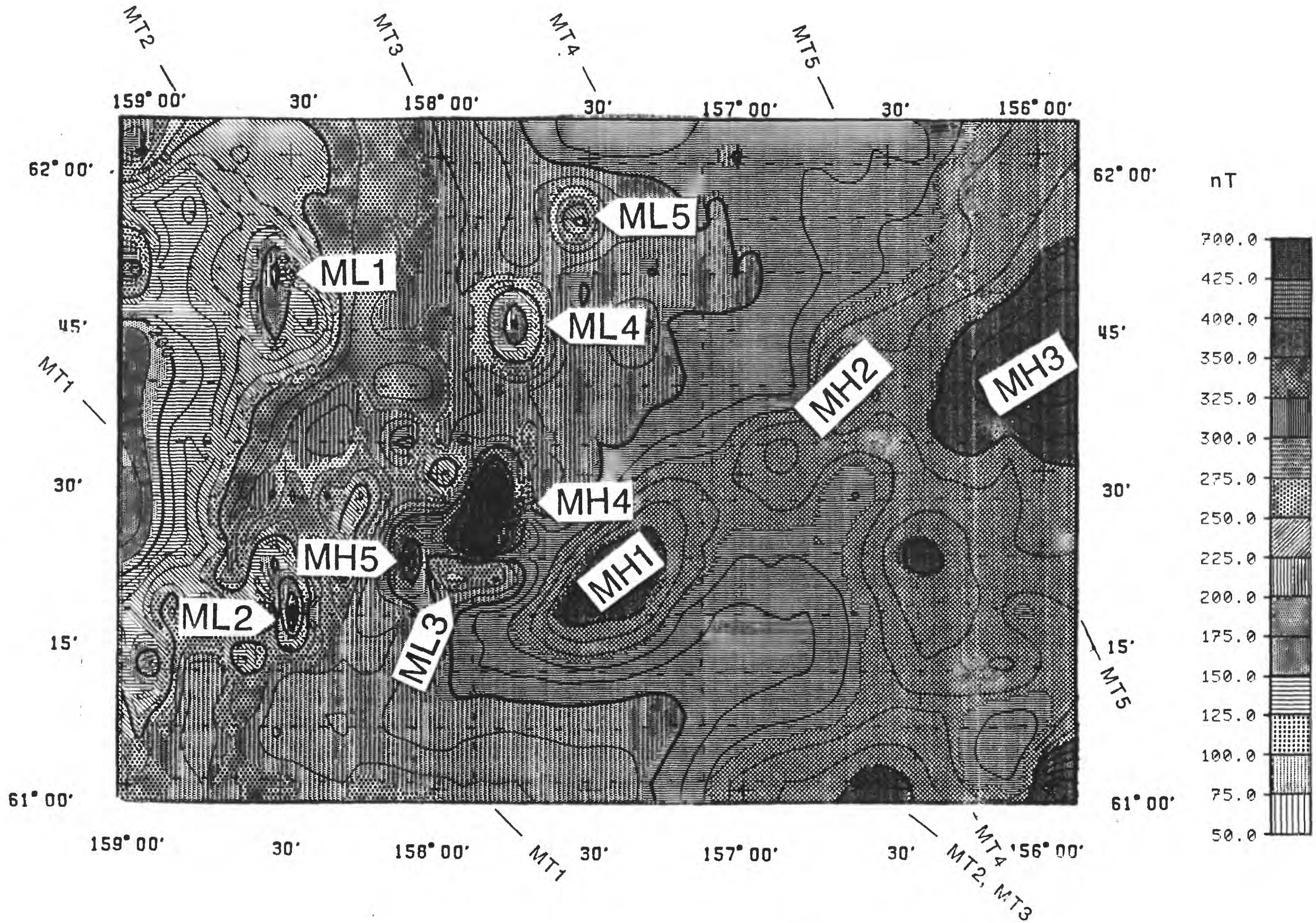

Figure 11. Residual total magnetic field map, Sleetmute quadrangle. Flight line elevation 400 ft. Contour interval 10 nanoTeslas. MT1-MT5 indicate proposed magnetotelluric and audiomagnetotelluric profiles.

The flight line spacing of the NURE data is too wide to accurately portray short-wavelength, high-amplitude (100-300 nT) anomalies that occur northwest of the Denali-Farewell fault. The background magnetic field there is lower than it is in the area southeast of the fault. Hence, the crust northwest of the fault (Kuskokwim Group and its basement) is less magnetic than the crust southeast of the fault (Holitna Group and its basement). However, the amplitude of magnetic anomalies is higher northwest of the fault due to the presence of intensely magnetic plutons, which show both normal and reverse magnetization.

Magnetic anomalies northwest of the Denali-Farewell fault include five lows, probably indicating reversely magnetized plutons, labeled on figure 11 as follows: ML1 (west side of Horn Mountain); ML2 (northern part of Buckstock Mountains); ML3 (Chuilnuk Mountains); ML4 (19 km west of Barometer Mountain); and ML5 (just north of the village of Eightmile). Two magnetic highs, probably indicating normally magnetized plutons, also lie northwest of the fault. They are labeled MH4 (south-southwest of Henderson Mountain) and MH5 (south of Chineekluk Mountain). Preliminary K/Ar radiometric data indicate the Late Cretaceous-early Tertiary plutons in the Sleetmute quadrangle were intruded between 69 and 63 m.y. ago (chapter 2, this report), during which time there were four normal epochs and four reversed epochs of the Earth's magnetic field (Ness and others, 1980).

Many other smaller magnitude highs and lows northwest of the Denali-Farewell fault are interpreted to indicate other magnetic plutons, both exposed and buried. Our preliminary interpretation of figure 11 is that the area northwest of the fault includes many small plutons scattered between the surface and a depth of a few kilometers. The apparent absence of broad magnetic highs or lows may indicate a shallow Curie-point isotherm. It is puzzling that many of the exposed plutons cause weaker magnetic anomalies than the inferred buried plutons. Two explanations seem plausible. First is the possibility that magnetization is associated with contact metamorphic aureoles, which have been eroded off the top of the exposed plutons. Second is the possibility that plutons with weak magnetic anomalies cooled during a time spanning a reversal of the Earth's magnetic field. Such a pluton would be partly normally-magnetized and partly reversely-magnetized, so that the normal and reverse components cancel out in the reconnaissance-scale aeromagnetic map (figure 11). A more detailed aeromagnetic survey, followed by field interpretation of the aeromagnetic map and paleomagnetic studies, would resolve these questions.

Southeast of the Denali-Farewell fault, magnetic anomalies have longer wavelengths and are better resolved. The magnetic highs, assumed to be correlative with the Holitna Group (MH1-MH3, fig. 11), have amplitudes of about 50 nT. The steepest part of the gradient north of magnetic high MH1 is about 8 km (5 mi) wide. Hence the maximum depth to magnetic rock, inferred to be the basement of the Holitna Basin, is about 8 km (5 mi). However, if the body is broad and flat-lying, it might be shallower. Gravity low GL1-GL2 (fig. 10) coincides with magnetic high MH2 and part of MH3. Based on data gathered from widely spaced gravity stations, however, there is no gravity low coincident with magnetic high MH1. Hence the gravity lows and magnetic highs are probably not related.

The tectonic setting in this southeast part of the Sleetmute quadrangle is very similar to that near Circle Hot Springs, Circle quadrangle, Alaska. Circle Hot Springs lies on the southern strand of the Tintina fault zone (the Hot Springs fault). Coincident with the lowland that lies northeast of the Hot Springs fault is a broad magnetic high and a shorter-wavelength gravity low. As in the Sleetmute quadrangle, the cause of the magnetic high is hidden by an alluvial basin. Preliminary magnetic and gravity modeling suggested that the source was a buried I-type granitic pluton (Cady and Weber, 1983). However, magnetotelluric soundings (J.W. Cady and C.L. Long, unpublished data) show that conductive rock, bearing an apparent resistivity of only 1-10 ohm-meters, roughly coincides with the modeled source of the magnetic anomaly. Only sedimentary rocks are known to have such a high conductivity. Magnetotelluric studies by Stanley and others (1989) indicated that black shales and slates in the Denali fault zone are both conductive and magnetic. Possibly the anomalies in both the Holitna Basin and at Circle Hot Springs are caused by buried black shales.

RADIOMETRICS

DATA COVERAGE

Reconnaissance gamma-ray spectrometer data were acquired in Sleetmute quadrangle as part of the NURE survey (Aero Service Division, 1980). Flying 122 m (400 ft) above ground, the spectrometer imaged a ground swath only 200 m (800 ft) wide. With a 10 km (6 mi) spacing, this amounts to only 2.5% of the quadrangle. Therefore, the radiometric data are difficult to contour, and gray-scale contour maps (figs. 12 to 17) are fuzzy. Nonetheless, several clear patterns stand out and are described below.

INTERPRETATION

The total-count gamma ray map (fig. 12) is dominated by the effects of topography (fig. 18). Although some of the topographic highs are coincident with known intrusive rock, this is not true in general. Higher gamma ray values occur over bedrock of the Kuskokwim Mountains than over the Quaternary deposits of the Holitna Basin. Within the topographically higher northwest quarter of the quadrangle, values observed over mountains (for example the Buckstock Mountains or Horn Mountain) are higher than values measured over river valleys (for example the Kolmakof or Kuskokwim Rivers). Within the southeast half of the quadrangle, the deepest lows occur in a northeast-trending belt in the lowlands associated with the Denali-Farewell fault (fig. 18; plate 1). Higher values occur over emergent Holitna Group basement to the southeast.

Comparison of figures 13 to 15 with the topographic map (fig. 18) shows that the distributions of potassium, thorium, and uranium are also dominated by topography. All probably largely reflect the degree of bedrock exposure. However, a qualitative evaluation of the intensity of anomalies and their correlation with topography suggests that anomalies TCA and TCB (fig. 12) have intensities out of proportion to the high topography with which they correlate. Intrusive rocks tend to be both anomalously radioactive and resistant to erosion, a combination that tends to amplify radiometric highs. However, parts of the high labeled TCC (fig. 12) occur over the topographically low Kuskokwim gorge, suggesting that higher radioactivity is indeed influencing the total count radiation. Anomalies TCB and TCD-TCE can be interpreted to indicate the presence of radioactive rocks exposed in the northwest and southeast limbs of a regional anticline. Anomaly TCC can be interpreted to indicate the presence of radioactive rocks exposed in the nose of the anticline, suggesting that the anticline is northeast plunging. The Red Devil mercury mine lies within the TCC anomaly.

In order to remove the dominant topographic effect, ratios of elements were calculated. One of the ratio maps (fig. 16, showing U/Th) appears relatively free of topographic effects. It shows anomalies U/TH A and U/Th B, offset a few miles northwest of gravity lows GL1 and GL2 (fig. 10). The U/K ratio map (fig. 17) shows a ring-shaped high, 15 km in diameter, labeled U/K A, that is centered in the deepest part of gravity low G2. This uranium/potassium anomaly may indicate accumulation of uranium associated with organic material in bogs. However, the anomaly is not well-defined by the widely spaced flight lines, and it may be an artifact of data processing.

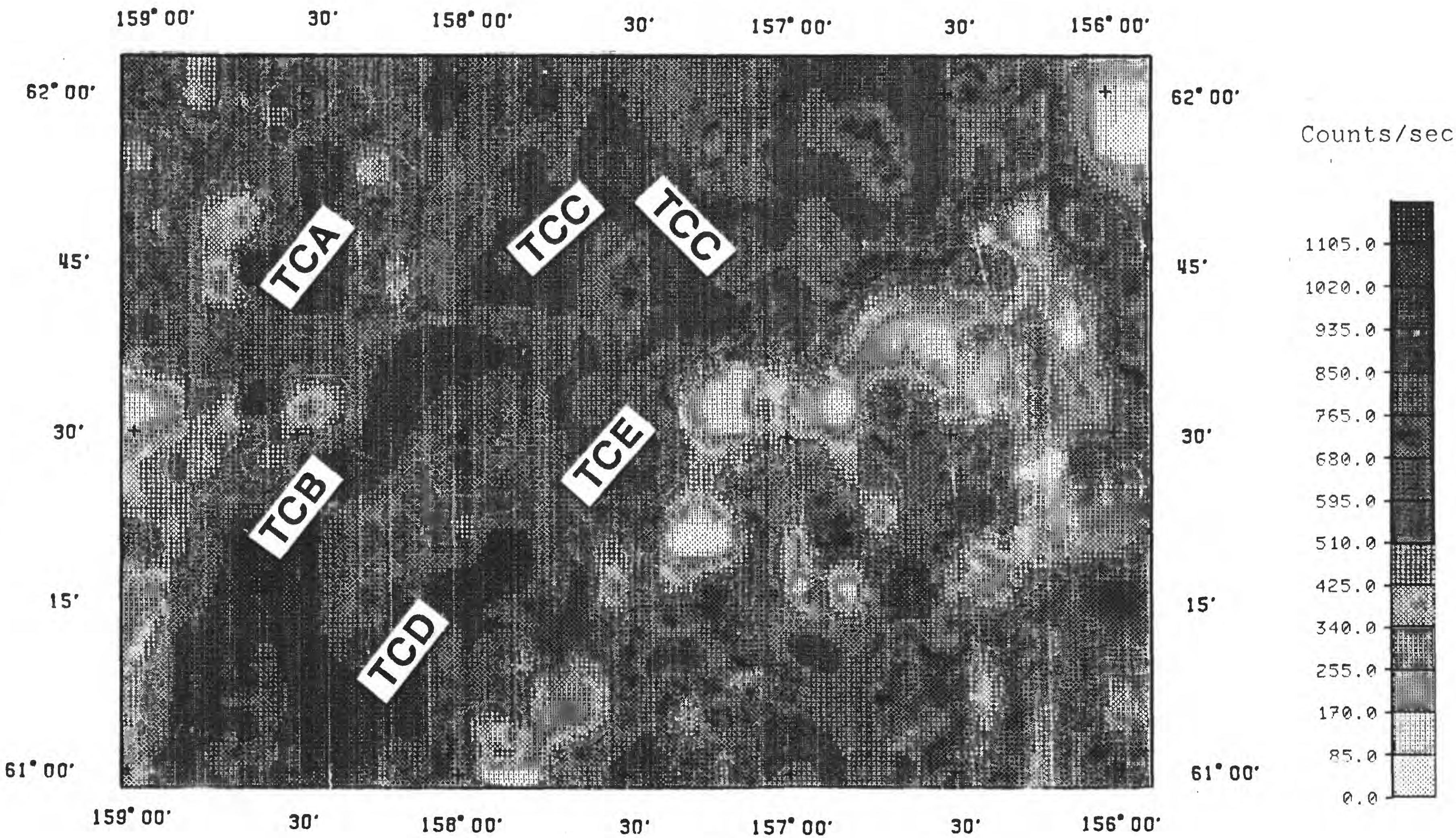

Figure 12. Total-count gamma ray radiometric data, Sleetmute quadrangle.

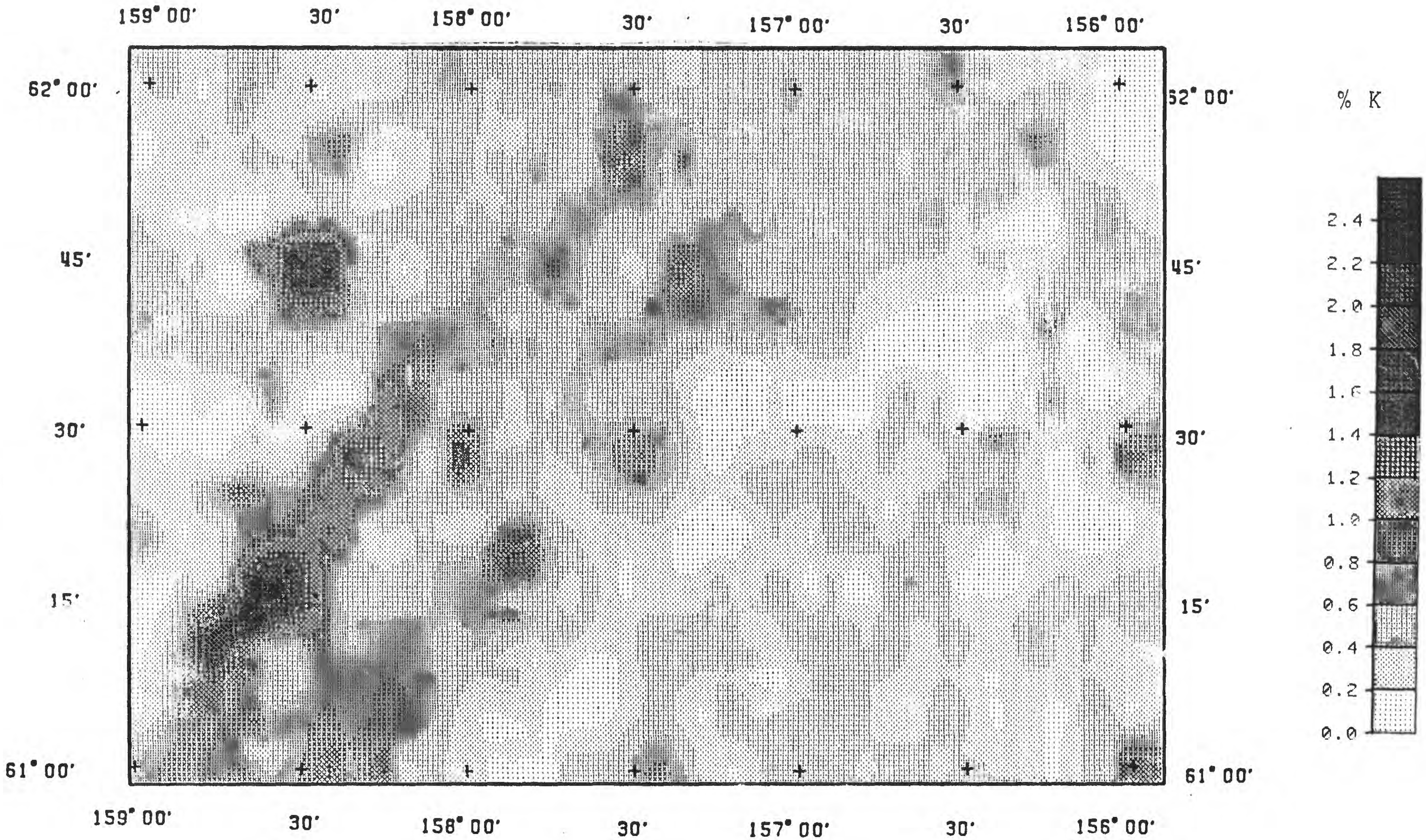

Figure 13. Potassium distribution, radiometric data, Sleetmute quadrangle.

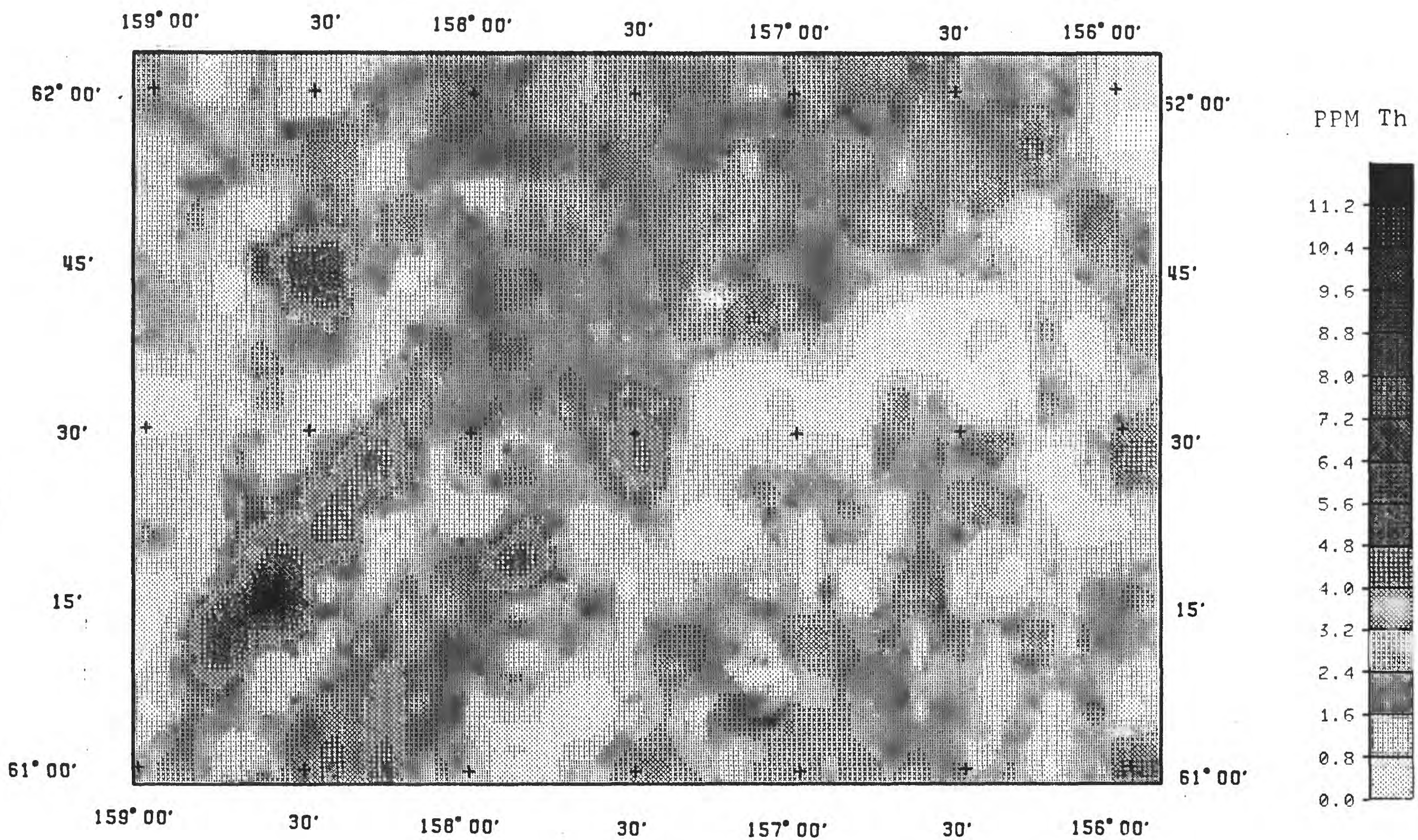

Figure 14. Equivalent thorium distribution, radiometric data, Sleetmute quadrangle.

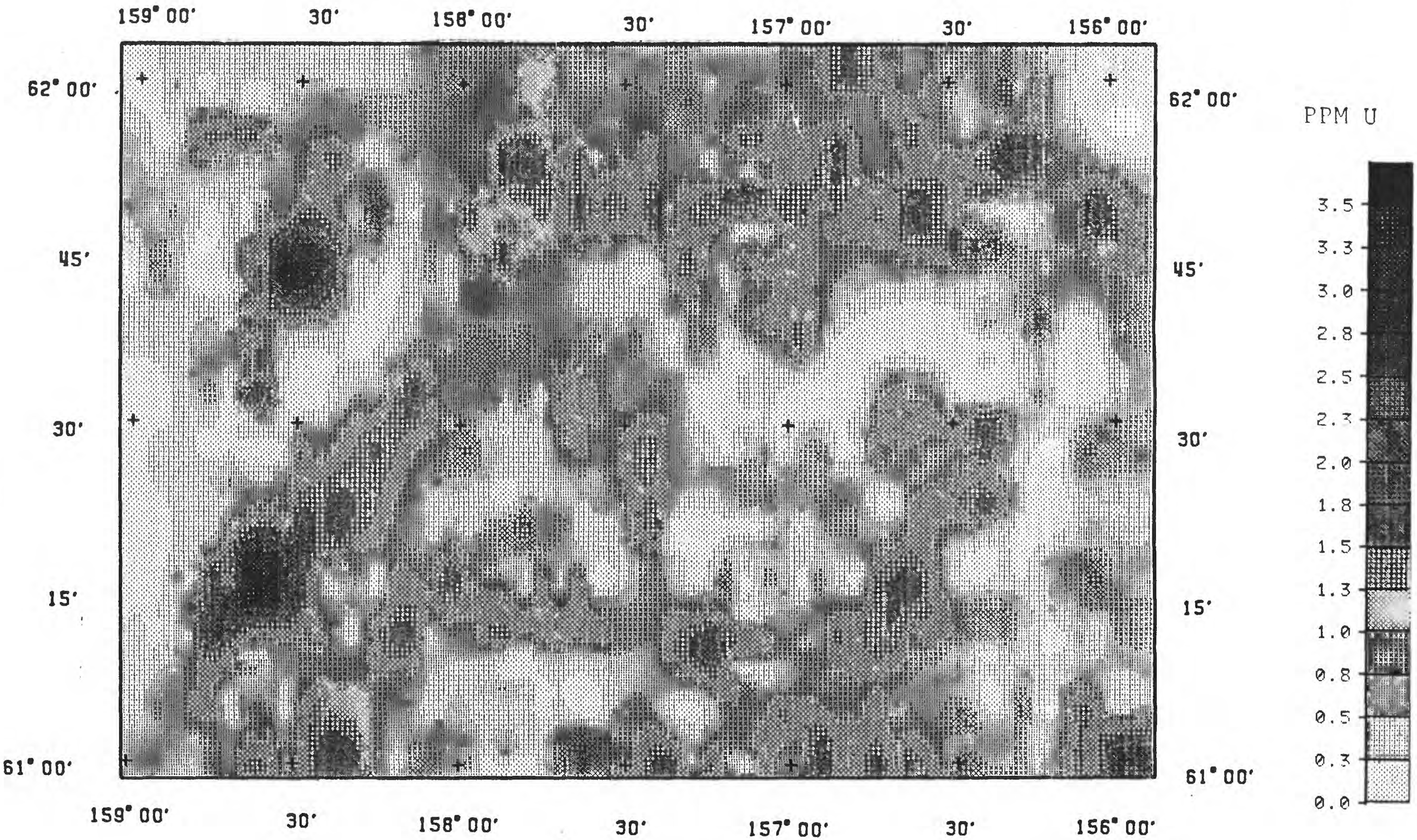

Figure 15. Equivalent uranium distribution, radiometric data, Sleetmute quadrangle.

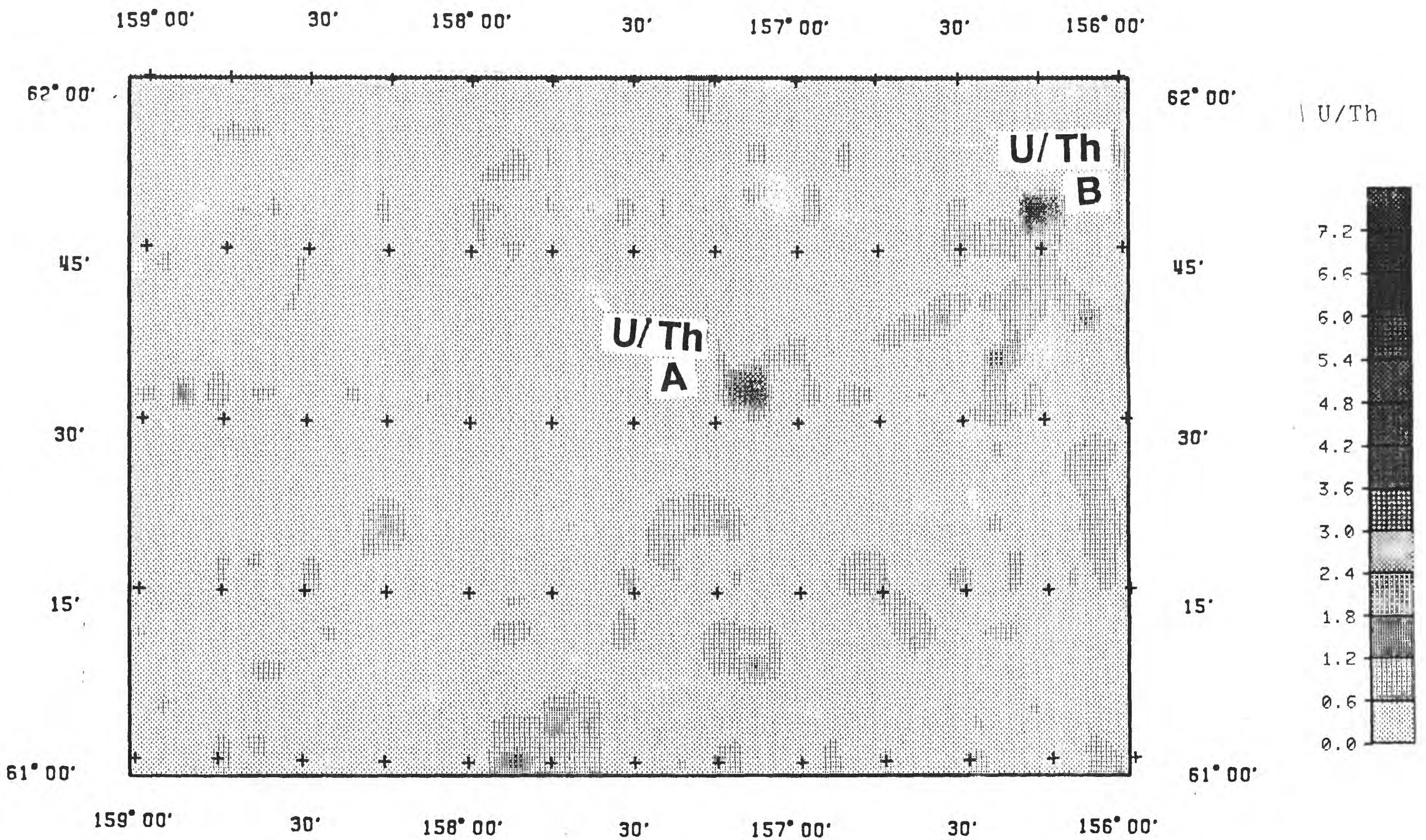

Figure 16. Uranium/thorium ratio, radiometric data, Sleetmute quadrangle.

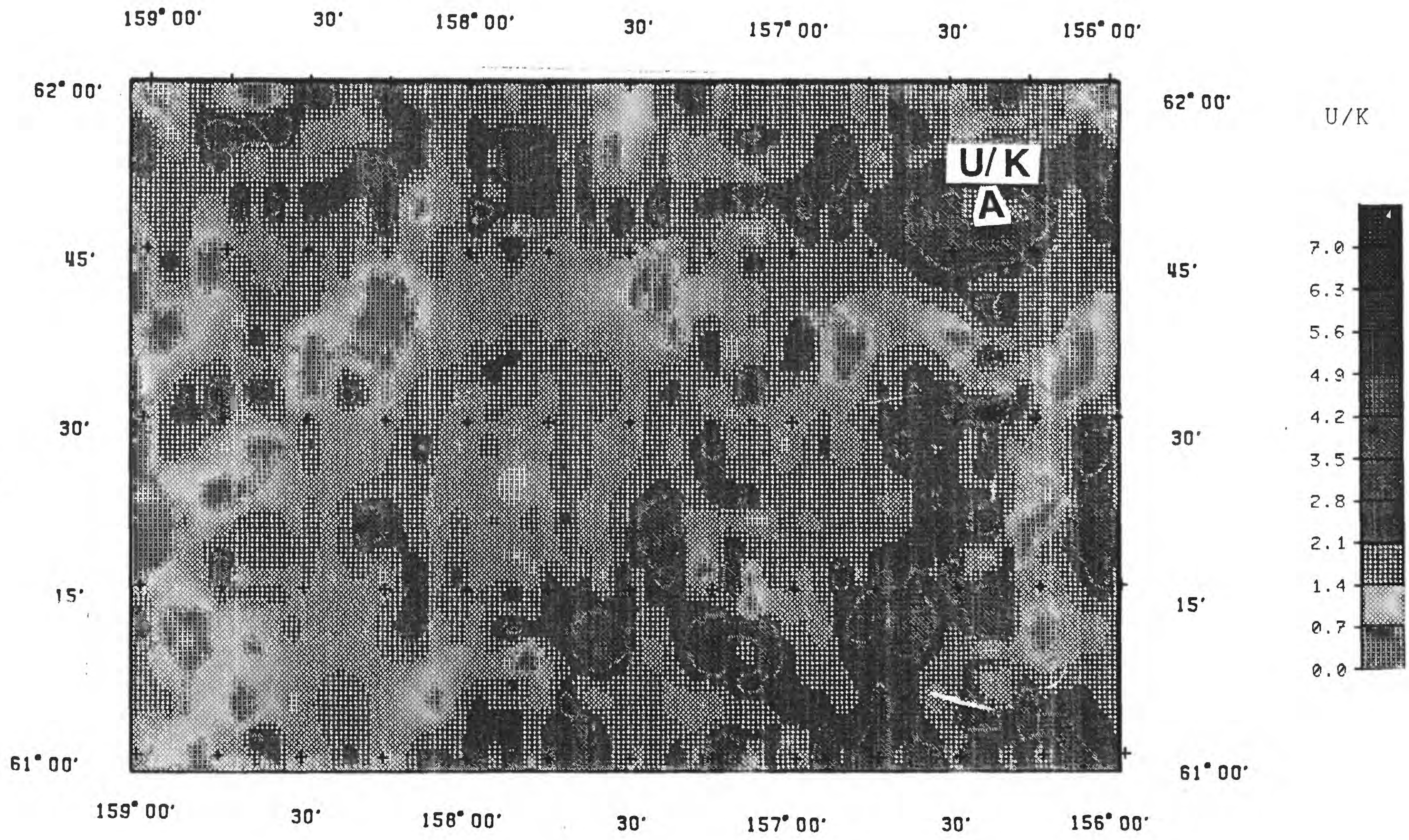

Figure 17. Uranium/potassium ratio, radiometric data, Sleetmute quadrangle.

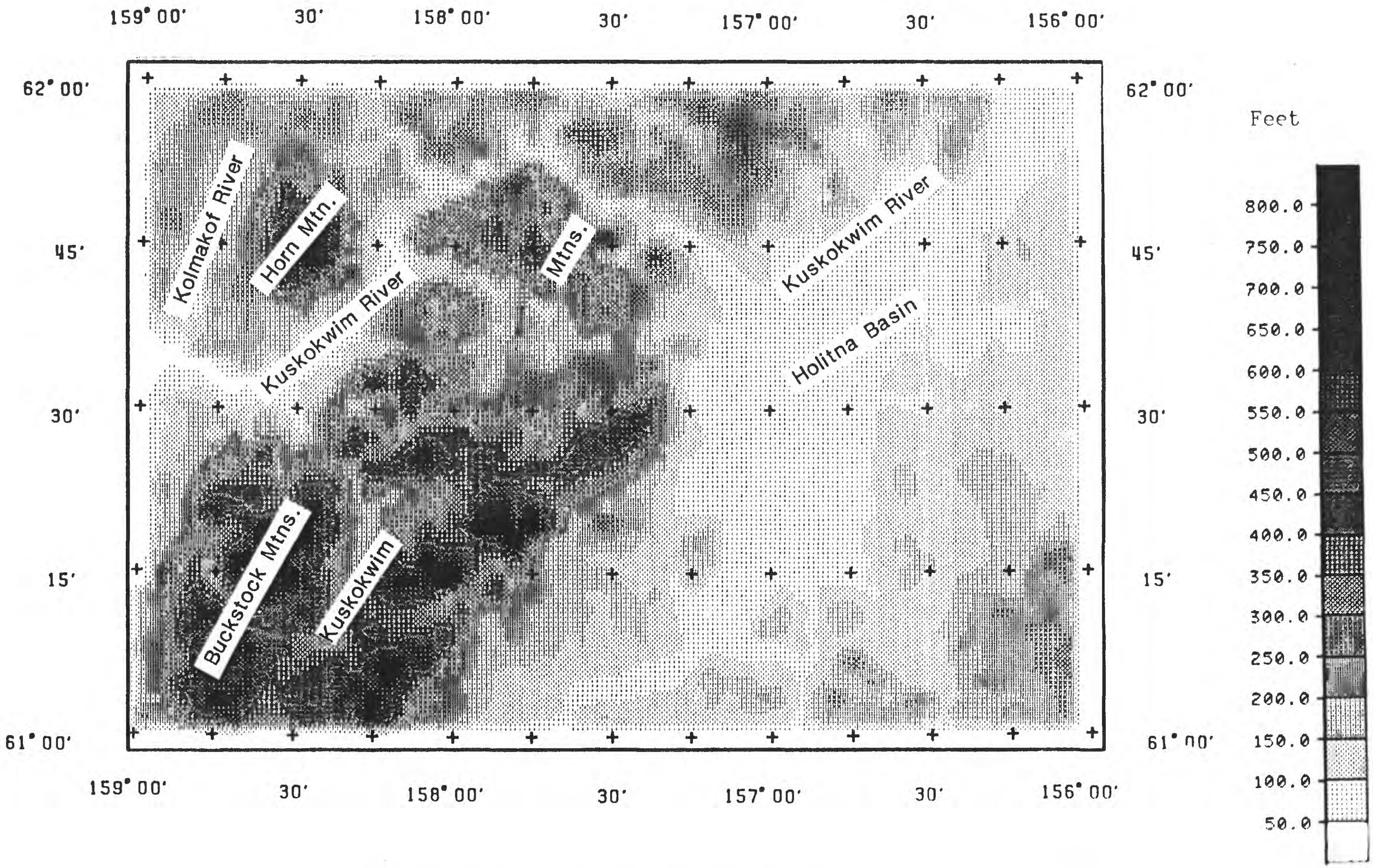

Figure 18. Shaded topographic map of the Sleetmute quadrangle. Elevation in feet.

CHAPTER 5. MINERAL RESOURCES

Polymetallic and nonmetallic mineral resources in the Sleetmute quadrangle have been described in Territorial, State, and Federal reports including those by Webber and others (1947), Cady and others (1955), Herreid (1962), Maloney (1962), Jasper (1963), Roedder (1963), and Sainsbury and MacKevett (1965) among many others. Additionally, Cobb (1972, 1976), Berg and Cobb (1967), Meyer (1985), and Bundtzen and others (1986) have compiled mineral deposit summaries. These compiled data are summarized in the appendix of this report.

MINING HISTORY

The Sleetmute quadrangle is geographically part of the Aniak mining district, which was defined by Ransome and Kerns (1954) as the area drained by the lower to middle Kuskokwim River from Bethel upstream to the village of Stony River. In the Sleetmute quadrangle this includes the George, Aniak, Holitna, Swift, Oskawalik, and Hoholitna Rivers. Recorded gold production from the Aniak district -- almost exclusively from placer sources -- is at least 235,000 oz[3] from 1911 to the present (Bundtzen and others, 1986). However, only three streams within the Sleetmute quadrangle have produced modest amounts of placer gold. New York Creek (plate 2, #30) and its tributary, Murray Gulch (plate 2, #29), were mined from 1911 to 1914 and more recently from 1979 to 1981. Total production for these two streams is estimated as 1,500 oz of placer gold (T.K. Bundtzen, unpub. records). Fortyseven Creek (plate 2, #41), was mined intermittently after its discovery in 1947, and has produced an estimated 2,500 oz of gold, mainly from the late 1970's (T.K. Bundtzen, unpub. records). Placer gold was also prospected and probably mined in small quantities from tributaries of the Kuskokwim River including Central, California, Eightmile, and Fuller Creeks (plate 2, #5, #7, #8, and #16, respectively).

The area around the village of Sleetmute is best known for past exploration, development, and production of lode mercury-antimony deposits. Cinnabar lodes were first discovered by Russian traders near the trading post at Kolmakof in 1838, but the Russians did not develop these mineral discoveries. Between 1909 and 1940, numerous lode deposits of cinnabar and stibnite were discovered in the Sleetmute quadrangle, mainly within a few kilometers (1 mi) of the Kuskokwim River. Total production of mercury from the Sleetmute quadrangle amounts to about 36,000 flasks or 89% of all the mercury mined in Alaska. The majority of this was produced from the Red Devil mine (plate 2, #22) between World War II and 1963. In addition, erratic production amounted to several hundred flasks[4] of mercury, which were retorted from high grade surface or near surface ores at the Willis, Alice and Bessie, and Barometer properties, (plate 2, #9, #10, and #19, respectively) prior to World War II.

The Red Devil mine was discovered by accident in 1933 when a 10 year old berry picker found pieces of high grade cinnabar rubble on a hillside overlooking the Kuskokwim River, about 10 km (6 mi) northwest of the village of Sleetmute (Herreid, 1962). It is noteworthy that although most cinnabar lode deposits in the area were successfully prospected using a gold pan (tracing placer cinnabar to its lode source), the streams draining the Red Devil lode system "didn't pan" according to prospector Hans Halverson (Herreid, 1962). The Red Devil mine was put into production during World War II when the liquid metal mercury was declared strategic, but

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3 All ounces are Troy ounces (31.1035 g)

4 One flask of mercury weighs 76 lbs

operations ceased in 1949 when the price sharply dropped. In 1953, the DeCourcy Mountain Mining Company[5] reopened the Red Devil mine, achieving full-scale production by 1956. In that year, an annual all time production high of 5,100 flasks was recovered from three Alaskan deposits (primarily from Red Devil). The Red Devil deposit was mined from five levels totalling 4,300 m (14,000 ft) of underground workings. Ground water seepage was a notable engineering problem in the mine and high capacity pumps were required to prevent flooding. When the pumps were shut down, the workings flooded within a matter of a few hours (Herreid, 1962). The mine was closed in 1963 when the majority of high grade ore shoots were exhausted. Total mercury production through that time was between 31,000 and 32,000 flasks won from 75,000 tons[6] of ore (Beckwith, 1965). In the late 1960's, the Red Devil mine was again opened largely due to high mercury prices caused by the Vietnam conflict. From 1969 to 1971, 3800 flasks were recovered. In this last mining phase, stibnite and cinnabar, concentrated by flotation, were shipped to Japan. The Red Devil mine was closed in 1972 and is currently flooded.

The Mountain Top cinnabar lode deposit (#34, plate 2 and appendix) was discovered in 1968 and small scale development has continued since that time. Several hundred tons of selected high grade ore has been retorted, mainly between 1981 and 1986; production is currently limited by the low price of mercury.

In addition to the historic production of mercury and gold in the Sleetmute quadrangle, two other commodities have been mined to a minor degree. First, modest amounts of placer scheelite have been concentrated and shipped from the Fortyseven Creek placer operation (plate 2, #41). Second, industrial minerals (mainly sand and gravel) have been extracted locally from Kuskokwim River channel lag deposits for construction use in the villages of Crooked Creek, Sleetmute, and Red Devil.

DESCRIPTION OF KNOWN AND POTENTIAL DEPOSIT MODELS

We have classified mineral deposits of the Sleetmute quadrangle into five specific models. Within the framework of these descriptive models we describe the essential characteristics of the deposits and offer speculations concerning exploration for new occurrences. In some cases we compare these models with those of Cox and Singer (1986), who presented worldwide examples, and those of Nokleberg and others (1987), who presented Alaskan examples.

RED DEVIL MERCURY-ANTIMONY DEPOSIT MODEL

A dozen mercury-antimony deposits, six of which have been exploited, are the best known mineral occurrences in the Sleetmute quadrangle. The largest of these is the Red Devil mine (plate 2, #22).

Geology

Host rocks for the Red Devil mine are micaceous lithic sandstone and siltstone of the Kuskokwim Group and mafic dikes that are generally altered to calcite, chalcedony, limonite, and sericite ("silica-carbonate" alteration of Cady and others, 1955). The deposits that compose the Red Devil mine occur on the southwest limb of a northwest-trending anticline. Bedding planes consistently strike N40-50° west and dip 35-60° southwest; altered mafic dikes strike

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5 Renamed Alaska Mines and Minerals, Inc. in 1959

6 Short tons (2,000 lbs) are used in this report

generally northeast and dip 40-65° southeast (Sainsbury and MacKevett, 1965). Mineralization occurs in about 20 plunging, chimney-like bodies located along intersections of at least two silica-carbonate altered dikes and a northwest-trending, high-angle wrench fault system (fig. 19). The exploited ore shoots range from a few centimeters to about 1 m (3 ft) in thickness and from less than 1 m (3 ft) to nearly 100 m (330 ft) in strike length. The northwest-trending zone of mineralization appears to be about 180 m (590 ft) wide and 450 m (1,500 ft) long; the zone may extend to the Barometer property (plate 2, # 19). Red Devil ore consists mainly of massive aggregates, encrustations, and breccia fillings of cinnabar, quartz, stibnite, and minor realgar and orpiment. Crystals of both cinnabar and stibnite are locally exceptionally well-formed and of "museum quality" (indeed, samples from Red Devil are displayed in institutions throughout the United States).

Herreid (1962) first described vertical mineral zonation at Red Devil. Near surface ore shoots are generally composed of quartz + cinnabar, but stibnite to cinnabar ratios increase with depth. On the fifth and deepest level, about 180 m (600 ft) below the surface, ore shoots mainly consist of stibnite + quartz and contain only a trace of cinnabar.

The importance of structural preparation to the mineralized zone is evident in the geometry of the ore shoots. The widest and most persistent ore bodies occur along the most competent dikes and sandstone lenses. The dikes clearly predate the mineralization, because cinnabar and stibnite have locally replaced dike rock. However, no absolute age control is available.

Some Red Devil ore was quite high grade and averaged as much as 30% mercury; however, other ore was more disseminated in nature. From 1942 to 1963, the Red Devil mine produced between 31,000 and 32,000 flasks of mercury from about 75,000 tons of ore indicating the average overall grade of the deposit was 1.55% mercury. Although no figures are available for antimony grade, it is considered to be roughly twice the mercury content, based on examination of various unpublished assay data and examination of mineralized rock samples.

Fluid inclusion data

Data from studies of fluid inclusions in transparent ore and gangue minerals from hydrothermal ore deposits can be used as evidence of the nature of the ore-forming fluid and the environment of ore deposition. Roedder (1984) has presented, in detail, the techniques and assumptions of this method.

Roedder (1963) discussed the results of heating and freezing runs on fluid inclusions in two quartz crystals from the Red Devil mine that contain both liquid(L) and vapor(V) CO_2. Photomicrographs of a typical microthermometric experiment of the Red Devil quartz crystals are presented in Roedder (1972, plate 5, fig. 1). The data are as follows:

Quartz crystal #1. L + V CO_2 homogenized to vapor at +22.8°C
Quartz crystal #2. L + V CO_2 homogenized to vapor at +26.15°C.

Microthermometric data obtained by H.E. Belkin from two-phase aqueous inclusions in both ore and gangue minerals from Red Devil are presented in table 2. The homogenization temperatures of the cinnabar-hosted inclusions typically range from 158°C to 164°C (with one at 192°C). The cinnabar-bearing, quartz-hosted fluid inclusions have homogenization temperatures that range from 169°C to 210°C, but average about 200°C. Freezing studies indicate a relatively uniform salinity of approximately 3.7 wt% NaCl equivalent for both quartz- and cinnabar-hosted inclusions.

Although the data set is limited, some inferences can be drawn concerning the environment of ore deposition at the Red Devil mine. Fluid inclusion studies typically provide the minimum temperature or pressure of trapping, but seldom both. Normally, the homogenization

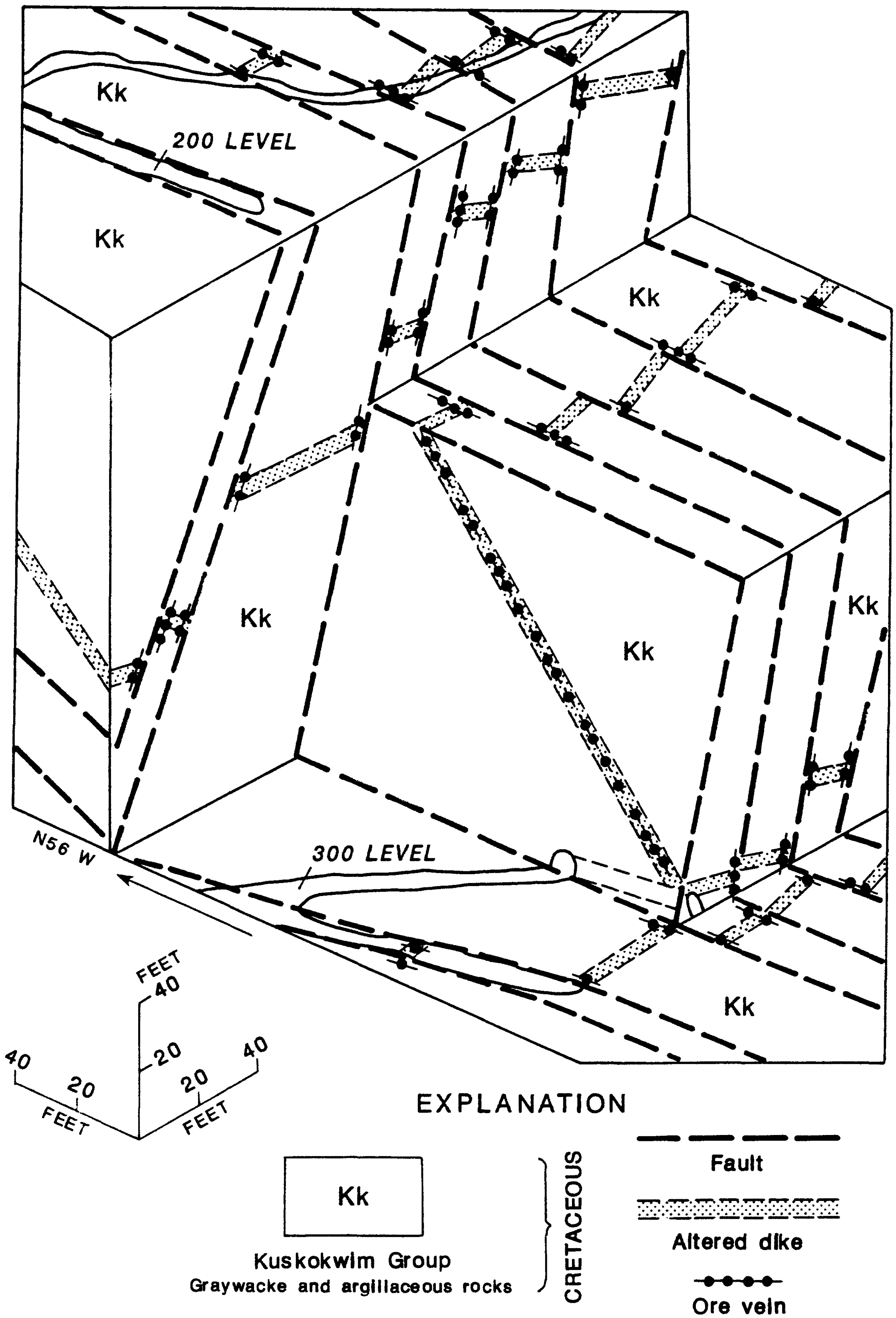


Figure 19. Generalized isometric block diagram of part of the Red Devil mine (from Sainsbury and MacKevett, 1965, fig. 3).

Table 2. Red Devil fluid inclusion data.*

Aqueous two-phase inclusions

Sample No.	Host	Type	Th	Tm	Wt% NaCl Equivalent
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	PS?	164	-2.2	3.7
71AGK801C	C	P	161	-2.2	3.7
71AGK801C	C	P	161	-2.2	3.7
71AGK808C	C	S?	nd	-2.1	3.5
71AGK810C	C	P	158	nd	nd
71AGK810C	C	P	192	nd	nd
71AGK803Q	Q	PS	200	-2.1	3.5
71AGK803Q	Q	PS	200	-2.1	3.5
71AGK803Q	Q	PS	200	-2.1	3.5
71AGK803Q	Q	PS	200	-2.1	3.5
71AGK804Q	Q	P	208	-2.3	3.9
71AGK804Q	Q	P	208	-2.3	3.9
71AGK804Q	Q	P	208	-2.3	3.9
71AGK804Q	Q	P	208	-2.3	3.9
71AGK804Q	Q	P	208	-2.3	3.9
71AGK804Q	Q	P	210	-2.3	3.9
USNM114797	Q	P	169	nd	nd

NOTES:
* = unpublished data, H.E. Belkin
C = cinnabar
Q = cinnabar-bearing quartz
P = primary inclusion
PS = pseudosecondary inclusion,
S = secondary inclusion
Th = homogenization temperature, Tm = final melting point of ice temperature (degrees centigrade)
nd = not determined

temperature is used to determine a characteristic isochore for the trapped fluid on a P-T diagram (Roedder and Bodnar, 1980). The pressure is usually determined by some independent method, and then the true temperature of trapping is obtained from the intersection of this pressure and the isochore. However, the presence of CO_2 inclusions and two phase aqueous inclusions (if we assume they are coeval) allows us to determine both the pressure and temperature at the time of inclusion trapping.

Assuming a CO_2 density of 0.23 to 0.25 g/cm^3 and a trapping temperature of 160°C to 200°C, a trapping pressure of approximately 150 to 200 bars is inferred. Moreover, if we assume that the inclusions were trapped in a water column, unrestricted from the water table to the depth of inclusion trapping, then the pressure indicates a depth of formation in the range of 1,500 m (about 5,000 ft). If the confining pressure was, in part, lithostatic then the depth of formation would be less than 1,500 m.

The limited data and the major assumptions involved with calculations highlight the need to conduct detailed fluid inclusion studies on the Red Devil deposit and related deposits in the Sleetmute quadrangle as an integral part of future investigations.

Stable isotope data

Stable isotope data have been obtained by R.J. Goldfarb for mineralized quartz, fluid inclusion water, and dickite samples collected from dump material at the Red Devil mine. Analyses from cinnabar-bearing quartz indicate $\delta^{18}O$ values of 24.4-26.4 per mil for the quartz, and δD values of -152 per mil for the associated fluid inclusion waters. Stibnite-bearing quartz exhibited $\delta^{18}O$ values of 26.6-27.4 per mil for the quartz, and δD values of -191 per mil for the associated fluid inclusion waters. Analysis of dickite from Red Devil yielded a δD value of -127 per mil.

The $\delta^{18}O$ values for Red Devil quartz samples are among the isotopically heaviest values for any mineralizing system within western North America. They are much heavier than the reported data for the epithermal and hot spring precious-metal deposits within the Basin and Range province of the western United States (Field and Fifarek, 1985). However, they are somewhat similar to the data reported for mercury- and antimony-bearing vein systems within the Canadian Cordillera (Nesbitt and others, 1987). Assuming quartz formation at 200°C (from the fluid inclusion data), and applying the fractionation factors for alpha quartz given in Friedman and O'Neil (1977), ore forming solutions would have been about 13 per mil lighter than the values seen in the quartz. Thus, ore solutions may have ranged from about 11-14 per mil, suggesting either fluids of a non-meteoric origin or extensive exchange between meteoric fluids and the Kuskokwim Group rocks. If the latter was correct, then an oxygen shift of approximately 35 per mil from the local meteoric water line would be required.

The amount of fractionation between quartz and water is inversely correlated with temperature. Hence, as temperature decreases (and the ore solutions undergo no other changes), the precipitated quartz will continue to become isotopically heavier. Thus, as noted by Nesbitt and others (1987) in the British Columbia systems, shallower and lower temperature mercury systems are typically a few per mil heavier in $\delta^{18}O$ than are antimony systems. Surprisingly though, this is not the case for the Red Devil system, where the heaviest fluids are from the reportedly deeper massive stibnite-bearing samples. Therefore, decreasing temperature could not be the major cause of the shift from an antimony-dominant zone to a shallower mercury-dominant zone.

Roedder (1963) reported the presence of an immiscible, CO_2-rich vapor phase within fluid inclusions in cinnabar-bearing quartz from Red Devil. It is therefore likely that the mercury was separated from the antimony within the ore fluids and was transported to higher levels within the vapor phase. According to W.J. Pickthorn (USGS, oral commun., 1988), cinnabar deposited from the vapor phase will be relatively pure, lacking significant concentrations of other metals such as antimony or arsenic. Analysis of cinnabar grains from Red Devil show no detectable amounts of any other metals besides mercury (S.J. Sutley, USGS, unpub. data, 1989).

Meteoric water from the Sleetmute quadrangle probably has a δD value of about -150 per mil (Taylor, 1979, fig. 6.3). Data reported in Bliss (1983) for three springs from the Tanana quadrangle, the closest reported data to the Kuskokwim region, indicate a range of -142 to -157 per mil for presumably unexchanged meteoric waters. The reason for the extremely light value of -191 per mil for δD from fluid inclusion waters in stibnite-bearing quartz at Red Devil is uncertain. However, the value of -152 per mil for the cinnabar-bearing quartz is believed to reflect a dominantly meteoric component to the released fluid inclusion waters. This value is still significantly lighter than that for the fluid that deposited the dickite. At 200°C, the kaolinite-water fractionation of about 20 per mil (Taylor, 1979, fig. 6.2) indicates that the dickite was precipitated from a fluid with a δD value of approximately -107 per mil.

The relatively light δD values for the fluid inclusion waters are believed to reflect the trapping of multiple generations of later, secondary fluid inclusions. Analysis of these waters, unrelated to the main period of quartz and metal deposition, may be of little value when trying to understand ore genesis (Pickthorn and others, 1987). However, the isotopic analysis of dickite, believed to be an ore-stage alteration phase (Sainsbury and MacKevett, 1960), does suggest that the ore solutions were distinctly heavier than meteoric waters of southwestern Alaska. The δD value of -107 per mil is still noticeably lighter than typical connate, metamorphic, and magmatic waters. Therefore, the presently limited isotopic data suggest some degree of mixing between meteoric solutions and deeper crustal fluids of an unknown origin.

The isotopic data, as well as the observed carbonate alteration at Red Devil, indicate ore fluids of a similar nature to those described by White and others (1973) for springs at Sulphur Bank, California. The latter are also enriched in ^{18}O and deuterium, relative to local meteoric water, and contain anomalous amounts of CO_2 and Hg. White and others (1973) concluded that the mercury-depositing system at Sulphur Bank reflected mixing of metamorphic fluids released from the dehydration of subducted Franciscan rocks with lesser amounts of meteoric fluids. These data are significantly distinct from that of the mercury-depositing springs in the Basin and Range province. For example, CO_2 concentrations are much lower and isotopic values are almost identical to those of local meteoric water for the well studied discharges at Steamboat Springs, Nevada.

In general, isotopically heavy mercury-antimony provinces are associated with convergent tectonic settings. The Red Devil and the other lodes in the Kuskokwim region were emplaced in a basin-fill sequence, but the tectonic setting and the mineralizing fluid source are uncertain. The limited isotopic data from the Red Devil deposit indicate that the mineralizing solutions involved mixing of meteoric water with a deeper crustal fluid. Our present knowledge is inadequate to determine whether this deep crustal fluid was magmatic, metamorphic, or connate water.

Comparable mercury deposits

Other mercury-stibnite deposits in the study area are geologically similar to the Red Devil system. At the Harvison, Willis, Alice and Bessie, Two Genevieves, Barometer, Vermillion, Kolmakof, and Mountain Top properties (plate 2, #3, #9, #10, #12, #19, #20, #27, and #34, respectively) cinnabar and minor stibnite mineralization is associated with shear zones in either competent silica-carbonate altered dikes or silicified sandstone. At the Fairview property (plate 2, #17), cinnabar-quartz veins form a thin stockwork in a rhyolite porphyry sill. At Mountain

Top (plate 2, #34), cinnabar and quartz are in highly competent hornfels(?) and altered silica carbonate (dike?) rock.

The common denominator in all the deposits is adequate structural preparation of competent host rocks to form fractures and shears capable of conducting ore solutions upward from deeper source terranes.

Genesis

The cinnabar-stibnite-bearing deposits of the Kuskokwim region are believed to represent occurrences formed in a hot springs to shallow epithermal environment. The fluid inclusion final homogenization temperatures from the Red Devil deposit suggest that much of the ore deposition occurred at temperatures of less than 200°C; the CO_2 densities indicate an immiscible mercury-rich vapor phase existed at near-surface depths. Stable isotope data show that at least a part of the hydrothermal fluid was non meteoric in origin. The mercury may have been leached from organic matter in the Kuskokwim Group sedimentary rocks that contained high background concentrations of the metal.

The Red Devil deposit type shows many similarities to other mercury-antimony-rich deposits within the western Cordillera. Such deposits include those of the California Coast Ranges (Barnes and others, 1973; White and others, 1973) and the Pinchi Mercury Belt of central British Columbia (Albino, 1988). Characteristically, they are anomalous in Hg, Sb, and As, but rarely show any base metal enrichments. Gold anomalies are rarely found within these shallowly-deposited ore systems. Silica-carbonate alteration of most host rocks reflects the relatively high CO_2 content of the ore fluids and the decreasing silica solubility with declining temperatures. Kaolinite (or dickite) is usually the stable aluminum silicate phase in the most altered wall rocks. Ore fluids of the Red Devil deposit type are significantly enriched in D and ^{18}O relative to local meteoric water. Spatial association with dikes of variable compositions reflects similar flow pathways for both the igneous melts and ore solutions, and(or) a preference for vein formation within the more brittle rocks along the permeable channels. The Red Devil deposit type, therefore, shows features common to both the hot-spring and silica-carbonate mercury deposit types (Rytuba, 1986a, b, respectively). These two separately classified deposit types may actually be genetically very similar, but with slight differences mainly in geological setting. It is interesting to compare the tonnage and grade of the Red Devil mine with other mercury mines. Between 1942 and 1963, the Red Devil mine yielded 75,000 tons of ore, which averaged about 1.55% mercury. Using the grade and tonnage model for hot-spring mercury (Rytuba, 1986c), which is based on deposits of the western United States, Red Devil falls into the upper 30th percentile in terms of tonnage, and the upper 5th percentile in grade. Using the silica-carbonate mercury model of Rytuba and Cargill (1986), Red Devil falls into the upper 40th percentile in terms of tonnage, and the upper 5th percentile in grade. In either case, at 1.55% mercury, Red Devil is considerably richer than mercury deposits mined elsewhere in the western United States.

As originally suggested by Lindgren (1933), shallow cinnabar-stibnite vein deposits may zone downward into higher temperature, precious-metal-rich parts of a single hydrothermal system. At both Endeavour Inlet, New Zealand (Pirajno, 1979) and Carbon Hill in the southern Yukon (Craig Hart, Aurum Geological Consultants, oral commun., 1989), stibnite-rich veins, similar to many within southwestern Alaska, zone downward into gold-rich veins. This occurs over a distance of about 300 m (980 ft) at the former deposit. The mercury-rich hot spring deposits at McLaughlin and Wilbur Springs in northern California also contain economic concentrations of gold (Nelson, 1988), suggesting in rare situations telescoping of the mercury- and gold-rich parts of these deposits. Thus, it is conceivable that many of the exposed mercury-antimony-bearing lodes in the Sleetmute quadrangle may define concealed gold-bearing veins.

ALKALIC EPITHERMAL GOLD-SILVER DEPOSIT MODEL

This deposit type has not specifically been recognized in the Sleetmute quadrangle. However, it has been documented in the Iditarod-Flat district to the north (Bundtzen and others, 1988b) and such deposits may exist within the volcano-plutonic complexes in the Sleetmute quadrangle.

Geology

Some Late Cretaceous-early Tertiary volcano-plutonic complexes host gold-silver-polymetallic ± scheelite deposits in the Iditarod-Flat district (Iditarod quadrangle), the Candle Hills area (McGrath quadrangle), and the Russian Mountains (Russian Mission quadrangle). In the Iditarod-Flat, Candle, and Russian Mountains areas, alkalic, highly differentiated monzonitic to quartz monzonitic stocks are hosts for joint-controlled and larger fault-controlled metal-bearing quartz veins. Veins in both structural settings contain a sulfide-scheelite-gold-quartz assemblage that is locally overprinted by a cinnabar + stibnite ± gold system. Anomalous tellurium, uranium, zirconium, cobalt, fluorine, and bismuth also occur in the mineral deposits and occurrences, but their paragenetic relationships are unclear. The mineralized zones in the Iditarod-Flat and Candle areas are the bedrock source for about 1.8 million ounces of placer gold mined in this area (Bundtzen and others, 1985).

In the Sleetmute quadrangle, volcano-plutonic complexes similar to those discussed above occur in the Horn, Kiokluk, and Chuilnuk Mountains. These are favorable target areas for the discovery of epithermal vein systems.

Comparable districts

The epithermal gold and silver deposits found within the Late Cretaceous-early Tertiary volcano-plutonic complexes of the Kuskokwim region are similar to other alkaline-to-subalkaline igneous rock-related gold districts described by Mutschler and others (1985) in the western United States. For example, the Zortman-Landusky deposit in central Montana is hosted in Tertiary calc-alkalic to alkalic intrusive rocks (Hastings, 1988). It consists of structurally-controlled epithermal bodies which form high-grade stockworks at depth and low-grade stockworks, breccias, and fractured zones near the surface. Mineralization consists primarily of native gold and silver associated with pyrite, arsenopyrite, and tellurides, in a gangue of quartz, kaolinite, calcite, and fluorite. Hydrothermal alteration, broadly classified as weakly argillic, is present adjacent to the ore bodies and consists of pyrite, kaolinite, silica, and potassium feldspar. Based on summaries by Giles (1983), Mutschler and others (1985), and Thompson and others (1985), alkalic-epithermal gold-silver deposits range in size from 500,000 to 50,000,000 tons and have grades ranging from 0.01 to 0.2 oz/ton gold and credits of other metals.

GOLD-TUNGSTEN-QUARTZ VEIN DEPOSIT MODEL

The quartz-scheelite-gold sheeted vein deposit at Fortyseven Creek (plate 2, #40) differs from the sulfide-gold-silver-bearing stockwork and fault-controlled systems discussed above in that intrusive stocks are not associated with the mineralization.

Geology

The Fortyseven Creek lode deposit is hosted in folded graywacke and siltstone of the Kuskokwim Group; the beds strike northeast and dip steeply either southeast or northwest, depending on fold axis orientation. No intrusive stocks crop out in the area of the deposit.

Altered hypabyssal rhyolite dikes are mapped within 1 km (0.6 mi) of the mineralization (Decker and others, 1984), but their relationship to the mineralization is not known.

The deposit is reported to consist of a silicified shear zone containing sheeted masses of quartz accompanied by arsenopyrite, stibnite, argentite, tellurides, scheelite, and wolframite, as well as minor to trace values of gold and silver (Cady and others, 1955). The lode strikes N45-55°E, can be traced for over 1,200 m (4,000 ft), and is as wide as 30 m (100 ft). The most heavily silicified part of the shear zone crops out near the ridgetop at the head of Fortyseven Creek. Placer gold and scheelite have been mined from stream and semi-residual placer deposits that are located immediately downstream and downslope from the zone of bedrock mineralization. Little else is known about the deposit and the age of mineralization is uncertain.

Comparable deposits and models

The Fortyseven Creek deposit is difficult to classify, perhaps in part because we know so little about it. In very general terms, it fits the "low-sulfide gold-quartz vein model" presented by Berger (1986) which includes deposits of the Mother Lode of California and the Chichagof district in Alaska. Deposits of this model are characterized by massive quartz veins concentrated in fault or shear zones in regionally metamorphosed volcanic and/or sedimentary rock. The veins contain native gold + pyrite + arsenopyrite + other sulfides, and locally tellurides ± scheelite. In addition to silicification, carbonate ± sericite alteration is found (Berger, 1986). The gold-scheelite-telluride veins at Fortyseven Creek occur in a silicified shear zone, and therefore generally fit the model. However, an essential characteristic of the low-sulfide gold-quartz vein model is the presence of regionally metamorphosed rocks. Nowhere does the Kuskokwim Group exhibit regional metamorphism, only local contact metamorphism.

The Fortyseven Creek deposit also shows some similarities to "simple antimony deposits" described by Bliss and Orris (1986). These deposits consist of veins and pods of stibnite + quartz ± pyrite ± calcite and minor arsenopyrite ± sphalerite ± tetrahedrite ± chalcopyrite ± scheelite ± free gold in faults and shear zones, generally in sedimentary rock. The Fortyseven Creek deposit differs in that stibnite is not the dominant sulfide and calcite is not reported as a vein constituent.

The Fortyseven Creek deposit also does not fit the alkalic epithermal gold-silver deposit model, mainly because it lacks exposed intrusive stocks. Since it does not fit any of the previously described models, we classify the Fortyseven Creek deposit under its own descriptive model of gold-tungsten-quartz vein type. However, given more information, it may prove to be associated with the alkalic epithermal gold-silver deposit model.

TIN-SILVER-BORON ENRICHED DEPOSIT MODEL

Poorly understood, boron-enriched mineralized systems are hosted by many of the Late Cretaceous-early Tertiary plutons associated with the volcano-plutonic complexes of the Kuskokwim region (Bundtzen and Gilbert, 1983; Miller and Bundtzen, 1987). Although no deposits of this type are known from Sleetmute quadrangle, the required host rocks are present.

Geology

These deposits are tin + silver ± copper systems that also contain anomalous bismuth, zinc, and lead in a quartz + tourmaline ± axinite ± fluorite gangue within shear zones, stockworks, and breccia pipes. They are most commonly located in cupola zones of monzonitic to quartz monzonitic stocks, but stockworks are also locally well developed in overlying and adjacent hornfels. Several examples of this type of mineralized occurrence are known in the Kuskokwim Mountains region. Four examples from Iditarod quadrangle include the Cirque and Tolstoi prospects of the Beaver Mountains (Bundtzen and Laird, 1982), and the Granite Mountain and VABM 2424 mountain occurrences (Miller and Bundtzen, 1987) of central Iditarod quadrangle. The Win-Won deposit in the Medfra quadrangle (Nokleberg and others, 1987) and the recently discovered Sleitat deposit in the Taylor Mountains quadrangle (Cominco Alaska, Inc., oral commun., 1989) also fit this model.

Comparable deposits

Tin-silver-boron deposits of the Kuskokwim Mountain region are not easily compared with other worldwide examples of tin deposits. Most tin-bearing, boron-enriched systems are associated with peraluminous silica-saturated granitic bodies or "S" type granites, whereas the monzonitic stocks in the Kuskokwim Mountains region are undersaturated and meta-aluminous. The Kuskokwim region deposits may be roughly analogous to "porphyry associated" tin-silver-copper deposits in Bolivia (Sillitoe and others, 1975), which are sometimes associated with undersaturated magmas and generally contrast with more classical tin granites described in Lindgren (1933) and Park and MacDiarmid (1975).

CARBONATE HOST DEPOSIT MODELS

Although no mines, prospects, or mineral occurrences are known from the Holitna Group of the Sleetmute quadrangle, these carbonate rocks are potential hosts for either Mississippi Valley type lead-zinc deposits or skarn and replacement deposits. Both types of deposits occur in similar rocks in the McGrath and Medfra quadrangles to the northeast. We emphasize that although the geology is permissive for these deposit types, their existence is only conjecture. A more realistic evaluation would require geochemical sampling and additional geological mapping.

Mississippi Valley type deposit model

This deposit type is characterized by galena and sphalerite carbonate replacement and vein deposits primarily in unmetamorphosed shallow-water carbonate host rocks. These strata-bound deposits most commonly occur in dolomite of diagenetic origin, but crinoidal limestone also served as host in the Tri-State district of Missouri (Brockie and others, 1968). Evidence indicates that low-temperature, saline, hydrothermal solutions, moving laterally out of an adjacent sedimentary basin, deposited the sulfides (Huchison, 1983). Depositional facies and structure are both major factors in ore control. Porous carbonate reef, tidal, and subtidal facies, and permeable solution-collapse structures are highly favorable hosts (Pratt, 1982; Briskey, 1986a, b). Examples of Mississippi Valley type (MVT) deposits occur in the central United States and Canada. These include (among many others), deposits in the upper Mississippi Valley base metal district (Heyl, 1968), southeast Missouri lead district (Snyder and Gerdemann, 1968), the Tri-State district (mentioned above), and the Pine Point district in the Northwest Territories (Macqueen, 1986). Developed MVT deposits range in size from about 1.6 to 1,600 million tons, and have grades of <1% - 16% zinc and <0.5% - 5% lead; some deposits contain high silver values also (Mosier and Briskey, 1986).

The shallow-water carbonate rocks of the Holitna Group are lithologically appropriate for MVT deposits, but without additional data, the potential for this mineralization in the Sleetmute quadrangle is considered to be low. Although evidence does not necessarily indicate a MVT deposit, Bundtzen and Nokleberg (1987) reported the occurrence of sphalerite and minor galena in carbonate rocks at Reef Ridge, about 200 km (125 mi) to the northeast in the Medfra quadrangle.

Skarn deposit models

Zinc-lead-silver, copper, and iron skarn deposits have all been reported from the Kuskokwim region. The zinc-lead-silver skarn deposits typically consist of sphalerite and lesser galena, accompanied in some cases by chalcopyrite or scheelite, in a calc-silicate gangue. The mineralization occurs as carbonate replacement near or somewhat distal to calc-alkaline plutonic rocks. Base-metal skarns at Bowser, Tin, and Sheep Creeks in the Farewell district of the McGrath quadrangle exemplify this type (Nokleberg and others, 1987). In the Tin Creek area, Szumigala (1987) described copper-zinc-lead-silver skarn and replacement bodies in Paleozoic carbonate and sedimentary rock overlain and intruded by Tertiary igneous rocks. Mineralizing fluids followed structural conduits, such as dikes or faults, to access and replace limestone located at great distances from known intrusive bodies. Using production statistics from 47 zinc-lead-silver skarn deposits throughout the world, Szumigala (1987) calculated that the 50th percentile, or average exploited deposit, was 2.1 million tons grading 0.079% copper, 5.8% zinc, 3.6% lead, and about 3 oz/ton silver.

The copper skarn deposit type is similar to the zinc-lead-silver skarn, but tends to occur closer to the intrusive source rock. The host rocks are typically carbonaceous sedimentary rocks intruded by felsic to intermediate plutons. Mineralization consists primarily of chalcopyrite, magnetite, bornite, ± molybdenite, accompanied by pyrite, arsenopyrite, or pyrrhotite, in a calc-silicate gangue. Gold may occur in oxidized or secondarily enriched zones. The prime example in this region of Alaska is the Nixon Fork mine located about 150 km (95 mi) northeast in the Medfra quadrangle, where chalcopyrite, pyrite, bornite, gold, and native bismuth occur in recrystallized Ordovician limestone. Gangue minerals are mainly diopside, garnet, plagioclase, epidote, and apatite. The skarn mineralization occurs in fractures and roof pendants overlying a 5-square-mile monzonitic pluton, near the Iditarod-Nixon Fork fault (Herreid, 1966). The skarn was mined intermittently between 1921-1960 and yielded 55,000 oz of gold and by-product copper (Herreid, 1966). Copper skarns also occur in the Farewell district (McGrath quadrangle), adjacent to small granodiorite stocks and sills (Bundtzen and others, 1982). Worldwide ore bodies of the copper skarn deposit type range in size from about 4,000 to 90,000,000 tons, but rarely have grades higher than 0.2 oz/ton gold (Jones and Menzie, 1986).

Intrusion-associated iron skarn deposits generally contain magnetite, hematite, and chalcopyrite in a calc-silicate gangue hosted in limestone-bearing sequences at or near intrusive rock contacts. The "Medfra" occurrence in the Medfra quadrangle consists of massive magnetite associated with minor chalcopyrite and sphalerite in epidote-garnet skarn hosted by an Ordovician shallow-water carbonate sequence (Bundtzen and Nokleberg, 1987). Computer modeling of data derived from a ground-level magnetometer survey yielded a volume estimate for the ore body of 11,600 m3 (Throckmorton and Patton, 1978). Using Throckmorton and Patton's (1978) estimate that the ore is between 10 and 60 volume percent magnetite, this calculates to a range of 6,600 to 40,000 tons of magnetite. Another example consists of a small magnetite-pyrite-chalcopyrite occurrence that crops out on Lone Mountain in the central McGrath quadrangle, adjacent to a small granite pluton (T.K. Bundtzen, unpub. data).

Because all three of the above skarn types occur in carbonate rocks correlated with the Holitna Group, we assume that skarns may also occur in the Sleetmute quadrangle. Interestingly, J.N. Platt (USGS, unpublished report, 1955) noted the occurrence of magnetite and garnet in the contact zone on the eastern side of the stock which is exposed in the southeast corner of the quadrangle (plate 1).

DESCRIPTION OF MINERAL TRACTS

Although detailed data of sufficient quality are not available for a complete mineral assessment, available data do allow a preliminary analysis. To aid in this resource assessment, we have divided the Sleetmute quadrangle into six tracts representing areas where one or more deposit types may occur (plate 3). Further work would add information that might modify these tracts and add others. In the case of Tracts #1, #2, #3, and #6, geologic information, including lithology, igneous rock chemistry, age, and structure, forms the basis for tract delineation. This is supplemented by 1) mine, prospect, and mineral occurrence information, 2) rock and stream sediment geochemistry, and in some cases, 3) geophysics. Of the remaining two tracts, #4 is defined primarily on the basis of geochemistry, and #5 is defined on geophysical information alone. Some of the tracts overlap, because they are roughly defined by deposit type.

The six mineral resource tracts are described and their locations justified in the following section. We have ranked the mineral tracts using a qualitative system employed by Taylor and others (1984). This system combines a high, moderate, or low mineral resource potential ranking with the level of certainty which is based on the amount of information (fig. 20).

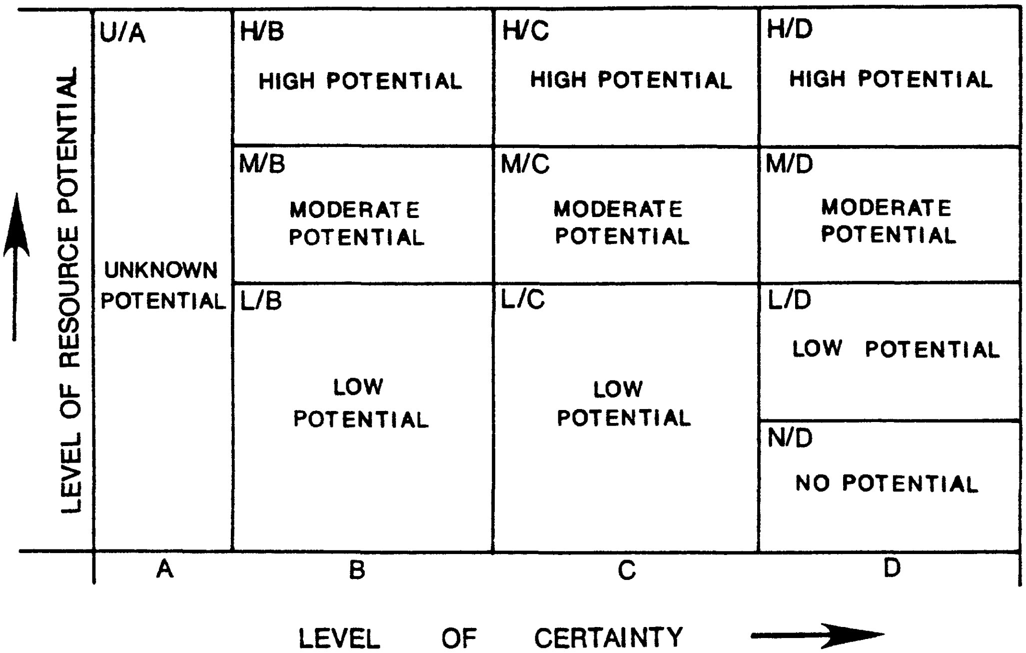
Building stone has not been included as a resource in our assessment. Bundtzen and others (1989) performed an evaluation of the sand, gravel, and aggregate resources along the Kuskokwim River between McGrath and Aniak. Only resources that actually lie along the river corridor would be considered economically viable, and in the Sleetmute quadrangle, Bundtzen and others (1989) recognized few potential sites. These would generally be limited to local use such as erosion control (riprap) and airport and road construction (aggregates, sand, and gravel).

TRACT 1

Tract 1 is the largest of the six tracts and encompasses over one half of the Sleetmute quadrangle. It delineates an area containing known and potential resources of mercury, antimony, and gold. Mercury deposits of the Red Devil type and placer gold occurrences are found within this tract. The host rocks are typically sandstone and shale of the Kuskokwim Group, as well as dikes and sills that cut the sedimentary rock.

Tract 1 is primarily defined by the occurrence of Kuskokwim Group sedimentary rock, but because rocks of the Gemuk Group could conceivably serve as host, they are also included. Tract 1 excludes rocks of the Holitna Group, because in our judgement the probability is low that they host Red Devil type mercury deposits. Although carbonate rocks host cinnabar mineralization at White Mountain (McGrath quadrangle), the mineralization is localized along an exposed portion of the Denali-Farewell fault zone. In the Sleetmute quadrangle, the Denali-Farewell fault bounds the Holitna Group on the northwest, but is buried under Quaternary deposits. Therefore we have limited Tract 1 to flyschoid sedimentary host rocks.

Overall, Tract 1 has a moderate to high potential, certainty level C (fig. 20), for the discovery of additional resources of mercury + antimony $\pm$ gold. Of the 42 known mineral localities indicated for Sleetmute quadrangle (plate 2), 33 help define Tract 1. Of these, 23 are mercury lode mines, prospects, or occurrences, 9 are placer gold prospects, and one is a lode occurrence of an unknown commodity, but probably mercury. Within Tract 1, seven subareas of greatest favorability are defined on the basis of lithology, structure, greater density of mineral occurrences, geochemical anomalies (where data is available), and geophysical data. The subareas, labeled 1a through 1g on plate 3, are described and individually ranked below.



DEFINITIONS OF MINERAL RESOURCE POTENTIAL

LOW mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment in which the existence of resources is unlikely.

MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence and where evidence indicates that mineral concentration has taken place.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

LEVELS OF CERTAINTY

A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information suggests the level of mineral resource potential.
C. Available information gives a good indication of the level of mineral resource potential.
D. Available information clearly defines the level of mineral resource potential.

Figure 20. The mineral resource potential/certainty classification system (after Taylor and others, 1984).

Subarea 1a is primarily underlain by Kuskokwim Group sedimentary rock intruded by sheets, dikes, and sills of hypabyssal peraluminous rhyolite (albite rhyolite of Cady and others, 1955), and by a small granitic body (plate 1). A cinnabar lode occurs on Juninggulra Mountain (#4, appendix and plate 2) and placer gold prospects occur on Crooked Creek (#1, appendix and plate 2). The subarea is an extension of the Snow Gulch placer gold district located approximately 5 mi (8 km) north in the Iditarod quadrangle. Subarea 1a has a moderate to high potential, certainty level B, for discovery of additional mercury and gold resources.

Subarea 1b is underlain by Kuskokwim Group sedimentary rock that is cut by dikes and sills of hypabyssal rhyolite and silica-carbonate altered dikes. Most of the mercury lode mines, prospects, and occurrences (17 total, including the Red Devil mine) and 3 placer gold prospects are located within this area, the boundary of which is further defined by extrapolation of structural and geophysical data. Although detailed data is not available, the broad structural style suggests that subarea 1b contains the nose of a regional northeast plunging anticline. The total count gamma ray radiometric data, which shows an arcuate-shaped high in the area west and northwest of Red Devil, also supports this inference (Chapter 4, this report). The structural environment around the nose of a plunging anticline would be favorable for up dip fluid movement and hence deposition of ore minerals. Subarea 1b has a high potential, certainty level D, for discovery of additional mercury-antimony resources.

Subarea 1c is underlain by Kuskokwim Group sedimentary rock cut by numerous, unmapped silica-carbonate altered dikes and sills (Cady and others, 1955). Because geochemical data is not available here, the only information (beyond favorable geology) to indicate this as a target area is the presence of one lode mercury mine (very small production), the Kolmakof property (#27, appendix and plate 2). Subarea 1c has a moderate potential, certainty level B, for discovery of additional mercury-antimony resources.

Subarea 1d is underlain by Kuskokwim Group sedimentary rocks and volcanic rocks of the Holokuk Basalt (plate 1). These units are cut by altered dikes and sills, and hypabyssal rhyolite dikes and sills; the Kuskokwim Group is also intruded by small granite bodies. One mercury lode mine (Mountain Top, #34, appendix and plate 2) and two lode occurrences are contained within this arcuate-shaped area. Stream sediment and pan concentrate anomalies of Hg, Sb, As, Ag, Au, Cr, and Mo, provide geochemical evidence that helps to outline the location of this subarea (fig. 8, areas #1, #2, #6, #7, and #8). Subarea 1d has a moderate to high potential, certainty level C, for discovery of additional mercury-antimony resources.

Subarea 1e is defined almost solely on the basis of favorable geology for mercury occurrences. There are no known mineral localities within this area, and only a minor amount of geochemical data is available. The bed rock is Kuskokwim Group sedimentary rock cut by numerous altered dikes, which suggests a favorable structural environment for mineralization. A few intermediate intrusive and hypabyssal rhyolite bodies are also present (plate 1). Some geochemical anomalies in altered dikes, stream sediment, and heavy-mineral-concentrate samples occur in the southern end of the subarea and consist of Hg, Sb, Ag, and Au (area #4, fig. 8). Subarea 1e has a moderate potential, certainty level B, for discovery of mercury-antimony resources.

Subarea 1f is roughly defined by Kuskokwim Group sedimentary rock intruded by en echelon sheets of hypabyssal rhyolite (plate 1). Although this target area contains only one known mineral occurrence (placer gold on Girl Creek, #36, appendix and plate 2), the lithologically and structurally favorable geology gives subarea 1f a moderate potential, certainty level C, for discovery of additional gold and mercury occurrences.

Subarea 1g is defined solely on the basis of geochemical anomalies of Hg + Sb + Ag in stream sediment and pan concentrate samples (area #13, fig. 8). The underlying bedrock is

Kuskokwim Group sandstone and shale; no dikes or other intrusive rocks are known. Subarea 1g has a moderate potential, certainty level B, for discovery of mercury-antimony resources.

TRACT 2

Tract 2 comprises two separate, but geologically similar areas centered around 1) the Horn Mountains, and 2) the combined Kiokluk-Chuilnuk Mountains, and is favorable for deposits of the alkalic epithermal gold-silver type or possibly the tin-silver-boron enriched type. Delineation of this tract is based primarily on geology, supported by geochemical and geophysical data. Tract 2 contains potential resources of gold, tungsten, and possibly tin and silver, related to intrusive rocks, volcanic rocks, and hornfels aureoles of the volcano-plutonic association and felsic (related?) dikes. A later overprint of mercury + antimony ± gold mineralization might also be present, as it is in the Iditarod-Flat district (Bundtzen and others, 1988b). Tract 2 has a moderate potential, certainty level C, for discovery of additional resources of gold, tungsten, and possibly tin, silver, mercury, and antimony.

The area centered around the Horn Mountains is underlain primarily by granitic to monzonitic plutons, basaltic to rhyolitic volcanic rocks, and hornfels of Kuskokwim Group sedimentary rocks. The area boundary extends southward where it also includes unmetamorphosed Kuskokwim Group intruded by dikes. One placer scheelite occurrence is located on the western flank of the Horn Mountains; three placer gold localities (a mine and two prospects) are located immediately south of the Horn Mountains, where Kuskokwim Group sedimentary rock is intruded by altered dikes and felsic dikes (Maddren, 1915). The boundary of Tract 2 in the Horn Mountain area is coincident with the outline of a geophysical anomaly (TCA, fig. 12) consisting of high total count gamma ray radiometric data, indicative of some sort of structural or lithologic control.

The second area in Tract 2 area is centered around the combined Kiokluk-Chuilnuk Mountains area, which is underlain by plutonic rocks, volcanic rocks, and hornfels sandstone of the volcano-plutonic association, and by unmetamorphosed Kuskokwim Group sedimentary rock. No mineral localities are known, but rock, stream sediment, and pan concentrate anomalies of Ag ± Au ± Sb ± Hg ± As ± Sn ± Cu ± Mo ± Pb ± Cr indicate mineral potential (areas #9, 11, and 12, fig. 8).

TRACT 3

Tract 3 consists of two small areas centered along the Denali-Farewell fault, that have characteristics similar to the gold-tungsten-quartz vein deposit type. The larger of the two areas is situated between the Boss Creek fault and the Denali-Farewell fault; the smaller area lies immediately south of the Denali-Farewell fault, near the Kulukbuk thrust fault. This tract is characterized by known and potential resources of gold + tungsten ± silver. Kuskokwim Group sedimentary rocks are the host and hypabyssal rhyolite dikes crop out within the larger of the two tract areas. This larger area contains the lode and placer deposits of Fortyseven Creek (#40 and #41, appendix and plate 2) and an unnamed occurrence (#39, appendix and plate 2), all of which lie along a major shear zone. Geochemical anomalies of Au + Ag + Sb + As ± Hg ± Mo ± Zn ± Cr are found in stream sediment, pan concentrate, and mineralized rock samples from this larger area (areas #13, #14, #15, and #16, fig. 8). The smaller area contains no known mineral localities, and is defined strictly on the basis of geochemical anomalies in As + Sb ± Au ± Mo (stream sediment, pan concentrate, and mineralized rock samples)(area #10, fig. 8). Tract 3 has a moderate potential, certainty level C, for discovery of additional resources of gold and tungsten.

TRACT 4

Tract 4 encompasses two very small areas defined exclusively by geochemical anomalies of As + Sb + Sn + W ± Au ± Ag ± Mo, which may be related to the tin-silver-boron enriched type mineralization model (note, samples were not analyzed for boron). In describing the tin-silver-boron enriched deposit type, we stated that the mineralization is most commonly located in cupola zones of monzonitic to quartz monzonitic stocks, but is also locally well developed in overlying and adjacent hornfels. The geology of Tract 4 is not entirely consistent with this geologic setting, but our data are so limited that we have relied on the geochemical anomalies alone to define the tract. The smaller, more western area is located on Holokuk Mountain, which is composed of hypabyssal peraluminous rhyolite (plate 1; Reifenstuhl and others, 1984). The mineralized area is delineated by rock, stream sediment, and pan concentrate anomalies of As + Sb + Sn + W ± Au (area #5, fig. 8), and may be associated with tourmalinized breccia described by Reifenstuhl and others (1984). The larger, more eastern area is also underlain by felsic igneous rock, but in this case it is rhyolite associated with the Holokuk Basalt (plate 1; Robinson and others, 1984). Stream sediment, pan concentrate, and mineralized rock samples anomalous in As + Sb + Mo + W ± Au ± Ag ± Sn, define this area (area #3, fig. 8). Tract 4 has a low potential, certainty level B, for discovery of tin and silver resources.

TRACT 5

Tract 5, defined exclusively by geophysical data, is possibly associated with the tin-silver-boron enriched or the alkalic epithermal gold-silver model. The tract is comprised of five areas in which the NURE aeromagnetic data indicate the possible existence of buried plutons. Three of these areas indicate the presence of reversely magnetized plutons; the other two areas are inferred to be associated with normally magnetized plutons (the normally and reversely magnetized plutons are probably of slightly different age). Although tenuous, the tract may contain polymetallic mineralization associated with the upper cupola region of a pluton, or its contact aureole. Tract 5 has an unknown potential, certainty level A, for deposits associated with buried plutons.

TRACT 6

Tract 6, comprising most of the area east-southeast of the Denali-Farewell fault, is defined only by the presence of potential host rock types. The carbonate and associated rocks of the Holitna Group may contain resources of lead, zinc, silver, copper, iron, or gold, but little data is available to adequately assess the potential for these commodities.

Carbonate rocks in Tract 6 are possible hosts for lead-zinc deposits of the Mississippi Valley type. Subarea 6a defines the outcrops of shallow-water platform facies, which potentially could be a particularly good prospect for MVT deposits. However, the occurrence of this type of mineralization is purely speculative since geochemical data is lacking for this part of the quadrangle. Tract 6a has a low potential, certainty level B, for the occurrence of MVT deposits.

Subarea 6b consists of two small areas in the southeast part of Sleetmute quadrangle that might possibly yield resources of zinc + lead + silver, copper ± gold, or iron. These two areas, underlain by carbonate rocks that are intruded by Tertiary granitic stocks (plate 1), may contain skarn and replacement mineralization. No supportive geochemical data is available, but similar deposits are known from neighboring quadrangles. Tract 6b has a moderate potential, certainty level B, for the occurrence of skarn mineralization.

SUMMARY

In the previous section we defined specific tracts or areas within Sleetmute quadrangle where certain deposit types might be expected to occur. No attempt has been made to rank these tracts by high, moderate, or low potential. Instead, the tracts define geologic terranes that are favorable for the occurrence of certain deposit types. Because mineral deposits usually occur in clusters, districts with known mines and prospects can be expected to have a high potential for additional deposits. However, a tract or area that lacks reported mineral occurrences should not automatically be ranked as low in potential; it may simply be poorly known.

CHAPTER 6. RECOMMENDATIONS FOR ADDITIONAL DATA ACQUISITION

Conclusions drawn in this report are based solely on existing data and are therefore somewhat limited in scope. Acquisition of more detailed geologic, geophysical, and geochemical data is required in order to more completely and accurately assess the resource potential of this relatively mineral-rich quadrangle. The geology of 91% of the Sleetmute quadrangle is known only at a reconnaissance scale; the remaining 9% has been mapped and compiled at a scale of 1:40,000. A reasonably complete mineral resource assessment will require additional mapping at a scale of 1:63,360, and compilation at 1:250,000. Due to the extensive quaternary and vegetative cover, detailed aeromagnetic and perhaps aeroradiometric surveys might be particularly useful in this quadrangle. Such geophysical surveys conducted under the NURE program, and evaluated during this pre-field study, suggest the potential for identifying several concealed plutons in the quadrangle. There may be a close genetic, and thus spatial, relationship between certain mineral occurrences and igneous rocks. High resolution geophysical data will therefore greatly aid in fully evaluating the mineral resource potential of the Sleetmute quadrangle. Finally, a regional geochemical survey is a necessity for accurate delineation of favorable mineral tracts.

Although the focus of new field work might be to define resource areas, numerous topical problems could also be addressed. These topical studies can provide additional understanding of the geology of the Sleetmute quadrangle and thus further aid in understanding where to look for specific types of deposits. We suggest the following topics would be worthwhile to pursue.

- detailed study of the Red Devil type mercury-antimony deposits, definition of their geochemical signature, and determination of whether the deposits are associated with gold mineralization at greater depth
- isotopic characterization of the Red Devil type mineralization
- determination of whether standard USGS spectrographic techniques are sufficiently sensitive or whether more accurate AA or ICP methods should be employed for routine chemical analyses for gold and mercury
- determining the validity of collecting stream sediment, organic material, or water samples in low, swampy terrain for use in mineral assessment
- definition of the regional distribution of naturally occurring mercury, a toxic substance, in the local surface waters
- definition of depositional facies within the Holitna Group, a Paleozoic carbonate sequence
- determination of depositional environments for both the Cretaceous basin-fill flysch sequence and for the Triassic and Early Cretaceous accretionary volcanic-arc complex
- comparative study of the three volcano-plutonic complexes exposed in the quadrangle
- geophysical expression and characterization of the Farewell terrane boundary
- location by geophysical definition of buried plutons

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APPENDIX

DESCRIPTIONS OF MINES, PROSPECTS, AND OCCURRENCES OF THE SLEETMUTE QUADRANGLE

NOTES TO ACCOMPANY APPENDIX:

Map number - refers to plate 2

Type - placer or lode:
- mine - has recorded production
- prospect - property evaluated, but no recorded production
- occurrence - mineralization reported or geochemical anomalies present

Production - mercury in flasks (1 flask = 76 lbs); gold in troy ounces

Abbreviations used: USGS - U.S. Geological Survey; USBM - U.S. Bureau of Mines; ADGGS - Alaska Division of Geological and Geophysical Surveys; DMEA - Defense Minerals Exploration Administration

Map number: 1 Type: Placer, prospect
Name: Crooked Creek

Location: Iditarod A-5 to Sleetmute D-7 and small part of D-8

Ore minerals: Gold

Production: None from the portion of Crooked Creek that lies within the Sleetmute quadrangle. Production from Quartz, Snow, and Ruby Gulches (which drain into Crooked Creek about 5 mi north of the quadrangle boundary) totaled over 2,100 oz between 1910-1914

Description: The main mineralization along Crooked Creek is in the Snow Gulch area, 5 mi north of the Sleetmute quadrangle boundary. However, Maddren (1915) reported that gold prospects were located as far south as Crevice Creek which lies in Sleetmute quadrangle. Bedrock in the Snow Gulch area consists of Kuskokwim Group sedimentary rock that is intruded by hypabyssal rhyolite porphyry dikes and plugs; gold mineralization in that area is probably related to these felsic bodies.

History: Placer gold was discovered in the Snow Gulch area in 1909 and between 1910 and 1914 the surrounding area was prospected.

References: Cobb, 1972
Cobb, 1976, p. 22
Maddren, 1915, p. 351-353

Map number: 2 Type: Lode, occurrence(?)

Name: Unnamed

Location: D-5

Ore minerals: Unknown

Production: None

Description: Unknown. Although a claim was staked, we have listed the locality as an occurrence, because no additional data is available.

History: Meyer (1985) reported that R and H Mining Company staked the property in 1968.

References: Meyer, 1985, map #40, p. 190

Map number: 3 Type: Lode, prospect
Name: Harvison

Location: D-5

Ore minerals: Cinnabar

Production: None reported, however, Jasper (1963) estimated that the 5 to 6 tons of sorted and stockpiled high grade ore would run 10% to 15% mercury

Description: Jasper (1963) described slightly silicified dark brown argillaceous sandstone cut by weathered and oxidized dike or sill. Cinnabar occurs as void fillings 2-4 inches in size, and as thin fracture filling veinlets in a fault breccia. Jasper (1963) reported the one breccia zone to be 2-3 ft in width. Berg and Cobb (1967) also discussed the property, but added no additional information.

History: John Harvison discovered the property in about 1963 by panning soil samples. By 9/15/63, his development work consisted of a trench with a 3-1/2 ft winze.

References: Berg and Cobb, 1967, p. 92
Cobb, 1972
Cobb, 1976, p. 31
Jasper, 1963

Map number: 4 Type: Lode, prospect
Name: Rhyolite

Location: D-7, Juninggulra Mt. Locality is incorrectly shown by Cobb (1972), perhaps because the airstrip location is incorrect on the Sleetmute quadrangle topographic map

Ore minerals: Cinnabar, stibnite

Production: None reported

Description: Graywacke and shale of the Kuskokwim Group are cut by complexly oriented dikes, sills, and a large rhyolite porphyry body which forms Juninggulra Mountain. Sainsbury and MacKevett (1965) divided the intrusive rocks into three types as follows: 1) most common are altered quartz diabase, trachyte, or lamprophyre that show faint relict pilotaxitic texture and specks and blebs of pyrite; 2) other dikes similar to above, but having an amgdaloidal texture (these seem to cut the first); and 3) youngest intrusive rocks are rhyolite porphyry, probably offshoots of the large body (these contain quartz and zoned plagioclase phenocrysts). All dikes are older than the Hg mineralization and show alteration to clay, carbonate, quartz, and limonite. Cinnabar occurs along small veinlets in fractured dike rock and graywacke, and also as disseminations in the altered dikes (Sainsbury and MacKevett, 1965). Berg and Cobb (1967) reported cinnabar in altered basaltic dikes and along contacts with sedimentary rock.

History: Maloney (1962) reported discovery in 1956, trenching in 1957, and USBM trenching 1958-59. Bruce Hickok of the Calista Native Corporation (personal commun., 1988) reported property selected by Calista. Since 1971, Henry Waterford has submitted yearly paperwork on the property.

References:
Berg and Cobb, 1967, p. 92
Cobb, 1972
Cobb, 1976, p. 51-52
Maloney, 1962
Sainsbury and MacKevett, 1965, p. 46-49

Map number: 5 Type: Placer, prospect(?)
Name: Central Creek

Location: D-6, but no information is available regarding the exact location along the creek

Ore minerals: Gold

Production: None reported

Description: Only information is from Cady and others (1955) who stated that during the course of their studies they saw evidence or heard reports of placer gold prospecting along this creek (and seven other creeks in the general area). Bedrock is Kuskokwim Group sedimentary rock; no dikes are shown on the Cady and others (1955, plate 1) geologic map.

History: Cady and others (1955) stated they either saw evidence or heard that this creek had been prospected, probably prior to 1951.

References: Cady and others, 1955, p. 120
Cobb, 1972
Cobb, 1976, p. 20

Map number: 6 Type: Lode, prospect
Name: Egnaty Creek

Location: D-5, south side of Kuskokwim River

Ore minerals: Cinnabar

Production: None reported

Description: Bedrock is sandstone and minor shale of the Kuskokwim Group; no igneous rocks reported. Selected USBM samples of bedrock assayed almost 1% Hg. Fine-grained cinnabar was found in about 100 of about 350 auger holes, and in some of the drill core (Maloney, 1968). Maloney (1968) did not mention the presence of either veins or quartz.

History: First staked by John Murphy and George Willis in 1966 (Meyer, 1985). USBM carried out an exploration program in 1966-67 which consisted of auger sampling material above bedrock, bulldozer trenching, diamond drilling, and soil sampling.

References:
Cobb, 1972
Cobb, 1976, p. 23
Maloney, 1968
Meyer, 1985, map #41, p. 191

Map number: 7 Type: Placer, prospect(?)
Name: California Creek

Location: D-5, but no information is available regarding the exact location along the creek

Ore minerals: Gold

Production: None reported

Description: Cady and others (1955) reported that a little placer gold was found on California Creek. Rhyolite dikes cut Kuskokwim Group sedimentary rocks in the vicinity of California Creek, and Cady and others (1955) speculated that these E-NE striking dikes probably trend across the headwaters of the creek. These workers apparently saw evidence of prospecting on this creek during the course of their field work.

History: Cady and others (1955) stated that a little placer gold was found on this creek; activity was probably prior to 1951.

References: Cady and others, 1955, p. 69 and p. 120
Cobb, 1972
Cobb, 1976, p. 19

Map number: 8 Type: Placer, prospect(?)
Name: Eightmile Creek

Location: D-5, but no information is available regarding the exact location along the creek

Ore minerals: Gold

Production: None reported

Description: Only information is from Cady and others (1955) who stated that during the course of their studies they saw evidence or heard reports of placer gold prospecting along this creek (and seven other creeks in the general area). Bedrock is Kuskokwim Group sedimentary rock; at least one rhyolite dike or sill cuts a ridge drained by the most eastern fork of this creek.

History: Cady and others (1955) stated they either saw evidence or heard that this creek had been prospected, probably prior to 1951.

References: Cady and others, 1955, p. 120
Cobb, 1972
Cobb, 1976, p. 24

Map number: 9 Type: Lode, mine (small production)
Name: Willis

Location: D-4, north side of Kuskokwim River

Ore minerals: Cinnabar, stibnite

Production: Total = a few flasks of mercury. Several references state that a few flasks of Hg were produced by Oswald Willis in a homemade retort; Cady and others (1955) stated production took place during World War I (1914-18)

Description: Mineralization is hosted in interbedded graywacke and shale of the Kuskokwim Group intruded by altered dikes and sills (Cady and others, 1955; Sainsbury and MacKevett, 1965). Sainsbury and MacKevett (1965) reported that ore formed principally in veins (up to 6 inches wide) along fractures where bedding plane faults intersect igneous rocks; cinnabar also is disseminated locally in fractures in dikes and nearby sedimentary rocks, or in argillized rock at contacts between intrusive and graywacke. Cinnabar and stibnite are intimately intergrown in many of the veins, but in others, cinnabar is the only sulfide mineral. Minor pyrite, hematite, and a little stibiconite(?) are also found. Gangue minerals consist of quartz, carbonate, limonite, and dickite (Sainsbury and MacKevett, 1965). Jasper (1961) suggested that results from stripping in 1953-54 were encouraging for possible development of a substantial large tonnage, low grade operation.

History: Property staked in 1909 by Oswald Willis and Jack Fuller (Cady and others, 1955); in 1943 it passed to nephew George Willis; in about 1957 property was optioned by Alaska Mines and Minerals Co. (Jasper, 1961). Development primarily limited to pits, trenches, and a few short adits. USBM conducted trenching and sampling in 1943. After extensive dozer stripping by George Willis in 1953-54, Jasper (1961) reported results were encouraging for possible development of a substantial large tonnage, low grade operation.

References:
Cady and others, 1955, p. 111
Cobb, 1972
Cobb, 1976, p. 56-57
Jasper, 1961, p. 70-72
Sainsbury and MacKevett, 1965, p. 15-18
Webber and others, 1947, p. 28-29

Map number: 10 Type: Lode, mine

Name: Alice & Bessie (claim group) formerly known as Parks prospect or property

Location: D-4, north side of Kuskokwim River. Cobb (1972) gave the same locality number to the Alice and Bessie and the nearby Ammeline prospect (#11, herein)

Ore minerals: Cinnabar, stibnite, native mercury

Production: Total = 175 flasks of mercury by end of 1961 (Malone, 1965). Of this, 130 flasks were produced by 1959 (Malone, 1962), 120 flasks by 1923 (Webber and others, 1947), and 700 lbs (a little more than 9 flasks) from 1906-14 (Smith, 1917)

Description: Sandstone and shale of the Kuskokwim Group cut by sills and dikes many of which have been hydrothermally altered (Smith, 1938; Webber and others, 1947; Cady and others, 1955; Sainsbury and MacKevett, 1965). Dikes/sills altered to mixture of quartz, carbonate minerals, clay (including dickite), and limonite. Mineralized veins and veinlets (up to 1 ft thick and 50 ft long) are spatially associated with intrusive and adjacent rocks. Mineralization, localized in fractures and along bedding-plane faults, consists of cinnabar, lesser stibnite, and minor pyrite in a gangue of quartz, carbonate, and clay (Sainsbury and MacKevett, 1965). Smith (1917) stated that the pyrite appears to be of a different age. He also observed that Parks Creek cuts ore-bearing rock and that native Hg can be found in the unconsolidated material.

History: Property was staked in 1906 by E.W. Parks, who from 1906-23 produced 120 flasks of mercury which he sold to placer miners in the Flat and Georgetown areas. In addition to trenches and other surface excavations, Parks had driven a crosscut adit for about 200 ft. In 1936, following Parks' death, W.E. Dunkle leased the property and extended the adit to 525 ft, adding a 240 ft drift; he dropped the lease in 1937 (Webber and others, 1947). USBM performed trenching and sampling in 1942. In 1954 the claims were acquired by George Willis and Robert F. Lyman who from 1955-56 performed exploratory work, but optioned the property to Cordero Mining Co. in late 1956. This company drilled in 1957; USBM visited property in July, 1957 (Jasper, 1961).

References:
Cady and others, 1955, p. 109-110
Cobb, 1972
Cobb, 1976, p. 13-15
Jasper, 1961, p. 69-70
Malone, 1962, p. 34-36
Malone, 1965, p. 41-42
Sainsbury and MacKevett, 1965, p. 11-15
Smith, 1917, p. 139-144
Smith, 1938, p. 97
Webber and others, 1947, p. 19-23

Map number: 11 Type: Lode, prospect
Name: Ammeline

Location: D-4, north of Kuskokwim River, north of Alice and Bessie mine, east along Parks Creek

Ore minerals: Cinnabar, and perhaps some stibnite

Production: None reported

Description: Hypabyssal albite rhyolite intrudes Kuskokwim Group sedimentary rocks. Cinnabar occurs in quartz veins filling fractures in the rhyolite. Cady and others (1955) stated on p. 70 of their report that vein composition is quartz-stibnite-cinnabar, however, on p. 111, they mention cinnabar only.

History: Unknown except that W.M. Cady of the USGS probably visited the property in 1944. Sainsbury and MacKevett (1965) did not visit the locale, but referred to Cady and others (1955).

References: Cady and others, 1955, p. 70 and p. 111
Cobb, 1972
Cobb, 1976, p. 16
Sainsbury and MacKevett, 1965, p. 20

Map number: 12 Type: Lode, occurrence

Name: Two Genevieves

Location: D-4, west of Cribby Creek, but not well located. Only location is from plate 3 of Cady and others (1955) which does not have modern topography

Ore minerals: Cinnabar

Production: None

Description: Property briefly discussed by Cady and others (1955). Country rocks are typical Kuskokwim Group, probably interbedded sandstone and shale. Cinnabar is localized in vugs and also in a breccia zone at the upper border of an altered sill that Cady and others (1955) call "silica-carbonate" rock. On p. 65 of this report, Cady and others mentioned the presence of graphite fragments in altered "basalt", stating that this is probably only of local significance. Sainsbury and MacKevett (1965) did not visit the property but utilized the description of Cady and others (1955).

History: Unknown

References:

Cady and others, 1955, p. 65 and p. 111
Cobb, 1972
Cobb, 1976, p. 54
Sainsbury and MacKevett, 1961,, p. 20

Map number: 13 Type: Lode, occurrence(?)

Name: Number 1 Discovery Claim

Location: D-4

Ore minerals: Probably cinnabar

Production: None

Description: Unknown. Although a claim was staked, we have listed the locality as an occurrence, because the claim was later abandoned.

History: Claim staked by Carl R. Henery in 1970; Thomas L. Roehmer was listed as the owner in 1978. The Henery claim was closed in 1983 (Meyer, 1985).

References: Meyer, 1985, map #30, p. 175

Map number: 14 Type: Placer, occurrence
Name: Unnamed

Location: C-7, location is very approximate; Cady and others (1955) reported it at the western foot of the Horn Mountains

Ore minerals: Scheelite

Production: None reported

Description: Only first hand reference to this locality is by Cady and others (1955) who stated that Harry Brink of Aniak reported placer scheelite to occur near the west foot of the Horn Mountains. The Horn Mountains form a volcano-plutonic complex, cored by monzonite and rimmed by volcanic rocks.

History: Unknown

References: Cady and others, 1955, p. 121
Cobb, 1972
Cobb, 1976, p. 33

Map number: 15 Type: Lode, prospect
Name: Cinnabar Chief

Location: D-4

Ore minerals: Cinnabar

Production: None reported

Description: Bedrock is Kuskokwim Group sedimentary rock; no dikes mapped at locality.

History: Meyer (1985) reported that G.C. Bettles of the Kuskokwim Mercury Co. prospected this property in 1926, but economic amounts of ore were not found.

References: Meyer, 1985, map #36, p. 186
Cobb, 1976, OF 76-606, p. 21

Map number: 16 Type: Placer, prospect(?)
Name: Fuller Creek

Location: C-4 to D-4, but no information is available regarding the exact location along this creek

Ore minerals: Gold

Production: None reported

Description: Only information is from Cady and others (1955) who stated that during the course of their studies they saw evidence or heard reports of placer gold prospecting along this creek (and seven other creeks in the general area). Bedrock is Kuskokwim Group sedimentary rock cut by large hypabyssal rhyolite bodies that crop out in the ridges drained by this creek.

History: Cady and others (1955) stated they either saw evidence or heard that this creek had been prospected, probably prior to 1951.

References: Cady and others, 1955, p. 120
Cobb, 1972
Cobb, 1976, p. 27

Map number: 17 Type: Lode, prospect
Name: Fairview

Location: D-4, south side of Kuskokwim River

Ore minerals: Cinnabar, stibnite

Production: None reported; Webber and others (1947) stated there was no production of any consequence

Description: Occurrence unusual because it is one of the few places in the area where mercury mineralization is found in association with hypabyssal albite rhyolite. A porphyritic albite rhyolite sill cuts interbedded sandstone and shale of the Kuskokwim Group. Webber and others (1947) reported the dike to be 120 ft wide and about 1000 ft long, striking N60W, dipping steeply NE (SW according to Cady and others, 1955). Veins of quartz, cinnabar, and stibnite occur in fractures in the central part of the sill which is about 120 ft thick (Cady and others, 1955). USBM trenched and sampled the property in 1943. One of their 29 samples ran 8 lbs of Hg per ton, but most averaged 1-2 lbs/ton (Webber and others, 1947).

History: Property was discovered by tracing detrital material to its source. It was first staked in 1935 or 1936 (Webber and others, 1947). USBM trenched the property in 1943, but by 1959 the trenches were sloughed and partly filled, so Sainsbury and MacKevett (1965) did not examine it.

References: Cady and others, 1955, p. 111
Cobb, 1972
Cobb, 1976, p. 25
Sainsbury and MacKevett, 1965, p. 19-20
Webber and others, 1947, p. 27-28

Map number: 18 Type: Lode, prospect(?)
Name: Unnamed

Location: D-4, SW of head of small creek that flows past Barometer mine

Ore minerals: Cinnabar, stibnite

Production: None reported

Description: Very little information. As elsewhere in this area, the country rocks are sandstone and shale of the Kuskokwim Group. Cady and others (1955) stated the prospect was reported to show cinnabar and stibnite. W.M. Cady of the USGS visited the mercury prospects of this area in 1944. No further work was done; Sainsbury and MacKevett (1965) repeated Cady and others (1955) observations for completeness.

History: Unknown

References:
Cady and others, 1955, p. 111
Cobb, 1972
Cobb, 1976, p. 58
Sainsbury and MacKevett, 1965, p. 21

Map number: 19 Type: Lode, mine
Name: Barometer

Location: D-4, south of Kuskokwim River

Ore minerals: Cinnabar, stibnite, realgar, orpiment(?) (only Webber and others, 1947, reported the last mineral)

Production: Total = 14 or 16 flasks of mercury. Webber and others (1947) stated 10 flasks were produced in 1938; Malone (1962) stated only 8 flasks came from 25 tons or ore. In 1940, 6 more flasks were produced in connection with assessment work (Cady and others, 1955)

Description: Cady and others (1955) reported the deposit is in a shaley zone of the Kuskokwim Group, but Sainsbury and MacKevett (1965) did not emphasize this. Sedimentary rocks are cut by altered dikes. The ore is apparently irregularly distributed along bedding joints and in openings along fault and fracture zones, and may be localized by intersections of dikes and bedding-plane faults (Cady and others, 1955; Sainsbury and MacKevett, 1965). Cinnabar is commonly associated with stibnite and realgar in a quartz-rich gangue near areas of what Cady and others (1955) termed "silica-carbonate" alteration. In 1943, the USBM trenched and sampled the property. Of 68 samples collected, the average mercury grade was 0.41 lb/ton, and maximum was 16.5 lbs/ton.

History: Discovered in 1921 by Hans Halverson by tracing pieces of float to their source; in 1922 he drove a 122 ft adit. In 1923 E.W. Parks purchased the claims, further prospected by surface means, and retorted a small amount of mercury. In 1931 Otto Rohlphs leased the property, drove a crosscut through the adit, but dropped the option in 1932. In 1928 Parks' estate leased the property to A.C Skidmore who dropped the lease after retorting 10 flasks (or 8 according to Malone, 1962). From 1939-40 a few more flasks were retorted in conjunction with assessment work (Webber and others, 1947). USBM trenched the property in 1943; DMEA sponsored further trenching in 1957. More trenches were dug in 1959-60 by Alaska Mines and Minerals, Inc. Visited by USGS in 1957 and 1959 (Sainsbury and MacKevett, 1965).

References: Cady and others, 1955, p. 110
Cobb, 1972
Cobb, 1976, p. 17-18
Malone, 1962, p. 37-39
Sainsbury and MacKevett, 1965, p. 18-19
Webber and others, 1947, p. 24-27

Map number: 20 Type: Lode, prospect

Name: Vermillion

Location: D-4, south side of Kuskokwim River, west side of McCally Creek (Cobb, 1972, gave this property the same locality number as the nearby Barometer mine)

Ore minerals: Cinnabar

Production: None reported

Description: This description is identical to that for the Mercury prospect (#21, herein), because in their brief description, Cady and others (1955) did not separate the two properties. These workers reported that small amounts of "ore mineral" occur chiefly as bedding plane stringers in a shaly zone of interbedded graywacke and shale of the Kuskokwim Group. The "ore mineral" is assumed to be cinnabar, although Cobb (1976) stated that stibnite might also be present. Sainsbury and MacKevett (1965) did not examine this property.

History: Cady and others (1955) apparently examined the property in 1944. They stated that both Vermillion and Mercury had been systematically trenched.

References: Cady and others, 1955, p. 111
Cobb, 1972
Cobb, 1976, p. 55
Sainsbury and MacKevett, 1965, p. 20

Map number: 21 Type: Lode, prospect
Name: Mercury

Location: D-4, south of Kuskokwim River, east side of McCally Creek, just NW of Red Devil (Cobb, 1972, gave this property the same locality number as the Red Devil mine)

Ore minerals: Cinnabar

Production: None reported

Description: This description is identical to that for the "Vermillion" prospect (#20, herein), because in their brief description, Cady and others (1955) did not separate the two properties. These workers reported that small amounts of "ore mineral" occur chiefly as bedding plane stringers in a shaly zone of interbedded graywacke and shale of the Kuskokwim Group. The "ore mineral" is assumed to be cinnabar, although Cobb (1976) stated that stibnite might also be present. Sainsbury and MacKevett (1965) did not examine this property.

History: Cady and others (1955) apparently examined the property in 1944. They stated that both Vermillion and Mercury had been systematically trenched.

References: Cady and others, 1955, p. 111
Cobb, 1972
Cobb, 1976, p. 41
Sainsbury and MacKevett, 1965, p. 20

Map number: 22 Type: Lode, mine
Name: Red Devil

Location: D-4, south of Kuskokwim River

Ore minerals: Cinnabar, stibnite

Production: Total = 36,141 +/- 408 flasks Hg from 1933-71. Of this, 2,972 +/- 8 flasks were produced from 1933-46 (Webber and others, 1947), 29,369 +/- 405 flasks from 1953-63 (Jasper, 1961), and 3,800 flasks from 1969-71 (T.K. Bundtzen, pers. comm., 1988). In 1970 stibnite was recovered in flotation

Description: Host rocks are interbedded graywacke and shale of the Kuskokwim Group cut by a few dikes that are generally altered to quartz, chalcedony, carbonate, and sericite (Malone, 1962). Most of the ore formed along and near intersections between altered dikes and NW-trending faults that mainly parallel bedding planes. Formation of ore was primarily by open space filling and consists of cinnabar associated with abundant stibnite in a quartz-rich gangue; less common realgar,orpiment, and antimony minerals are also found (MacKevett and Berg, 1963). Stibnite- cinnabar ratio increases with depth (Malone, 1962). Ore shoots did not continue below 460-480 ft (Donald Grybeck, USGS, personal commun., 1988). MacKevett and Berg (1963) reported that clay minerals (dickite among them) occupy central parts of some ore-bearing veinlets, but are more conspicuous in barren veinlets away from ore bodies. Jasper (1961) stated that while no native mercury was found at the property, old timers reported appreciable amounts in material panned along McCally Creek, west of the property.

History: The property was staked by Hans Halveson in 1933. From 1933-46 activity consisted of prospecting and minor production. In 1952 DeCoursey Mountain Mining Company acquired a lease on the property and a DMEA loan. From 1953-63 the mine was active with the exception of the period between October, 1954 to March, 1956 when mine and mill equipment was being rebuilt after a fire. The mine was reopened in 1969 with Japanese capital, and production continued until 1971. During this last period of production, ore was not retorted on site as it had previously been, but was shipped as a concentrate. This summary is a synthesis of information from the following sources: Webber and others (1947), Jasper (1961), Malone, (1962), Meyer (1985), and T.K. Bundtzen (pers. comm., 1988).

References:
Cobb, 1972
Cobb, 1976, p. 47-50
Jasper, 1961, p. 73-75
MacKevett and Berg, 1963
Malone, 1962, p. 13-20 (this section was actually written by Gordon Herreid, mine geologist)
Meyer, 1985, map #28, p. 166-171
Sainsbury and MacKevett, 1965, p. 2-3, and p. 8-10
Webber and others, 1947, p. 3, and p. 9-18

Map number: 23 Type: Lode, occurrence
Name: McCally Creek

Location: C-4, head of McCally Creek on NE slope of Barometer Mountain at elevation 1,000 ft

Ore minerals: Cinnabar

Production: None

Description: Only description is from Cady and others (1955) who stated that traces of cinnabar were found in graywacke and shale of the Kuskokwim Group near the contact with porphyritic albite rhyolite. They did not mention visiting this property, so it may have been second hand information.

History: Unknown

References: Cady and others, 1955, p. 111
Cobb, 1972
Cobb, 1976, p. 39

Map number: 24 Type: Lode & placer, prospect(staked)
Name: Landru

Location: C-4, along the Kuskokwim River, 1/4 mile below the village of Sleetmute

Ore minerals: Cinnabar

Production: None reported

Description: Only mention of this prospect is by Joesting (1942) who reported that considerable rich float was found, but was not traced to its source. The country rock here is sandstone and shale of the Kuskokwim Group. Joesting (1942) stated the ore contained both cinnabar and metacinnabarite.

History: Joesting (1942) reported that Herschell and Hortense Landru owned this prospect, probably in 1941, but perhaps earlier.

References: Cobb, 1972
Cobb, 1976, p. 38
Joesting, 1942, p. 23

Map number: 25 Type: Placer, prospect(?)

Name: Stony River

Location: C-2, perhaps into D-2

Ore minerals: Gold (?)

Production: None

Description: Unknown.

History: Thirty-two claims were staked in 1970, and apparently there was some activity until 1976 (Meyer, 1985).

References: Meyer, 1985, map #24, p. 162

Map number: 26 Type: Lode, prospect (was staked)
Name: Mellick's

Location: C-4, west bank of the Kuskokwim River, behind Mellick's Trading Post

Ore minerals: Cinnabar

Production: None reported

Description: Cady and others (1955) reported that a small amount of cinnabar occurs in the Kuskokwim Group sandstone and shale behind Mellick's Trading Post. Cady and others (1955, plate 1) mapped two biotite basalt dikes within a half mile south of the trading post.

History: Nick Mellick and George H. Willis staked a claim in 1952; claim closed in 1983 (Meyer, 1985)

References: Cady and others, 1955, p. 111
Cobb, 1972
Cobb, 1976, p. 40
Meyer, 1985, map #25, p. 180

Map number: 27 Type: Lode, mine (small production)
Name: Kolmakof

Location: Uncertain; Cobb (1972) located it in C-8, but Smith and Maddren (1915) and Jasper (1961) stated it may be in eastern Russian Mission quad; location is one used by Meyer (1985)

Ore minerals: Cinnabar

Production: Total = a little more than 2 flasks of mercury. A small amount of ore was shipped before 1898 (Jasper, 1961) and about 2 flasks of mercury were produced in 1909 or 1910 (Cady and others, 1955)

Description: Graywacke and shale of the Kuskokwim Group cut by numerous sills (including one 25 ft thick) and fewer dikes (Smith and Maddren, 1915) now altered to silica, carbonate, and probably clay (Cady and others, 1955). Berg and Cobb (1967) reported that the thick sill is exposed for 400 ft. Cinnabar occurs in narrow stringers and as disseminations in fractures and brecciated zones in the sill and enclosing rocks (Cady and others, 1955).

History: Found in about 1838 by Russian traders, this was the first cinnabar discovery in Alaska (Cady and others, 1955; T.K. Bundtzen, personal commun.). USBM performed trenching and sampling in 1944, trenching and stripping in 1954 (Jasper, 1961) and trenching plus auger hole sampling from 1969-70 (Merrill and Maloney, 1974). Exploration did not reveal more ore (Merrill and Maloney, 1974).

References:
Berg and Cobb, 1967, p. 92
Cady and others, 1955, p. 116
Cobb, 1972
Cobb, 1976, p. 35-36
Jasper, 1961, p. 67-68
Merrill and Maloney, 1974
Meyer, 1985, map #62
Sainsbury and MacKevett, 1965, p. 49-50

Map number: 28 Type: Placer, prospect(?)
Name: Unnamed

Location: C-8

Ore minerals: Gold

Production: None

Description: Unknown.

History: Meyer (1985) reported that claims were staked in 1970.

References: Meyer, 1985, map #61, p. 222

Map number: 29 Type: Placer, mine (small production)
Name: Murray Gulch

Location: C-7, tributary of New York Creek

Ore minerals: Gold

Production: Total = about 1,500 oz gold from Murray Gulch and New York Creek (#30) combined. From Murray Gulch itself, Maddren (1915) reported about $1,000 worth from 1911-14 and Cady and others (1955) reported sporadic production thereafter totalled a few thousand dollars. Further production 1979-81

Description: Northwest striking hypabyssal rhyolite dikes (up to 3 ft thick) cut Kuskokwim Group sedimentary rock in the upper part of Murray Gulch (Maddren, 1915). Gold occurs downstream from these dikes (Cady and others, 1955). Maddren (1915) reported coarse gold both from deep gravel beneath the stream and from bench gravels about 70 ft above the present flood plain. The gold from the bench level is rough showing little abrasion by stream action.

History: Gold was discovered on Murray Gulch in 1910 and mined until 1914. Prospecting and sporadic mining probably continued until at least 1955 (the time of Cady and others' report). Property was exploited chiefly by trenches, short shafts, and drifts in frozen ground. Murray Gulch and New York Creek (#30) were again mined from 1979-81.

References: Cady and others, 1955, p. 119
Cobb, 1972
Cobb, 1976, p. 43
Maddren, 1915, p. 353-355

Map number: 30 Type: Placer, prospect
Name: New York Creek (see also Murray Gulch, #29)

Location: C-7

Ore minerals: Gold

Production: Total = about 1,500 oz gold from New York Creek and its tributary, Murray Gulch (#29).

Description: Bedrock consists of Kuskokwim Group sedimentary rocks crosscut by NE-trending dikes exposed in the upper part of Murray Gulch and also along the bluff below the confluence of New York Creek and the Kuskokwim River. Maddren (1915) reported coarse gold to occur in strips of bench gravels along New York Creek.

History: Gold was discovered on Murray Gulch, a tributary of New York Creek in 1910. Between 1910 and 1914 prospecting was expanded to include the main stream, particularly near the mouth of the gulch (Maddren, 1915). The New York Creek and Murray Gulch area was again mined from 1979-81.

References: Cady and others, 1955, p. 119
Cobb, 1972
Cobb, 1976, p. 45
Maddren, 1915, p. 353

Map number: 31 Type: Placer, prospect(?)
Name: Oskawalik River

Location: C-5, location approximate. Cady and others (1955) report the location to lie near Henderson Mountain; Meyer (1985) indicated over 20 mi of the river, from the mouth upstream

Ore minerals: Gold

Production: None reported

Description: Cady and others (1955) reported that during the course of their studies they saw evidence or heard reports of placer gold prospecting along this creek (and seven other creeks in the general area). Bedrock is Kuskokwim Group sedimentary rock intruded by a small granodiorite stock at Henderson Mountain.

History: Cady and others (1955) stated they either saw evidence or heard that this river had been prospected, probably prior to 1951. Meyer (1985) reported at least one claim was staked somewhere along the river between 1980 and 1982.

References: Cady and others, 1955, p. 120
Cobb, 1972
Cobb, 1976, p. 46
Meyer, 1985, map #43, p. 193

Map number: 32 Type: Lode, occurrence

Name: Unnamed

Location: B-6

Ore minerals: Unknown; Hg and Au anomalies

Production: None

Description: Rhyolite breccia grab sample collected by ADGGS. Rock geochemical values of Au = 0.3 ppm, Ag = 0.6 ppm, Hg = 2.9 ppm, and As = 927 ppm reported by Robinson (1984c).

History: Sampled by the ADGGS.

References: Robinson, 1984c, rock sample #15352

Map number: 33 Type: Placer, prospect(?)
Name: Gold Run

Location: B-7, but information is not available regarding the exact location along this creek

Ore minerals: Gold

Production: None reported

Description: Only information is from Cady and others (1955) who reported that during the course of their studies they saw evidence or heard reports of placer gold prospecting along this creek (and seven other creeks in the general area). Bedrock is Kuskokwim Group sedimentary rock cut by hypabyssal rhyolite dikes.

History: Cady and others (1955) stated they either saw evidence or heard that this creek had been prospected, probably prior to 1951.

References: Cady and others, 1955, p. 120
Cobb, 1972
Cobb, 1976, p. 30

Map number: 34 Type: Lode, mine

Name: Mountain Top

Location: B-6

Ore minerals: Cinnabar, minor stibnite

Production: Total = about 165 flasks of mercury produced 1982-86 (T.K. Bundtzen, written commun., 1988). In 1972, Sorg and Estlund had reported 200 flasks of reserves were in sight.

Description: Bedrock composed of interbedded graywacke and shale of the Kuskokwim Group in association with olivine basalt interpreted as dike rock by Sorg and Estlund (1972) but as flow rock by Reifenstuhl and others (1984). The basalt is cut by four faults along which the igneous rock is pervasively brecciated and altered to silica, dolomite, clay, and minor iddingsite. The country rock is also intensely altered along these faults and thin quartz veinlets are locally numerous. Mineralization consists of open-space-filling veins of cinnabar +/- dolomite within the fault zones in the basalt. Stibnite is found as deeply weathered float fragments and as crystal aggregates in small quartz veinlets (Sorg and Estlund, 1972). These workers also reported that small quantities of liquid and solid hydocarbon accompany the cinnabar. Sorg and Estlund (1972) also documented the occurrence of dickite and buddingtonite at Mountain Top.

History: James R. Wylie discovered the deposit in 1968 by panning detrital cinnabar to its source. Wylie explored the property using a hand auger and bulldozer. The USBM drilled 7 holes, the deepest of which was 50 ft, in 1970. Sorg and Estlund (1976) mapped the property in 1971. Yearly assessment work has probably been done since 1968; property was active during 1988.

References: Cobb, 1976, p. 42
Reifenstuhl and others, 1984
Sorg and Estlund, 1972

Map number: 35 Type: Lode, occurrence
Name: Unnamed

Location: B-6

Ore minerals: Unknown; Hg anomaly

Production: None

Description: Rhyolite dike rock grab sample collected by ADGGS. Rock geochemical value of 1.9 ppm Hg reported by Robinson (1984c).

History: Sampled by the ADGGS.

References: Robinson, 1984c, rock sample #2982

Map number: 36 Type: Placer, prospect(?)

Name: Girl Creek

Location: A-7, but no information is available regarding the exact location along this creek

Ore minerals: Gold

Production: None reported

Description: Only information is from Cady and others (1955) who reported that during the course of their studies they saw evidence or heard reports of placer gold prospecting along this creek (and seven other creeks in the general area). Bedrock is Kuskokwim Group sedimentary rock cut by hypabyssal rhyolite dikes.

History: Cady and others (1955) stated they either saw evidence or heard that this creek had been prospected, probably prior to 1951.

References: Cady and others, 1955, p. 120
Cobb, 1972
Cobb, 1976, p. 29

Map number: 37 Type: Lode, occurrence
Name: Unnamed

Location: A-6

Ore minerals: Unknown; Hg anomaly

Production: None

Description: Iron-stained sandstone grab sample collected by ADGGS. Rock geochemical data shows 1.1 ppm Hg (Robinson, 1984a).

History: Sampled by the ADGGS

References: Robinson, 1984a, rock sample # 2987

Map number: 38 Type: Placer, prospect (?)
Name: Timber Creek

Location: A-8 or possibly Taylor Mountains D-8, location is very approximate; Cady and others (1955) reported it only as "Timber Creek"

Ore minerals: Gold

Production: None reported

Description: Only information is from Cady and others (1955) who reported that during the course of their studies they saw evidence or heard reports of placer gold prospecting along this creek (and seven other creeks in the general area). Bedrock is Kuskokwim Group sedimentary rock and Gemuk Group sedimentary and volcanic rocks both intruded by hypabyssal rhyolite dikes.

History: Cady and others (1955) stated they either saw evidence or heard that this creek had been prospected, probably prior to 1951.

References: Cady and others, 1955, p. 120
Cobb, 1972
Cobb, 1976, p. 53

Map number: 39 Type: Lode, occurrence
Name: Unnamed, but on same ridge as the Fortyseven Creek lode (#40)
Location: A-6

Ore minerals: Unknown; Au, Ag, Hg anomalies

Production: None

Description: Quartz vein material and altered sandstone grab samples collected by ADGGS. Rock geochem values from four samples have the following values: up to 2.4 ppm Au, up to 16.7 ppm Ag, up to 3.3 ppm Hg, up to 161 ppm Sb, and up to 3510 ppm As (Robinson, 1984a).

History: Sampled by the ADGGS

References: Robinson, 1984a, rock samples #15536, #15537, #15538, and #3284

Map number: 40 Type: Lode, prospect
Name: Fortyseven Creek

Location: A-6, just off the east side of the ridge that Fortyseven Creek drains

Ore minerals: Gold, scheelite, wolframite, arsenopyrite, jamesonite, stibnite, argentite, and gold-silver tellurides

Production: None reported from the lode, see placer (#41)

Description: Bedrock is interbedded graywacke and shale of the Kuskokwim Group. Mineralization is associated with an extensive shear zone (roughly 1000 ft wide and 1-1/2 miles long) that approximately parallels bedding and is heavily silicified and impregnated with quartz. Bundtzen and Nokelberg (1987) reported that the shear zone is intruded locally by altered hypabyssal rhyolite dikes. Metallic minerals present include gold, scheelite, wolframite, arsenopyrite, jamesonite, stibnite, argentite, and traces of gold-silver tellurides (Cady and others, 1955). Quartz is the chief gangue mineral, accompanied by lesser tourmaline and sericite. The scheelite occurs as coarse particles enclosed in quartz and associated with tourmaline and sericite (Cady and others, 1955).

History: Deposit discovered in 1947 by Russell Schaeffer after the USGS field party had been in the area (Cady and others, 1955).

References:
Bundtzen and Nokelberg, 1987, p. 24
Cady and others, 1955, p. 119-120 and p. 120-121
Cobb, 1972
Cobb, 1976, p. 26

Map number: 41 Type: Placer, mine

Name: Fortyseven Creek

Location: A-6

Ore minerals: Gold, scheelite

Production: Total = about 2,500 oz of gold. Schaeffer sold a minor amount of gold and scheelite prior to 1950 (Cady and others, 1955), but main production was from 1981-86

Description: Lode occurrence located near the ridge line at the head of Fortyseven Creek. Placer gold and scheelite were recovered in a gulch just below the lode occurrence, and more placer gold was recovered below the junction of Fortyseven Creek and the Denali-Farewell fault (which runs NE along the base of the mountains); however, no significant placer concentrations occur between the gulch and the fault (Cady and others, 1955). Schaeffer reported to Cady and others (1955) that below the fault there were two types of placer occurrences. The first is on the bedrock itself, with a minor amount of gold scattered in the overlying gravel; the second is on a "yellow clay hardpan" where gold and scheelite are concentrated.

History: Discovered by Russell Schaeffer in 1947. Cady and others (1955) reported that he shipped a minor amount of both gold and scheelite recovered by placer methods. Property was mined again from 1981-86.

References: Cady and others, 1955, p. 119-120, and p.120-121
Cobb, 1972
Cobb, 1976, p. 26