GEOLOGICAL SURVEY CIRCULAR 783

The Alaskan Mineral Resource Assessment Program: Background Information to Accompany Folio of Geologic and Mineral Resource Maps of the Big Delta Quadrangle, Alaska

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ABSTRACT

The geology, geochemistry, geophysics, and Landsat imagery of the Big Delta quadrangle, 16,335 km^2 in the Yukon-Tanana Upland of east-central Alaska, were investigated, and maps and reports were prepared by an interdisciplinary research team for the purpose of assessing the mineral potential. The quadrangle is dominantly a complex terrane of greenschist- to amphibolite-facies metamorphic rocks that have been intruded by Mesozoic and Tertiary dioritic to granitic rocks and are overlain by Tertiary sedimentary and volcanic rocks. Serpentinized peridotite and associated greenstone, graywacke, and chert crop out in some places.

The quadrangle is bisected by the northeastward-trending Shaw Creek fault, which, on the basis of aeromagnetic interpretation and geologic data, is postulated to have left-lateral offset of as much as 48 km. On the northwest side of the Shaw Creek fault, metamorphic rock units have a northwesterly regional trend, and the oldest rocks could be Precambrian in age. Gneiss and schist in the southwestern part of the quadrangle are derived from both igneous and sedimentary protoliths, some of which may be as old as Precambrian. Other rock units, which include calcareous schist and thin-layered marble, black quartzite, semischist, and cataclastic rocks, are considered to be of probable Paleozoic age, although no fossils have yet been found in these rocks. Radiolarians and conodonts in chert associated with greenstone and ultramafic rocks indicate that the chert is of Permian age.

Potassium-argon ages on igneous rocks of the Big Delta quadrangle fall into two groups: those with biotite, muscovite, hornblende, and sanidine ages between 50 to 69 m.y.; and those with biotite, hornblende, and sanidine ages between 88 to 105 m.y. The younger of these two groups appears to indicate the time of a plutonic event marked by intrusion of mostly small, isolated plutons, including hypabyssal stocks, and the eruption of silicic volcanic rocks. Most of the plutons are quartz monzonite to granite.

The older group of ages (88 to 105 m.y.) on igneous rocks includes ages on the largest plutons of the Yukon-Tanana Upland. The rocks range from diorite to quartz monzonite in composition. The potassium-argon ages on the metamorphic rocks of the Big Delta quadrangle, like those obtained elsewhere in the Yukon-Tanana Upland, appear to have been partly or completely reset by subsequent thermal events.

Vein and placer gold deposits have been mined in the Big Delta quadrangle, and although indications of mineralization are widespread, no other mineral deposits have yet been identified. The geologic, geochemical, and geophysical data are compatible with several types of deposits, including porphyry copper, massive sulfide, and skarn deposits. In certain aspects, the geology of the quadrangle is similar to areas in the eastern part of the Yukon-Tanana Upland and Canada where mineral deposits are known.

INTRODUCTION

PURPOSE AND SCOPE

This circular, together with a separately available folio of open-file maps of the Big Delta quadrangle, is one of a series of U.S. Geological Survey reports intended to provide information for formulating a sound long-range national mineral policy to aid in Federal, State, and local land-use planning, to provide significant data for mineral explorations; and to increase the geologic understanding of the area. The work was carried out under the Alaskan Mineral Resource Assessment Program (AMRAP), authorized by Congress to begin on July 1, 1974.

The Big Delta mineral resource assessment consists of this Circular, geologic, geophysical, and geochemical maps, interpretation of Landsat imagery, and an analysis of the mineral endowment (table 1). Some of the geologic data were collected prior to July 1, 1974. Most of the field and laboratory studies were carried on from 1975 to 1977 by an interdisciplinary team of scientists.

Table 1.--*Component maps of the Big Delta mineral resource assessment*

Map	Subject
U.S. Geological Survey open-file report 78-529	
78-529-A (Weber and others, 1978)	Preliminary geology.
B (Griscom, 1979)	Aeromagnetic map and interpretation.
C (Albert and Steele, 1979)	Interpretation of Landsat imagery.
D (Menzie and Foster, 1979)	Mineral resources.
E (Hessin and others, 1978)	Geochemical distribution and abundance of copper, lead, and zinc in nonmagnetic heavy-mineral concentrate samples.
F (Hessin and others, 1978)	Geochemical distribution and abundance of bismuth, antimony, and silver in nonmagnetic heavy-mineral concentrate samples.
G (Hessin and others, 1978)	Geochemical distribution and abundance of tin, tungsten, and molybdenum in nonmagnetic heavy-mineral concentrate samples.
H (Hessin and others, 1978)	Geochemical distribution and abundance of cobalt, chromium, and nickel in nonmagnetic heavy-mineral concentrate samples.
I (Hessin and others, 1978)	Geochemical distribution and abundance of copper, lead, and zinc in minus-80-mesh stream sediment.
J (Hessin and others, 1978)	Geochemical distribution and abundance of cobalt, chromium, and nickel in minus-80-mesh stream sediment.
K (Hessin and others, 1978)	Geochemical distribution and abundance of copper, lead, and zinc in the oxide residue.
L (Hessin and others, 1978)	Geochemical distribution and abundance of cobalt, chromium, and nickel in the oxide residue.
M (Hessin and others, 1978)	Geochemical distribution of copper, lead, and molybdenum in the ash of willow leaves.
N (Hessin and others, 1978)	Geochemical distribution and abundance of zinc and cadmium in the ash of willow leaves.

GEOGRAPHY AND ACCESS

The Big Delta quadrangle covers approximately 16,335 km^2 in east-central Alaska (fig. 1) between lat 64° and 65° N. and long 144° and 147° W. Three physiographic provinces are included in the quadrangle: the Yukon-Tanana Upland (Wahrhaftig, 1965), the Tanana Lowland, and the Northern Foothills of the Alaska Range (fig. 2). Most of the quadrangle is in the Yukon-Tanana Upland, a maturely dissected mountainous terrain, unglaciated except for a few valleys in the eastern part of the quadrangle, where elevations reach 1,788 m. The parts of the upland that border the valley of the Tanana River are extensively covered by loess and sand. Most of the upland is covered by brush and trees, although some high areas are tundra.

The Tanana River flows northwesterly in a broad braided channel across the southwestern part of the quadrangle and is joined from the south by the Gerstle, Delta, and Little Delta Rivers, all glacial streams. Major tributaries from the northeast draining the Yukon-Tanana Upland are the Goodpaster and Salcha Rivers, both clear streams. A few small lakes occur at the margin of the upland and the Tanana valley, including Healy, Volkmar, Quartz, Birch, and Harding Lakes, named in order from southeast to northwest.

The Tanana Lowland is largely filled by Holocene alluvial deposits and Pleistocene and Holocene fan deposits and glacial deposits derived from alpine glaciers in the Alaska Range to the south. Much of the lowland is wooded; near Delta Junction, there are large open swampy areas and tracts that have been cleared for farmland.

Only a few square kilometers of intricately dissected Tertiary sedimentary rocks in the southwestern corner of the quadrangle make up the

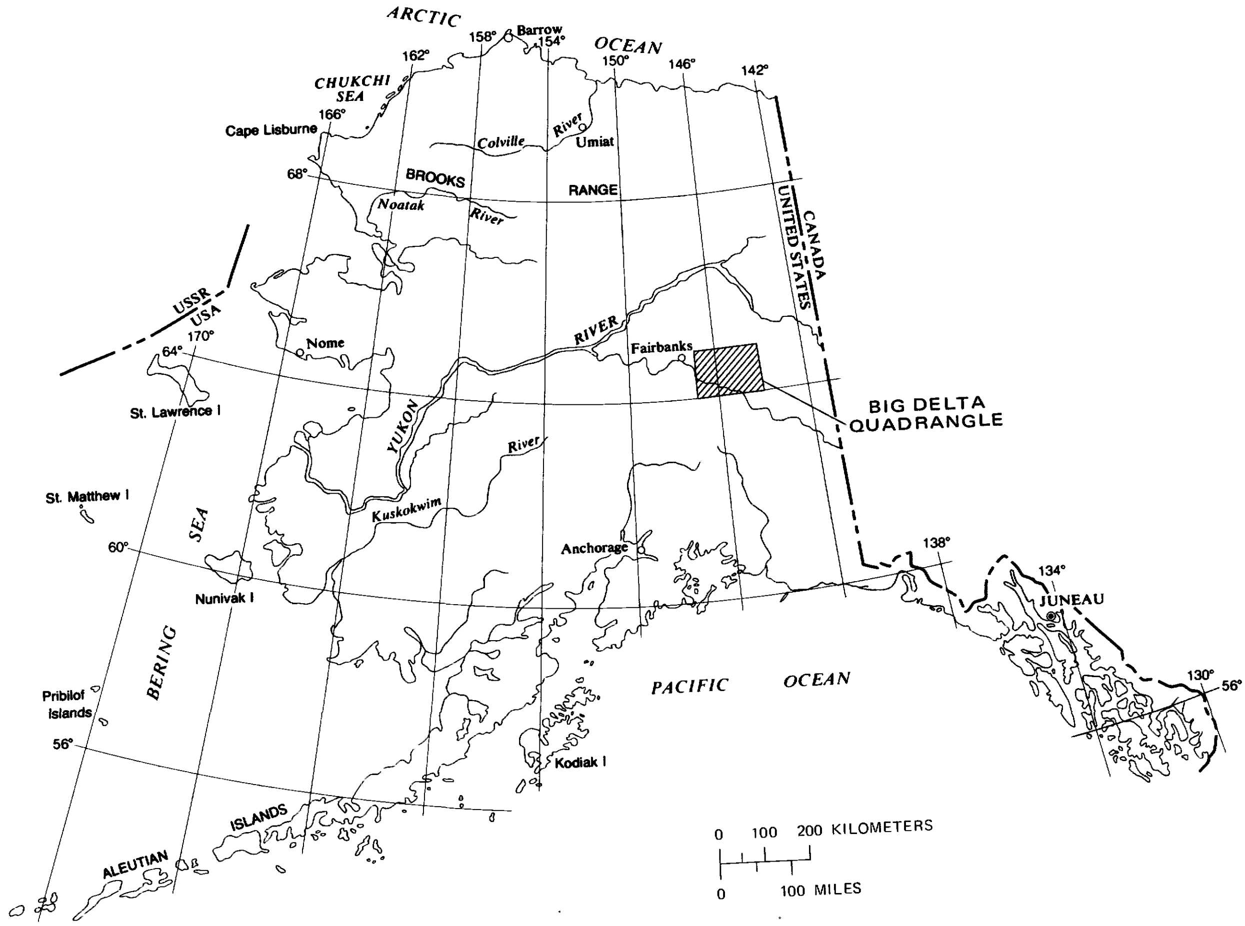

FIGURE 1. — Index map showing the location of the Big Delta quadrangle, Alaska.

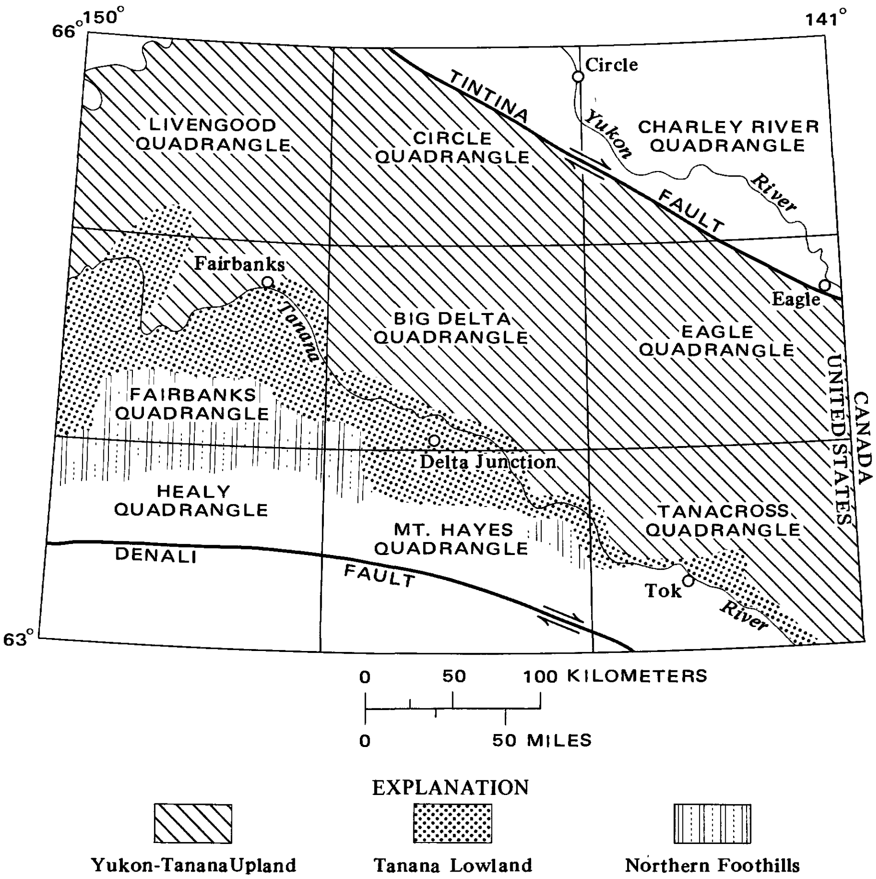

FIGURE 2. — Physiographic provinces of the Big Delta quadrangle and its location in relation to major faults.

Northern Foothills province. The Little Delta River flows northward from the Alaska Range through the province.

Most of the quadrangle is without roads, but the Richardson Highway cuts across the southwestern part of the quadrangle, and about 35 km of the Chena Hot Springs road traverses the northwestern corner.

Delta Junction is the only town; a small part of Fort Greeley, an Army installation for cold-weather testing and training south of Delta Junction, extends into the quadrangle. Delta Junction has a paved airstrip and several small gravel strips. Other airstrips that can be used by light bush planes are at Caribou Creek and Tibbs Creek.

MINERAL PRODUCTION AND EXPLORATION

Mineral production from the Big Delta quadrangle, excluding sand and gravel, is limited to gold from both lode and placer deposits and silver recovered from the gold ore. Placer gold was first discovered in the Big Delta quadrangle on Tenderfoot Creek in 1905 and soon thereafter on nearby creeks and on Caribou and Butte Creeks in the Salcha River drainage. Placer production from the Tenderfoot Creek area, commonly known as the Richardson district, is estimated at 95,000 troy oz gold and 24,000 troy oz silver (Bundtzen and Reger, 1977). A much smaller amount of gold was produced from Caribou Creek, where a dredge operated for a short time; other placer production from the Big Delta quadrangle has been very small. Lode gold was discovered in quartz veins in the early 1930's on Black Mountain near Tibbs Creek; several mines were explored, including the Blue Lead and Blue Lead extension, the Gray Lead, the Grizzly Bear, Hidden Treasure, and the Michigan Lead; some had minor production. Total production to about 1941, when work terminated, was about 32 troy oz gold and 25 troy oz silver from an estimated 150 tons of ore (Thomas, 1970). In the mid-1970's there was minor renewed activity in this area and possibly minor production. Some old tailings were reworked.

Antimony occurs in this area but has not been found in sufficient quantity to mine.

Native bismuth has been reported from the placer concentrates of No Grub Creek in the Salcha drainage and is believed to occur in gold-bismuth-bearing quartz veins that trend at 35°-45° angles across the creek. No effort has been made further to explore this occurrence or recover bismuth.

There has been some prospecting for molybdenum in the southeastern part of the quadrangle and for nickel in silica-carbonate rock associated with ultramafic rocks in the northern part of the quadrangle.

In general, prospecting for metalliferous deposits has not been particularly active in the Big Delta quadrangle in recent years and not as active as in some adjacent quadrangles. In part, the lack of recent geologic maps and the difficulty of access to much of the area without helicopter may have discouraged prospecting.

Little prospecting has been done for uranium minerals in the quadrangle.

Commercial deposits of oil, gas, and coal are not known in the Big Delta quadrangle. A Tertiary coal-bearing formation that has produced some coal near Nenana occurs in the southwestern corner of the quadrangle. It is unlikely that significant amounts of good quality coal will be found near the surface in this area.

ACKNOWLEDGMENTS

Many scientists have participated and contributed to the geologic mapping of the Big Delta quadrangle. Rachel M. Barker, who assisted in 1964, and Allen Clark and his party, who contributed much data and field support in 1972, are particularly thanked. Much assistance was given by local Alaskans, by the U.S. Army, and by commercial fixed-wing and helicopter crews.

The able assistance in the office of Alice M. Cantelow, Diana J. Nelson, Steven T. Luthy, Barbara C. Thompson, and many others is much appreciated. Kathleen M. Johnson helped prepare the reference list. Gary C. Curtin assisted in preparing the geochemical data. Henry C. Berg, coordinator of AMRAP, has given continued assistance and guidance throughout the project.

GEOLOGIC INVESTIGATIONS

PREVIOUS GEOLOGIC AND MINERAL RESOURCE INVESTIGATIONS

The first recorded scientific observations in the Big Delta quadrangle were probably made by Lieutenant H. T. Allen on his remarkable traverse across the eastern Alaskan Range and down the Tanana River to the Yukon in 1885 for the U.S. War Department (Allen, 1887). Allen made the first reliable map of the Tanana River. The first geologic expedition that traversed part of the Big Delta quadrangle was that of A. H. Brooks and W. J. Peters in 1898, when they ascended the White River, portaged to the headwaters of the Tanana River, and descended the Tanana to its confluence with the Yukon (Brooks, 1900).

Systematic geologic study of the Yukon-Tanana Upland was undertaken in 1903 by L. M. Prindle with other U.S. Geological Survey geologists, but he made few or no observations in the Big Delta quadrangle that year. A topographic party led by T. G. Gerdine covered the northern and eastern parts of the Goodpaster River drainage and part of the area between the Goodpaster and Salcha River drainages with reconnaissance topographic mapping reported in Prindle (1905, p. 14). The Big Delta quadrangle seems to have been largely excluded in many of the early geologic studies of the Yukon-Tanana Upland in favor of the more important gold-producing areas of Eagle, the Fortymile, Circle, and Fairbanks. Prindle included the geology of the eastern two-thirds of the quadrangle in his "Description of Circle quadrangle" (1906a) and discussed the gold placer mining of the Salcha region. In 1937, Mertie published his compilation of the available data on the Yukon-Tanana region, including the Big Delta quadrangle, and this report has served as the basis for all further geologic work and is still the principal reference on parts of the area.

PRESENT STUDY

Reconnaissance geologic mapping and geochemical sampling under AMRAP was carried on principally in the field seasons of 1975 and 1977; limited geologic mapping was done in 1974 and 1976. Preliminary geologic maps at a scale of 1:63,360 have been published for the A-1, A-2, A-3, B-1, and C-4 quadrangles (Weber and others, 1975, 1977a; Foster and others, 1977; fig. 3). Some geologic and geochemical data used in this study were collected in 1972 by a field party led by Allen Clark making a reconnaissance study of the large ultramafic masses in the northern part of the quadrangle. Some reconnaissance data were collected by the U.S. Geological Survey in cooperation with the Office of the Engineer, U.S. Army, Defense Intelligence Agency in 1964.

Samples for potassium-argon age determinations were mostly collected in 1975, and some of the data have already been made available (Wilson, 1976).

The aeromagnetic map of the Big Delta quadrangle used for aeromagnetic interpretation in this study was compiled from a survey flown in 1973 for the State of Alaska, Division of Geological and Geophysical Surveys (1975).

POTASSIUM-ARGON AGES FROM THE BIG DELTA QUADRANGLE

Thirty-two potassium-argon age determinations on 26 different rocks are reported here. Eighteen, on 14 different rocks, were made as a part of AMRAP, and some of these ages are included in an open-file report (Wilson, 1976). The rest were determined at the Geochronology Laboratory of the Geophysical Institute, University of Alaska, Fairbanks.

The potassium-argon ages on igneous rocks of the Big Delta quadrangle fall into two groups: those with biotite, muscovite, hornblende, and sanidine ages between 50 to 69 m.y and those with biotite, hornblende, and sanidine ages between about 88 to 105 m.y. The younger of these two groups appears to indicate the time of a plutonic

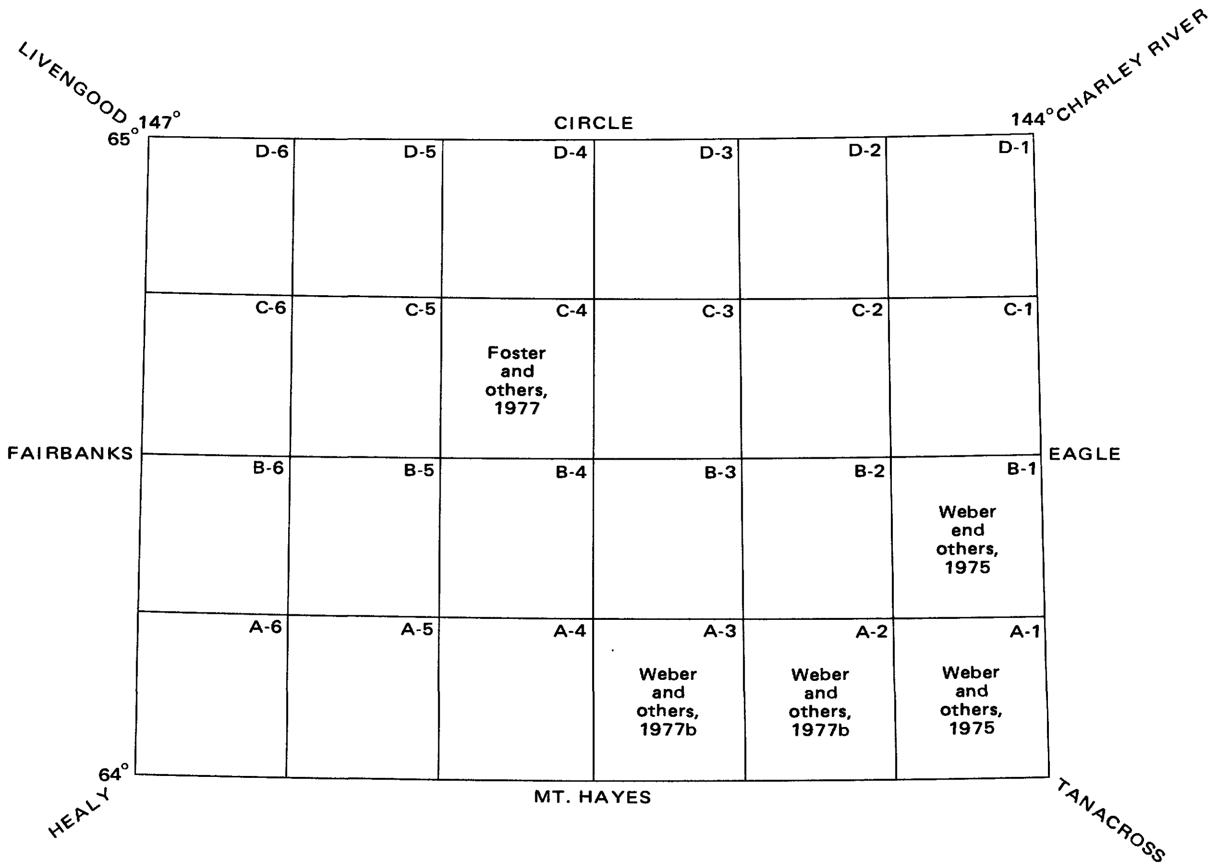

FIGURE 3. — Reference map of the Big Delta 1:250,000-scale quadrangle showing the 24 larger scale (1:63,360) quadrangles and the published maps.

event marked by intrusion of mostly small, isolated plutons, including hypabyssal stocks, and the eruption of silicic volcanic rocks. The plutons are mostly quartz monzonite to granite and range from medium grained equigranular, through coarse grained equigranular to porphyritic.

One of the largest plutons of this intrusive event is the Tors pluton in the northwestern part of the quadrangle. A biotite age from a quartz monzonite in the southeastern part of this pluton (locality 75AFr 2000b, fig. 4; and table 2) is 49.8 ± 1.5 m.y., the youngest age yet obtained for a plutonic rock in the Yukon-Tanana Upland. A pair of mineral ages from another quartz monzonite (75AFr2001, fig. 4; table 2) in the same pluton, 2.2 km northeast, are 67.7 ± 2 on biotite and 62.7 ± 2 on muscovite. The muscovite age may be younger than the biotite age because the rock contains both disseminated muscovite and muscovite in veinlets. The differences in the ages of rocks from the Tors pluton at these two localities, suggest that the Tors pluton may be composite.

The Eielson pluton, about 20 km southeast of the Tors pluton, has a biotite age of 67 ± 2 m.y. (Forbes and Weber, 1975, p. 656). Dated volcanic rocks include a porphyritic rhyolite with a sanidine age of 61.6 ± 2 m.y. (75ASj528, fig. 4; table 2) in the eastern part of the Big Delta quadrangle and two welded tuffs in the Tanacross quadrangle to the southeast, one with a sanidine age of 56.4 ± 2 m.y. (Foster and others, 1976) and the other a sanidine age of 57.8 ± 2 m.y. (J. G. Smith, written commun., 1976).[1] Also, the porphyritic syenite of Mount Fairplay in the east-central part of Tanacross quadrangle has a biotite age of 67.2 ± 2 m.y.[2] and an amphibole age of 59.5 ± 3 m.y. (J. G. Smith, written commun., 1976). The occurrence of several plutons in the Big Delta quadrangle with biotite and muscovite ages of 50 to 68 m.y., small plutons in the Tanacross quadrangle with biotite ages in this age range, and the association of dated volcanism of similar age to these plutons suggest that most of the Tertiary plutonic ages represent times of emplacement and cooling. The Nisling Range alaskite of Tempelman-Kluit and Wanless (1975), a suite that occurs as high-level batholiths in the southern parts of the continuation of the Yukon-Tanana Upland in the Yukon Territory, Canada, has biotite ages determined by them to be 50 to 60 m.y. and may represent the same event; if it does, this event was fairly widespread in east-central Alaska and parts of Canada.

The older group of ages (88 to 105 m.y.) on igneous rocks includes ages on the largest plutons of the quadrangle and of the Yukon-Tanana Uplands. These plutonic rocks are abundant and widely distributed throughout the quadrangle and intrude a previously regionally metamorphosed gneiss, schist, and quartzite terrane. The rocks range from diorite to quartz monzonite in composition, and potassium-argon age determinations have been made on pyroxene diorite, granodiorite, and quartz monzonite. The rocks are mostly medium grained and equigranular; a few are porphyritic. Generally, they are without planar fabric or microfabric. Concordant biotite and hornblende ages on two mineral pairs from plutons of this group have been determined in the Big Delta quadrangle (75AFr2175 and 75AFr2184, fig. 4; table 2), and a concordant biotite hornblende mineral pair in the same age range occurs in a pluton to the south in the Mount Hayes quadrangle (biotite, 88.8 ± 2.7 m.y. and hornblende, 92.9 ± 2.8 m.y., recalculated ages from Wilson, 1976). Biotite ages from plutonic rocks in the range of this older group occur in the Tanacross quadrangle to the southeast (Foster and others, 1976), and a concordant mineral pair with biotite yielding an age of 92.8 m.y. and a hornblende giving an age of 89 m.y. were determined in the Eagle quadrangle to the east from a granodiorite pluton (Foster, 1976). In the southwestern Big Delta quadrangle on Democrat Creek, an age of 86.9 ± 2.6 m.y. on potassium feldspar from a quartz-feldspar porphyry with an aphanitic to fine-grained quartz-sercite groundmass was determined by Bundtzen and Reger (1977), although these workers consider this to be a minimum age that may date hydrothermal alteration and mineralization. Sanidine ages of 93.9 m.y. and 93.5 m.y. (J. G. Smith, written commun., 1976)[3] from a welded tuff in the Tanacross quadrangle appear to indicate volcanism associated with intrusive activity. The wide distribution of potassium-argon ages

[1]Sample 74ASj111, Tanacross B-1 quadrangle, 63°28′44″ N., 141°18′15″ W. Sanidine: percent K_2O, 8.59; $^{40}Ar_{rad}$ 7.263 X 10^{-10} moles/g; percent $^{40}Ar_{rad}$ 67; calculated age 57.8 ± 2 m.y.

[2]Sample 74ASj144, Tanacross C-3 quadrangle, 63°39′15″ N., 142°14′42″ W. Biotite: percent K_2O, 8.64; $^{40}Ar_{rad}$ 8.513 X 10^{-10} moles/ g; percent $^{40}Ar_{rad}$ 81; calculated age 67.2 ± 2 m.y. Amphibole: percent K_2O, 0.503; $^{40}Ar_{rad}$ 0.4398 X 10^{-10} moles/g; percent $^{40}Ar_{rad}$ 58.0; calculated age 59.5 ± 3 m.y.

[3]Sample 74ASj143, Tanacross B-6 quadrangle, 63°24′08″ N., 143°55′02″ W. Sanidine: percent K_2O, 12.485; $^{40}Ar_{rad}$ 17.29 X 10^{-10} moles/g; percent $^{40}Ar_{rad}$ 92; calculated age 93.9 ± 3 m.y. Sanidine: percent K_2O, 12.85; $^{40}Ar_{rad}$ 17.23 X 10^{-10} moles/g; percent $^{40}Ar_{rad}$ 87; calculated age 93.5 ± 3 m.y.

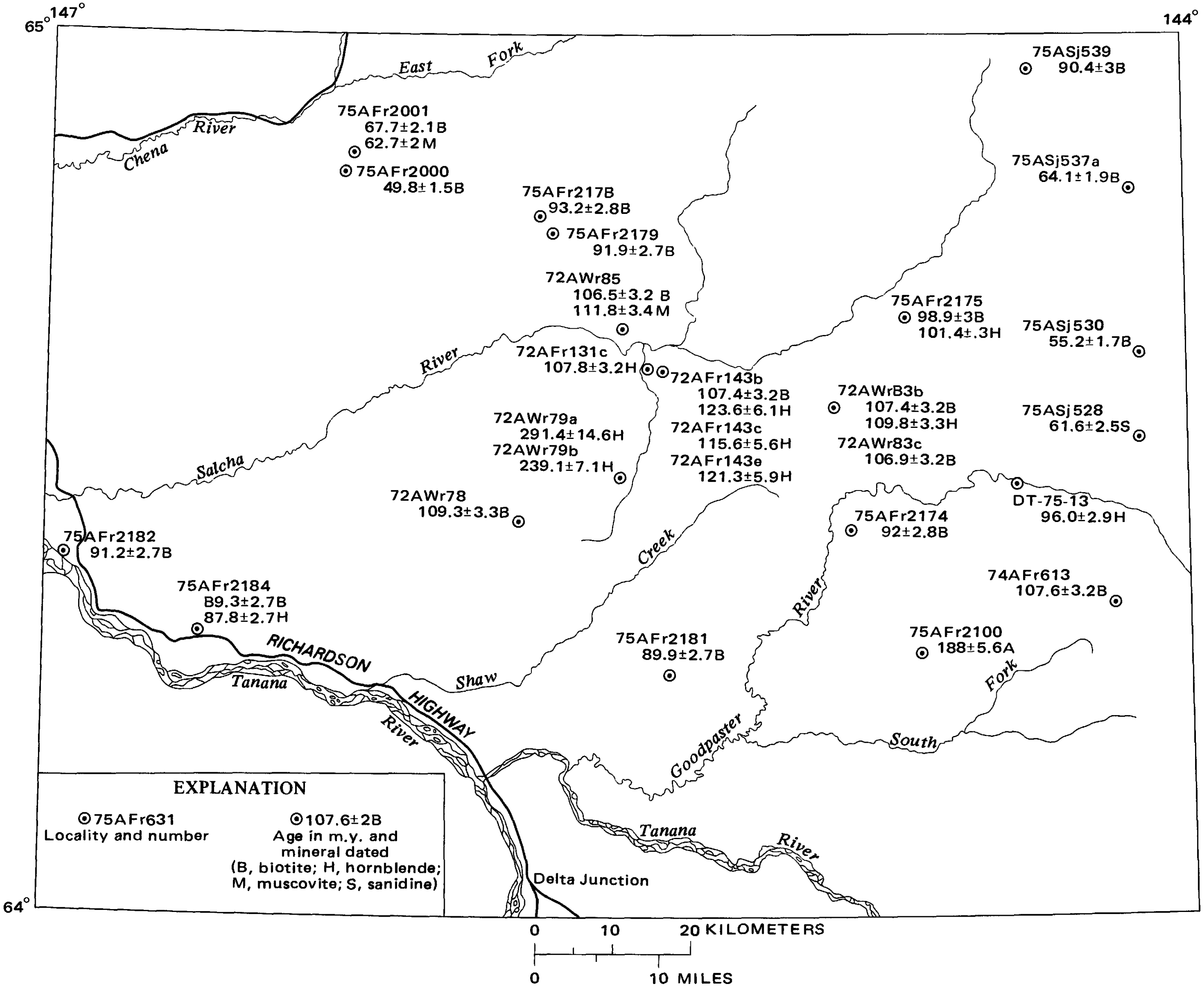

FIGURE 4. — New potassium-argon ages of rocks of the Big Delta quadrangle.

on hornblende and biotite from plutonic rocks in the 88- to 105-m.y. range in the Big Delta quadrangle and other parts of the Yukon-Tanana Upland, the occurrence of concordant mineral pairs, and the associated volcanism suggest that the ages are emplacement and cooling ages indicative of a major thermal event about 88 to 105-m.y. ago. This event is recognized in the Yukon Territory, Canada, where biotite ages determined by Tempelman-Kluit and Wanless (1975) range from 91.5 to 99.6 m.y. in their Coffee Creek quartz monzonite.

The potassium-argon ages on the metamorphic rocks of the Big Delta quadrangle, like those obtained elsewhere in the Yukon-Tanana Upland, appear to have been partly or completely reset by subsequent thermal events and are therefore difficult to interpret. At this time, these ages can only be considered as minimum ages for the dated rocks. Further study and application of other

Table 2.--*New potassium-argon ages, Big Delta quadrangle, Alaska*

[Ages were determined using standard isotope dilution techniques for extraction and measurement of argon and flame photometry for potassium (Dalrymple and Lanphere, 1969). The plus-or-minus value assigned to each is an estimate of the standard deviation of analytical precision (Cox and Dalrymple, 1967), together with an estimate of accuracy based on evaluation of the uncertainties in concentration of the ^{38}Ar tracer and potassium measurements.]

Sample No.	Location quadrangle and latitude longitude	Rock type	Mineral dated mesh size	Percent K_2O	$^{40}Ar_{rad}$ (moles/gm X10^{-10})	$^{40}Ar_{rad}$ (percent)	Age in million years plus or minus analytical uncertainty	Dated by
				Igneous rocks				
1. 75AFr2001	Big Delta C-5 64°52'09"N, 146°12'07"W.	Quartz monzonite	Biotite -------- 60-100 ---------	8.06 8.07 8.065	7.938	73	67.7±2.1	F. H. Wilson
			Muscovite ------ 60-100 ---------	10.33 10.31 10.32	9.417	61	62.7±2.0	
2. 75AFr2000b	Big Delta D-5 64°51'10"N, 146°13'59"W.	Biotite quartz monzonite	Biotite -------- 60-100 ---------	8.72 8.78 8.75	6.36	68.6	49.8±1.5	----Do.-----
3. 75AFr2178	Big Delta D-4 64°48'18"N, 145°45'26"W.	Pyroxene diorite	Biotite -------- 100-200 --------	8.24 8.28 8.26	11.37	87.5	93.2±2.8	----Do.-----
4. 75AFr2179	Big Delta D-4 64°46'33"N, 145°41'02"W.	------do-------	Biotite -------- 60-100 ---------	8.87 8.85 8.86	12.02	91.1	91.9±2.7	----Do.-----
5. 75ASj539	Big Delta D-1 64°58'18"N, 144°23'36"W.	Granodiorite	Biotite -------- 60-150 ---------	9.10 9.17 9.135	12.19	92.7	90.4±3	----Do.-----
6. 75ASj537a	Big Delta D-1 64°49'N, 144°08'18"W.	Quartz monzonite	Biotite -------- 60-100 ---------	8.98 8.96 8.97	8.42	75.5	64.1±1.9	----Do.-----
7. 75AFr2175	Big Delta C-2 64°40'50"N, 144°45'50"W.	Granodiorite	Biotite -------- 60-100 ---------	9.12 9.07 9.095	13.30	68.0	98.9±3	----Do.-----
			Hornblende ----- 100-200 --------	1.057, 1.063 1.058, 1.047 1.056	1.59	75.5	101.4±3	
8. 75ASj530	Big Delta C-1 64°37'48"N, 144°12'W.	Granite	Biotite -------- 60-100 ---------	9.00 8.87 8.935	7.206	68.8	55.2±1.7	----Do.-----
9. 75ASj528	Big Delta C-1 64°33'18"N, 144°10'24"W.	Rhyolite	Sanidine ------- 60-100 ---------	12.31 12.24 12.28	11.07	23	61.6±2	J. G. Smith
10. 75AFr2174	Big Delta B-2 64°26'23"N, 144°50'51"W.	Pyroxene quartz diorite	Biotite -------- 60-100 ---------	8.38 8.38 8.38	11.40	88.8	92±2.8	F. H. Wilson
11. 75AFr2181	Big Delta B-3 64°17'06"N, 145°21'09"W.	Pyroxene diorite	Biotite -------- 60-100 ---------	9.03 9.08 9.055	11.94	83.1	89.9±2.7	----Do.-----
12. 75AFr2182	Big Delta B-6 64°24'25"N, 146°58'10"W.	-------do-------	Biotite -------- 60-100 ---------	9.47 9.42 9.445	12.73	83.1	91.2±2.7	----Do.-----
13. 75AFr2184	Big Delta B-6 64°19'02N, 146°33'06"W.	Hornblende granodiorite	Biotite -------- 60-100 ---------	8.77 8.75 8.76	11.53	88.4	89.3±2.7	----Do.-----
			Hornblende ----- 60-100 ---------	1.129, 1.124 1.140, 1.117 1.1285	1.461	74.3	87.8±2.7	
14. 74AFr613	Big Delta B-1 64°20'37"N, 144°15'12"W.	Quartz monzonite	Biotite --------	8.895 9.010 8.752	14.28	94.5	107.6±3.2	D. L. Turner
15. DT75-13	Big Delta B-1 64°30'N, 144°28'W.	-------do-------	Hornblende -----	0.740 0.740 0.740	10.05	65.2	96.0±2.9	----Do.-----

Table 2.--*New potassium-argon ages, Big Delta quadrangle, Alaska*--Cont.

Sample no.	Location quadrangle and latitude longitude	Rock type	Mineral dated mesh size	Percent K_2O	^{40}Ar rad (moles/gm $\times 10^{-10}$)	$^{40}Ar_{rad}$ (percent)	Age in million years plus or minus analytical uncertainty	Dated by
			Metamorphic rocks					
16. 75AFr2100	Big Delta B-2 64°17'53"N. 144°38'20"W.	Garnet amphibolite	Amphibole ------- 100-120 ---------	0.242 0.245 0.2435	0.696	68.2	188±5.6	F. H. Wilson
17. 72AFr131c	Big Delta C-3 64°36'51"N. 144°23'45"W.	Amphibolite	Hornblende ------	0.307 0.308 0.310 0.308	.49	58.2	107.8±3.2	D. L. Turner
18. 72AFr143b	Big Delta C-3 64°36'18"N. 145°18'23"W.	Biotite amphibolite	Biotite ---------	7.950 8.045 7.997	12.73	90.9	107.4±3.2	----Do.-----
			Hornblende ------	0.539 0.522 0.530	.98	84.1	123.6±6.1	----Do.-----
19. 72AFr143c	Big Delta C-3 64°36'18"N. 145°18'23"W.	Hornblendite	----do-----------	0.353 0.360 0.360 0.342 0.354	.61	73.5	115.6±5.6	----Do.-----
20. 72AFr143e	Big Delta C-3 64°36'18"N. 145°18'23"W.	-----do-----	----do-----------	0.368 0.382 0.375	.68	68.7	121.3±5.9	----Do.------
21. 72AWr83b	Big Delta C-2 64°35'09"N. 144°55'35"W.	Augen gneiss	Biotite ---------	8.540 8.530 8.535	13.59	83.0	107.4±3.2	----Do.------
			Hornblende ------	1.549 1.552 1.554 1.552	2.53	88.3	109.8±3.3	----Do.------
22. 72AWr83c	Big Delta C-2 64°35'09"N. 144°55'35"W.	-----do-----	Biotite ---------	8.760 8.740 8.750	13.88	79.6	106.9±3.2	----Do.-----
23. 72AWr85	Big Delta C-3 64°40'35"N. 149°25'55"W.	-----do-----	---do------------	8.474 8.478 8.476	13.39	90.0	106.5±3.2	----Do.------
			Muscovite ------	10.235 10.253 10.244	17.01	87.0	111.8±3.4	----Do.------
24. 72AWr79a	Big Delta C-3 64°30'01"N. 145°29'10"W.	Amphibole gneiss	Hornblende -----	0.243 0.253 0.248	1.13	83.0	291.4±14.6	----Do.-----
25. 72AWr79b	Big Delta C-3 64°30'01"N. 145°29'10"W.	---do----	----do----------	0.256 0.253 0.254	.94	79.9	239.1±7.1	----Do.------
26. 72AWr78	Big Delta B-4 64°26'50"N. 145°45'30"W.	Biotite gneiss	Biotite	8.640 8.610 8.625	13.99	89.1	109.3±3.3	----Do.-----

Constants used in age calculations are:

$\lambda\beta = 4.963 \cdot 10^{-10} yr^{-1}$

$\lambda\varepsilon = 0.572 \cdot 10^{-10} yr^{-1}$

$\lambda\varepsilon^{1} = 8.78 \cdot 10^{-13} yr^{-1}$

$^{40}K/^{40}K$ (total) $= 1.167 \cdot 10^{-4}$ (mole/mole) dating techniques are needed in order to determine the age of the metamorphic rocks and the history of metamorphic events in the Yukon-Tanana Upland.

DESCRIPTION OF COMPONENT MAPS OF THE BIG DELTA QUADRANGLE FOLIO

GEOLOGY (78-529-A)

The Big Delta quadrangle is dominantly a complex terrane of greenschist- to amphibolite-facies metamorphic rocks that have been intruded by Mesozoic and Tertiary dioritic to granitic rocks and are locally overlain by Tertiary sedimentary and volcanic rocks. Ultramafic rocks and associated greenstone and chert crop out in some places. This terrane lies sandwiched between two major faults, the Tintina to the north and the Denali to the south, both outside the Big Delta quadrangle. It has been postulated that much of this fault-bounded terrane is allochthonous (Tempelman-Kluit, 1976) or that it is a continental fragment that moved in over oceanic crust along an ancient continental margin that lay along what is now the Tintina fault line (Foster and Keith, 1974).

The part of the Big Delta quadrangle south of the Tanana River is mostly Tertiary nonmarine sedimentary rocks, extensive Pleistocene glacial deposits derived from alpine glaciers in the Alaska Range to the south, and Pleistocene and Holocene alluvial and windblown deposits.

On the north side of the Tanana River particularly in the western part of the quadrangle for distances of as much as 50 km northward from the river, the bedrock is largely obscured by extensive deposits of windblown sand and loess, locally as much as 50 m thick. The Big Delta quadrangle is in an area of discontinuous permafrost, and much of the ground in the large swampy areas along the Tanana River, in the lower Shaw Creek valley, the Chena, the lower Salcha and Goodpaster River valleys, is permanently frozen.

During the Pleistocene a few small alpine glaciers developed in some of the highest mountains in the eastern and northeastern parts of the quadrangle, resulting in the formation of cirques, U-shaped valleys, and small morainal and outwash deposits.

Along the lower reaches of Shaw Creek and extending northeastward, the quadrangle is bisected by a major fault, the Shaw Creek fault, postulated on the basis of aeromagnetic interpretation and geologic data to have left-lateral strike-slip movement of as much as 48 km.

A band of partly serpentinized ultramafic rocks with associated greenstone, chert, quartzite, and graywacke occurs on the northwest side of this fault in the northern part of the quadrangle. These rocks are believed to be in thrust relation with the underlying semischists, greenschists, quartzite, and marble. Radiolarians and conodonts found in the chert associated with the ultramafic rocks indicate a Permian age for the chert (D. L. Jones, oral commun., 1978). Although many of the other metamorphic rocks of the quadrangle, including those beneath the thrust, are postulated to be of Paleozoic age, no fossils have been found in them.

Some of the highest grade metamorphic rocks of the quadrangle occur in a gneiss dome south of the Salcha River in the central part of the quadrangle. The central part of the dome is composed of greatly deformed sillimanite gneiss. Other possible gneiss domes are in the West Point area, in the C-1 quadrangle in the vicinity of bench mark "Edge," and in an area of augen gneiss in the southwestern part of the quadrangle. More gneiss and schist occur in the southwestern part of the quadrangle. Protoliths were both igneous and sedimentary rocks, and some may have been as old as Precambrian.

On the northwest side of the Shaw Creek fault, metamorphic rock units have a generally northeasterly regional strike, and an apparent stratigraphic sequence is recognized, with the oldest rocks postulated to be on the north and west. The oldest rocks, mostly quartz-mica schist, quartzite, and some amphibiolite, could be as old as Precambrian.

Unfossiliferous thin-layered marbles, calcareous phyllite, and calcareous schist appear to overlie the quartz-mica schist but may be in fault relation. A metasedimentary sequence characterized by black quartzite and black siliceous slaty rock overlies the calcareous rocks in apparent stratigraphic succession and crops out in the center of a synform in the northwestern part of the quadrangle. These rocks are overlain either unconformably or in thrust contact by a greenschist facies metamorphic unit that includes semischist, greenschist, marble, quartzite, and greenstone. A widespread rock type of this unit is light-green or gray semischist characterized by rounded to angular, glassy clear gray or bluish-gray quartz grains that range in size from less than

1 to 5 mm in diameter. Some of the semischists are feldspathic. Locally, this unit is in contact with, or perhaps grades into, a unit composed predominantly of quartzitic and feldspathic cataclastic rocks. The cataclasized rocks may be in a large part cataclasized equivalents of the semischist unit, but rocks with widely ranging degrees of cataclasis are common throughout the quadrangle in many different rock units. Although no fossils have yet been found, greenschist-facies rocks of this sequence, comprising the calcareous unit, black quartzite unit, semischist, and cataclastic unit, are considered to be of probable Paleozoic age, largely on the basis of lithologic similarities to Paleozoic sequences elsewhere in Alaska and in the Yukon Territory of Canada.

The metamorphic history of the Big Delta quadrangle is still in doubt, as the time or times of metamorphism is uncertain. The youngest regional metamorphism occurred before Late Triassic or Early Jurassic time, for metamorphic rock fragments are caught up in granitic rock along the margin of a Jurassic pluton in the adjacent Eagle quadrangle.

Intrusive history before the Mesozoic is difficult to determine, although some small dioritic bodies apparently were emplaced in the Paleozoic. The Permian age of the chert, which is associated with a peridotite mass, documents a late Paleozoic or younger period of major tectonic activity during which oceanic rocks were emplaced on a substratum that is largely continentally derived. The main period of felsic intrusive activity was in middle Cretaceous time and was followed by felsic intrusive and volcanic activity in the Paleocene, possible extending into Eocene time. Local thermal metamorphism occurred adjacent to some of the granitic intrusions. The Big Delta quadrangle seems to have been subject to erosion during most of Mesozoic and Cenozoic time; locally subaerial deposits were laid down in the early Tertiary and glacial, windblown, and alluvial deposits in the Pleistocene and Holocene.

AEROMAGNETIC MAP AND INTERPRETATION (78-529-B)

The aeromagnetic map (sheet 1) of the Big Delta quadrangle was made in 1974 and released by the State of Alaska as an open-file map (Alaska Div. Geol. Geophys. Surveys, 1975). The variations in the magnetic field as depicted on maps such as these provide valuable information concerning the lateral and vertical extent of rock units containing varying amounts of magnetic minerals, generally magnetite. Aeromagnetic maps are a most useful support for a geologic mapping program as well as for mineral resource assessment. An interpretative map (sheet 2) identifies various rock units in the Big Delta quadrangle that have characteristic magnetic anomalies, thereby enabling the interpreter to extrapolate geologic information from known areas into covered or inaccessible regions. In particular, this aeromagnetic map makes it possible to locate the contact-metamorphosed rocks bordering various plutons, some of which are concealed. In addition, the map indicates the position of several masses of ultramafic rocks.

INTERPRETATION OF LANDSAT IMAGERY (78-529-C)

An abridged interpretation of Landsat imagery of the Big Delta quadrangle, Alaska, is given on a black and white Landsat mosaic (band 7) of the State of Alaska assembled by the U.S. Department of Agriculture and on computer-enhanced black and white and color Landsat imagery processed by the U.S. Geological Survey in Flagstaff, Ariz. Landsat scenes selected for computer enhancement are 1768-20342 and 1768-20345, taken August 30, 1974, and 1029-20383, taken August 21, 1972. Parts of these three scenes have been mosaicked by computer so as to cover the entire quadrangle by one image.

Color computer-enhanced products used in the interpretation include linearly "stretched" standard false-color, sinusoidally "stretched" false-color, and simulated natural color images. A black and white diagonal first-derivative image also was used. Copies of these products are available at nominal cost from the EROS Data Center, Sioux Falls, S.D. (Albert and Steele, 1978, sheet 1, table 1).

Information obtained from the various Landsat products includes lineaments, circular and arcuate features, and telegeologic units identified as unique color and "textural" patterns on the color computer-enhanced imagery.

A number of lineaments correspond to mapped faults; some of these indicate that these faults may extend beyond their mapped limits.

Several circular and arcuate features are spatially associated with intrusive bodies; others may reflect intrusive bodies that have not reached the surface.

Telegeologic units identified on the computer-enhanced imagery show a fair to good correlation with mapped geologic units (Weber and others, 1978). This correlation is best for unconsolidated deposits and sedimentary rocks. Correlations with igneous and metamorphic rocks, though fair, are not as good, perhaps because of similarities between actual rock types from one geologic unit to another. Some geologic units can be seen in more than one telegeologic unit, this suggests that some lithologic differences within these geologic units may be distinguishable by telegeology.

MINERAL RESOURCES (78-529-D)

The mineral resources map of the Big Delta quadrangle delineates areas that, on the basis of geologic, geochemical, and geophysical data, are considered to have the greatest potential for new mineral resources, and known mineral prospects and mines are shown. The kinds of deposits that may be present in these areas are described, and estimates of grades and tonnages of ore that might be expected are given.

Vein and placer gold deposits are known in the quadrangle, and, although indications of mineralization are widespread, no other mineral deposits have yet been identified. The geologic, geochemical, and geophysical data are compatible with several different types of deposits, and in certain aspects of the geology, the quadrangle is similar to areas in the eastern part of the Yukon-Tanana Upland and Canada where mineral deposits are known.

Kinds and ages of intrusions, geochemical anomalies, and aeromagnetic interpretation suggest that porphyry copper deposits may be present in the eastern and northern parts of the quadrangle. Porphyry molybdenum may also occur. Massive sulfide deposits associated with both mafic and felsic metavolcanic rocks could occur in association with basaltic greenstones and greenschists in the northeastern part of the quadrangle. The possibility of skarn deposits as a source of copper and tungsten should be investigated.

Most of the gold from the Big Delta quadrangle has come from placer deposits in two areas, the Richardson district (Banner and Tenderfoot Creeks and tributaries) and, in lesser amount, Caribou Creek and nearby tributaries to the Salcha River. Although minor prospecting continues in both areas, large future production is not expected. Most of the creeks in the Big Delta quadrangle have been fairly thoroughly prospected, and the possibility of new discoveries of major gold placer deposits is not especially promising. In some areas, however, glacial deposits and thick deposits of windblown silt and sand could cover deep placers.

Some additional gold-bearing quartz and antimony-bearing quartz veins can be expected to be found in the area of previous lode gold mining near Tibbs Creek, but it seems unlikely that large near-surface occurrences have been missed.

Although ultramafic rocks occur in the Big Delta quadrangle, evidence for large deposits of chromite, nickel, platinum, or asbestos has not been found.

Some areas that appear geologically favorable for mineral deposits, such as the extensively altered zones in the east-central part of the quadrangle, do not have favorable geochemical anomalies.

RECONNAISSANCE GEOCHEMISTRY (78-529-E-N)

A geochemical reconnaissance study was made of the Big Delta quadrangle during the summer field seasons of 1975 and 1977 to aid in identifying areas of possible mineral occurrences. The data delineate areas that contain anomalous concentrations of certain metallic and nonmetallic elements sought.

During the two field seasons, samples of stream sediments, heavy-mineral concentrates of stream sediments, and willow leaves and twigs were collected at approximately 600 sites within the quadrangle at an average density of one site per 20 km^2. Wherever possible, a composite sample of stream-sediment and heavy-mineral concentrate was collected across the width of the stream.

The minus-80-mesh stream-sediment and heavy-mineral concentrates are composed mainly of detrital material that has been mechanically introduced into a stream from bedrock and colluvium within a particular drainage basin. Data from stream sediments and heavy-mineral concentrates are most useful, therefore, for outlining occurrences of outcropping mineralized rock.

The secondary iron and manganese oxides coating stream-sediment grains (oxide residue) are considered scavenging agents that concentrate elements that have been leached from bedrock and colluvium and are migrating as ions in solution. The hydromorphic anomalies produced by the scavenging processes form patterns that outline both known and possible areas of concealed mineralized rock. Willows take up ions moving in soil and ground water and concentrate them in the leaves and twigs. The hydromorphic anomalies produced by this process are similar to those produced by the scavenging action of the iron and manganese oxides. In this way, the data from the ash of willow leaves and twigs supplement information of the other sample media.

North of the Tanana River for distances of 5 to 50 km, there is an extensive cover of windblown silt and sand that ranges from 0.1 m to more than 50 m thick. The windblown mateial is largely derived from glacial and alluvial material from the Alaska Range and contaminates the stream sediment of this area. It contains comparatively few heavy metals.

In the higher eastern parts of the quadrangle, small alpine glaciers formed during the Pleistocene. Most of these glaciers, however, were confined to single valleys, and the glacial deposits are derived from the same drainage area as the more recent stream sediments and probably have a minor effect on the analytical results.

Sample preparation began at the collecting site, where the stream-sediment samples were sieved through a 2-mm screen and the minus-2-mm fraction collected. The sediment mateiral for heavy-mineral concentrate was sieved through a 2-mm screen after a preliminary separation of heavy minerals from the bulk of the stream sediment by panning.

The samples were air dried in the field and the stream sediments then sent to the Geological Survey laboratory in Anchorage, Alaska. In the laboratory, the dried stream sediment was sieved through a minus-80-mesh screen and the minus-80-mesh fraction was analyzed for silver, arsenic, beryllium, cadmium, cobalt, chromium, copper, iron, magnesium, manganese, molybdenum, nickel, lead, antimony, tin, titanium, tungsten, and zinc by a semiquantitiative emmission spectrographic method for geologic materials (Grimes and Marranzino, 1968). These samples were analyzed for copper, lead, zinc, mercury, and gold by atomic absorption (Ward and others, 1969).

The other sample media were prepared and analyzed in the U.S. Geological Survey laboratories in Denver, Colo. The amorphous iron-manganese oxides were leached from the stream sediment using oxalic acid as described by Alminas and Mosier (1976). The oxide residue of the oxalic acid leachate was analyzed by the semiquantitative spectrographic method of Grimes and Marranzino (1968).

The heavy-mineral concentrates were sieved through a 20-mesh (0.8 mm) screen and the minus-20-mesh fraction processed in bromoform (density = 2.86) to remove the remaining light-mineral grains. The heavy minerals were further separated according to magnetic susceptibility by use of a hand magnet and a Frantz Isodyamic Separator.[4] A nonmagnetic fraction was obtained at a setting of 0.6 amperes and split. One split was pulverized and analyzed by the spectrographic method of Grimes and Marranzino (1968). The remaining split of the nonmagnetic fraction was saved for mineralogical examination.

The willow leaves were air dried, separated from the twigs, and shredded using a commercial blender. This material was then ashed in a furnace at 500° C and the resulting ash samples analyzed by a semiquantitative spectrographic method for plant materials (Mosier, 1972).

The distribution and abundance of copper, lead, zinc, cadmium, molybdenum, tin, tungsten, bismuth, antimony, cobalt, chromium, and nickel are shown in this folio (78-529-E through N). Complete analytical data for minus-80-mesh stream sediment, nonmagnetic heavy-mineral concentrates of stream sediment, oxide residue (the oxalic acid leachable fraction) of stream sediment, and the ash of willow leaves and twigs are available in an open-file report (O'Leary and others, 1978). Analytical data for rock samples are available in another open-file report (Foster and others, 1978).

The results indicate that all four sample media are useful in this terrane for outlining areas of both known and possible mineral occurrences. The results further suggest that mineral occurrences are more completely defined by data from a combination of sample media than by data from any one of the sample media alone.

[4]The use of trade names is for descriptive purposes only and does not constitute endorsement of these products by the U.S. Geological Survey.

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