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DISCUSSION

INTRODUCTION

This geologic map is one of a series of maps that summarizes resource investigations conducted by the Alaska Division of Geological and Geophysical Surveys in the upper Kuskokwim region during 1977-84. In addition to geologic maps (Gilbert, 1981; Bundtzen and others, 1982; Gilbert and others, 1982; Gilbert and Solie, 1983; Kline and others, 1986; Bundtzen and others, 1987; Gilbert and others, 1988), several reports were produced that address the area's intrusive and stratigraphic relationships (Potter and others, 1980; Solie and others, 1982; Blodgett and Gilbert, 1983; Bundtzen and Gilbert, 1983; Gilbert and Bundtzen, 1983a; Kline, 1983; Savage and others, 1983; Solie, 1983; Dickey, 1984; Gilbert and Bundtzen, 1984; Hahn and others, 1985; Solie and Su, 1987); structure and tectonics (Bundtzen and Gilbert, 1983; Gilbert and Bundtzen, 1983b); economic resources (Solie and Dickey, 1982; Bundtzen and Gilbert, 1983); and Quaternary geology (Kline, 1983; Kline and Bundtzen, 1986). The McGrath A-3 Quadrangle contains pre-Cenozoic rocks typical of the Dillinger terrane of Jones and others (1981, 1982) and the Dillinger-Mystic succession of Gilbert and Bundtzen (1984). Complex fold patterns and intrusive relationships in the area are characteristic of the southwestern Alaska Range.

STRUCTURE

FOLDS

From outcrop to nappe scale, a low-grade dynamic metamorphic event deformed pre-Cenozoic rocks in the McGrath A-3 Quadrangle into a series of subisoclinal, overturned folds (Gilbert and others, 1988). The largest of these are the Middle Fork anticline (cross section A-A' and B-B') in the northwest corner of the quadrangle and the North Fork anticline (cross section D-D') in the southwest (fig. 1). Other large isoclinal folds occur in the southern part of the quadrangle (cross sections C-C' and D-D'); these complexly repeat Paleozoic strata. Most of the major isoclinal folds verge west or northwest, except in the southeast where vergence is reversed (cross sections B-B' and C-C'). This relationship produces a series of subsidiary north-trending antiforms and synforms in the core of a large fan fold (cross section C-C'; fig. 1). A complementary reversal in vergence from northeast to southwest was mapped by Bundtzen and others (1987) immediately to the east of the McGrath A-3 Quadrangle.

FAULTS

The most prominent high-angle fault in the McGrath A-3 Quadrangle is the Big River fault (and related splays). It diverges from the Farewell fault system about 4 km north of the quadrangle boundary, crosses the northwestern part of the quadrangle, and trends south for about 30 km, offsetting late Quaternary deposits. Small drag folds, deflections in bedding attitudes and stream orientations, and an apparent bend in the ridges adjacent to the fault suggest a component of right-lateral movement. Another high-angle fault in the western part of the quadrangle trends northwest for about 10 km, juxtaposing contrasting parts of the Middle Fork plutonic complex.

Local thrust faults occur along bedding surfaces and within incompetent horizons parallel to axial surfaces of major subisoclinal folds. In the northwestern part of the quadrangle, the thrusts produce digitations on the upright limb of the Middle Fork anticline.

ECONOMIC GEOLOGY

The Farewell region of the Alaska Range contains a large number of metallic mineral occurrences associated with Paleozoic strata and Cenozoic igneous complexes. At present, most economic interest is directed to areas northeast and south of the McGrath A-3 Quadrangle; however, in the western part of the quadrangle, anomalous copper, cobalt, and nickel occur in massive sulfide and mafic diabase (Tim) of the Chip Loy prospect (table 4; Herreid, 1968).

A reconnaissance study (Reed and Miller, 1980) of uranium and thorium in the southern Alaska Range suggests that the Windy Fork pluton (Twg; fig. 1) is enriched in uranium and thorium, at least locally. No anomalous radioactivity, however, was detected within the Middle Fork plutonic complex (fig. 1) during limited hand-held scintillometer surveys in 1982.

Eudialyte, a mineral containing rare-earth elements (REE), was observed in veins proximal to the Windy Fork pluton and in granite talus (Tmg) within the Middle Fork plutonic complex. Also present in some samples of the Middle Fork granite (Tmg) is a cerium-rich, iron-titanium silicate, probably chevkinite. The presence of these minerals suggests REE-enrichment within the peralkaline granites.

Table 1. *Engineering properties of selected Quaternary units, McGrath A-3 Quadrangle, southwestern Alaska*

Map unit	Description	Topography	Drainage	Permafrost	Frost susceptibility	Slope stability	Bearing strength	Possible uses	Avoidances
Alluvium, undifferentiated (Qa)	Poorly to well-sorted fluvial silt, sand, and boulder gravel of fans, terraces, and trunk and tributary streams. May grade into distal outwash (Qdo) deposits	Horizontal to gently sloping surfaces. Older surfaces may be dissected, and mantled with eolian and colluvial deposits	Good in recently deposited alluvium above stream level; fair to poor in older alluvium where permafrost has developed and where covered by silty colluvium and peat	Absent in younger deposits; occurs occasionally in older deposits mantled with silt and peat	Minimal in well-drained modern alluvium; may be moderate to intense in permafrost-bearing active layer mantled with silt and peat	Generally stable, except for ice-rich permafrost-bearing deposits subject to thaw instability and areas adjacent to cutbanks or free faces, where sudden, rapid collapse may occur due to stream erosion or surface loading	Good to fair	Thawed, well- to moderately sorted alluvium generated by larger streams useful as source of sand and gravel	Older terrace and fan deposits that contain permafrost and have significant cover of eolian, organic, or colluvial sediments generally undesirable as materials source
Terrace alluvium (Qat)	Poorly to moderately well sorted fluvial silt, sand, and gravel above flood plains of active streams	Horizontal to gently sloping surface. Older surfaces may be dissected, and mantled with eolian and colluvial deposits	Good in younger permafrost-free deposits without significant cover of organic silt	Present discontinuously in older deposits. May be ice rich in organic silt or where silt infiltrated into gravels by percolating ground water	Terrace gravels generally not susceptible to heave, but occurs in organic silt that caps older terrace alluvium	Generally stable, except for free faces and ice-rich permafrost-bearing deposits. Fill terraces may be subject to slumping and rapid erosion along stream cuts and free faces; strath terraces may be susceptible to slumping along stream cuts	Variable	Terraces along larger streams and rivers are generally the most productive materials sites	
Alluvial-fan deposits (Qaf)	Poorly to moderately sorted fluvial sediment that forms fan-shaped deposits. Consist mainly of coarse-grained clasts but interbedded with discontinuous layers of finer grained material. Occur where a decrease in stream gradient favors deposition, such as where tributaries join higher order streams	Mountain fans slope 1.5° to 5° (average 2°) and are commonly forested, except on highly active fans. Both stable and aggrading fans contain numerous abandoned channels. In places, fans are deeply dissected due to fluctuating base level or diminished sediment supply. Surface area generally <6 mi^2 (10 km^2)	May be inhibited in older, inactive fans mantled by appreciable thickness of silt and organics	May occur in older, inactive fans mantled by appreciable thickness of silt and organics	Frost stable, except silt and organics on old fan surfaces, especially where shallow zones of permafrost inhibit drainage	Generally stable, except where overburden is susceptible to frost heaving	Good	Younger fans are good source of aggregate sand and gravel. In general, fans are suitable construction sites, except where susceptible to mudflow or avalanche	Very steep, short tributaries where potential for mudflow is greatest
Colluvial-alluvial deposits (Qca)	Poorly to moderately sorted interbedded colluvial and fluvial material that forms steep fan- and apron-shaped deposits. Generally found on valley floors and piedmont slopes where steep-gradient ephemeral streams merge with higher order streams	Similar to, but generally steeper and smaller than, alluvial fans	Moderate to poor. Deposits subject to avalanche and torrential flooding during periods of snowmelt or heavy precipitation	Common along north-facing slopes, especially in older deposits. Percentage of segregated ice may be high where silt and organics are prevalent	High in deposits with high silt content and poor drainage	Thaw-unstable where perenially frozen or where containing excess ice. Deposits of predominantly silty material susceptible to creek, especially where saturated by near-surface ground water, such as spring along faults. Colluvium forms sag ponds along active fault trace	Variable but generally fair to poor	Local pods or lenses in fans may be source of small quantities of moderately sorted, gravel-rich fluvial sand	Fan surfaces may be subject to avalanche, mudflow, subsidence, and local liquefaction; therefore, caution should be exercised during excavation and construction activities
Colluvium, undifferentiated (Qc)	Generally unsorted, unstratified to crudely stratified deposits derived from mass-wasting processes, such as solifluction and landslide. Include talus and mixed slope colluvium. Deposits that resulted from episodic mass movement may be interbedded with surface organics or thin layers of fluvial sediment	Variable, ranging from hummocky lobes (landslide debris) to very steep cones and aprons with smooth, convex-upward profiles (talus)	Variable, depending on percentage of silt- to clay-sized material and stage of permafrost development	Present in toes of thick talus accumulations, sometimes with significant interstitial ice, and in talus that grades into rock glaciers containing permafrost; present discontinuously in deposits situated at lower levels of north-facing slopes	High in deposits that contain large proportions of silt or organic silt	Steep colluvial deposits, such as talus aprons at or near angle of repose, generally unstable. In addition, talus subject to snow avalanches, mudflows, and rock falls	Variable but generally fair to poor	Generally unsuitable as materials source, although finer grained colluvium may be used as fill	Deposits that show signs of recent deposition or shifting should not be used as building sites
Till and tillites (Qdt)	Unsorted to poorly sorted, unstratified drift deposited by glacial ice as ground, terminal, and lateral moraines. Cobble- and boulder-size clasts subangular to subrounded, polyhedrally faceted, and lithologically varied, representing wide variety of sources up valley. Till units vary in composition, depth of weathering, and surface morphology because of age, aspect, elevation, exposure, vegetation, and dominant clast types, all of which control ratio and duration of surface modification. Thickness ranges from a few inches (centimeters) to >190 ft (>60 m). In extreme northwestern part of quadrange, a few older till units are cemented with calcite and thus classified as tillite	Varies with age, slope, aspect, elevation, and vegetation: pre-Wisconsin till subdued to completely masked; lower Wisconsin till commonly blanketed with peat and eolian deposits but exhibits subdued hummocks and wholly or partially filled kettles; and upper Wisconsin till discontinuously covered with peat and loess, thus shows primary morainal morphology	Integrated in pre-Wisconsin till; moderately integrated in lower Wisconsin till; and poorly integrated in upper Wisconsin till	Widespread in till covering foothills plateau in northern part of quadrangle near Middle Fork Kuskokwim River. In areas with thick peat development, permafrost table lies about 3 ft below surface of deposit; interstitial ground ice and occasional large ice masses common throughout upper 15 ft of deposit	Subject to moderate to intense seasonal frost heave. May be thaw unstable following surface disturbance if deposit contains ice-rich permafrost	Stable in permafrost areas if kept frozen. Subject to failure where saturated or where oversteepened by stream erosion	Good in permafrost free till on low to moderate slopes with no appreciable peat and loess accumulation; poor in thawed, thick peat mantle along cutbanks and steep valley walls	Poor source of clean sand and gravel because of poor sorting and variable clay and silt content. Till commonly overlies outwash gravels, which may be extracted if shallow	Saturated or overdeepened deposits, which may be subject to slump failure; and permafrost areas, where local thaw subsidence may occur
Outwash (Qdo)	Stratified drift deposited by glacial meltwater in channels and as large fans and terraces. Deposits become finer grained and better sorted with increasing distance from source, eventually becoming indistinguishable from nonglacial alluvium. Material proximal to source consists of cobble and boulder gravel and stringers of silt and sand. Cut-and-fill structures and clast imbrication can be seen in cutbanks and test pits	Gently sloping, relatively flat surfaces exhibiting abundant braided channel scars often accentuated by differences in vegetation. Most distinguishable outwash deposits in quadrangle occur as fans or valley trains	Good where outwash gravels are at or near surface of deposit; very poor where peat and silt cover promoted frost development and near springs where water table is close to ground surface	Sporadic, occurring where accumulations of peat and organic silt promoted development of segregated ice. Ice typically limited to fine-grained overburden	None, unless thickly mantled by silty organic material	Stable, except cutbanks along active streams	Good in gravel below peat and silt overburden	Good materials source, although may need mechanical sizing for poor to moderate sorting. Provides good foundation where peat and silt overburden is stripped or absent	Cutbanks along active streams may slough; thus are not recommended for structure sites

Table 2. *Upper Ordovician and Lower Silurian graptolites*[a] *from McGrath A-3 Quadrangle, southwestern Alaska*

Map no.	Field no.	Museum no.[b]	Collection site	Fossil	Age and correlation
F-1	82WG241	A-1893	Black argillite (SOsh) 16 ft (5 m) stratigraphically below 10-ft (3-m)-thick laminated limestone that marks base of phyllitic calcareous sandstone (Ss) unit	*Retiolites* of *R. geinitzianus angustidens* Elles and Wood, *Monograptus spiralis* cf. subsp. *contortus* Perner, *M.* sp. aff. *M. priodon* (Bronn), and *Monoclimacis* sp. aff. *M. cremulata* (Tornquist)	Late Early Silurian; correlative with *M. spiralis* Zone of Lenz, 1982, Royal Ontario Museum 130
F-2	83JC63	- -	Sheared rocks of black shale (SOsh) unit	Fragmentary specimens, poorly preserved and distorted by tectonic activity: *Retiolites geintizianus geintizianus* (Barrande), *Monograptus* cf. *M. exigus primulus* Boucek and Pribyl, *M.*; aff. *M. proteus* (Barrande), *M. sp.* (with tubed thecae like *M. flemingii*), *Pristiograptus* sp., and *Monoclimacis* sp.	Late Early Silurian; approximately correlative with *Monograptus crispus* Zone
F-3	83JC59	- -	Black shale (SOsh) unit	Sparse fauna, poorly preserved: *Glyptograptus* sp., *Climacograptus?* sp., and *Didymograptus?* sp.	Probably Middle Ordovician
F-4	82WG306a	A-1934	Near top of black shale (SOsh) unit	*Monograptus turriculatus* (Barrande), and *M. exiguus primulus* Boucek and Pribyl	Late Early Silurian; correlative with *M. turriculatus* Zone
F-4	82WG306c	A-1932	Laminated limestone and siltstone (lS) 6 ft (2 m) stratigraphically above contact with black shale (SOsh) unit	*Monograptus* sp., *Pristiograptus* sp., and possible diplograptid	Early Silurian
F-4	82WG306d	A-1933	Black siltstone stratigraphically on top of laminated limestone (lSl) that marks base of phyllitic sandstone (Ss) unit	*Monograptus* aff. *M. flemingii* (Salter), and *Cyrtograptus* aff. *C. rigidus* Tullberg	Early Late Silurian (Wenlockian)
F-5	82WG286a	A-1951	Black organic siltstone of black shale (SOsh) unit	*Climacograptus* sp. (The semicircular apertural excavations resemble *C. caudatus* and *C. tubuliferous* of late Middle Ordovician age, but the specimen lacks the distinctive appendages of those species.)	Late Middle Ordovician(?)
F-5	82WG287c	A-1948	Black organic siltstone immediately above site of sample 82WG286a	Poorly preserved diplograptids: *Climacograptus*? and *Glyptograptus?*	Probably Middle or Late Ordovician
F-5	82WG287d	A-1949	Black organic siltstone immediately above site of sample 82WG287c	*Orthograptus* cf. *O. amplexicaulis* (Hall), and *Dicranograptus*? sp.	Late Middle or Late Ordovician
F-5	82WG287e	A-1950	Black organic siltstone immediately above site of sample 82WG287d and just below contact with limestone	*Akidograptus* sp. (or *Orthograptus acuminatus*), *Atavograptus* sp., *Dimorphograptus?* sp., and *Climacograptus* sp.	Earliest Silurian; approximately correlative with *O. acuminatus* through *A. atavus* Zones
F-6	83WG88b	- -	Lower part of black shale (SOsh) unit	*Tetragraptus* of *T. quadribrachiatus* type	Approximately Early Ordovician

[a] Fauna identified by Claire Carter, U.S. Geological Survey.
[b] Specimens with museum numbers are part of the paleontologic collection of the University of Alaska Museum, Fairbanks, Alaska.

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Table 3. *K-Ar analyses*[a] *for selected rock samples, McGrath A-3 Quadrangle, southwestern Alaska*

Map (field) no.	1(82DNS211)	2(82DNS196)[b]	2(82DNS196)[c]	3(82DNS197)	3(82DNS197)	4(82DNS209)	5(82DNS193)	6(82DNS195)[c]	7(83BTFWF)
Rock type	Quartz monzonite	Gabbro	Gabbro	Quartz monzonite	Quartz monzonite	Quartz monzodiorite	Granite	Granite	Alkali granite
Mineral dated	Biotite	Biotite	Biotite	Biotite	Amphibole	Biotite	Amphibole	Amphibole	Aegirine-augite
K_2O (wt%)	8.305	7.843	7.843	8.554	0.938	8.776	1.260	1.018	0.070
Sample wt (g)	0.3924	0.6133	0.6133	1.0569	5.1950	0.4416	1.6443	5.0868	1.7910
$\frac{^{40}Ar^*}{(moles/g) \times 10^{-11}}$	68.8	64.4	64.	70.7	7.85	72.6	10.6	8.28	0.237
$\frac{^{40}Ar^*}{^{40}K \times 10^{-3}}$	3.34	3.31	3.31	3.34	3.38	3.34	3.41	3.28	1.37
$\frac{^{40}Ar^*}{^{40}Ar(total)}$	0.553	0.667	0.663	0.869	0.729	0.761	0.613	0.709	0.209
Age[d] ± 1σ (m.y.)	56.6 ± 1.7	56.1 ± 1.7	56.1 ± 1.7	56.6 ± 1.7	57.2 ± 1.7	56.6 ± 1.7	57.7 ± 1.7	55.6 ± 1.7	23.5 ± 0.7

[a] Analyses by J.D. Blum, DGGS-UAF Cooperative Geochronology Laboratory, Fairbanks, Alaska.
[b] Run 1.
[c] Run 2.
[d] Constants used in age calculations: $\lambda_\epsilon + \lambda'_\epsilon = 0.581 \times 10^{-10} yr^{-1}$; $\lambda_\beta = 4.962 \times 10^{-10} yr^{-1}$; and $^{40}K/K_{total} = 1.167 \times 10^{-4}$ mol/mol.
* Radiogenic isotope.
σ Standard deviation.

Table 4. *Geochemical analyses*[a] *for selected rock samples from Chip Loy prospect, McGrath A-3 Quadrangle, southwestern Alaska*
[Results reported in ppm unless otherwise noted]

Sample no.[b]	Cu	Pb	Zn	Au	Ag	Mo	Sb	W[c]	As	Co	Ni	Fe	Pt	Pd	Mn	Comments
KW19458	590[d]	55[d]	41[d]	ND[e]	- -	- -	- -	- -	- -	49[d]	540[d]	- -	ND[e]	ND[e]	- -	Boxwork
KW19459	11,400[c]	57[d]	185[d]	0.001[e]	- -	- -	- -	- -	- -	960[c]	12,750[c]	30 pct[f]	ND[e]	ND[e]	- -	Massive sulfide mineralization
KW19460	970[c]	29[d]	47[d]	ND[e]	- -	- -	- -	- -	- -	595[c]	ND[c]	60 pct[f]	ND[e]	ND[e]	- -	Massive sulfide mineralization
2542	83	7	26	ND	ND	3	ND	2	ND	43	1,140	39,100	- -	- -	328	Limonitic phyllitic calcareous sandstone (Ss)
2543	5,540	23	226	ND	5.6	4	ND	2	378	496	8,200	163,000	- -	- -	292	Limonitic phyllitic calcareous sandstone (Ss) - Contains 1-ft (0.3-m) zone of massive sulfide mineralization
2544	2,300	35	153	ND	2.3	5	ND	2	111	291	5,320	147,000	- -	- -	401	Massive sulfide mineralization
2545	579	18	ND	ND	1.5	4	ND	3	105	14	456	150,000	- -	- -	117	Phyllitic calcareous sandstone (Ss) - Surface altered to ferricrete
2546	4,670	40	ND	ND	3.1	17	ND	2	22	863	14,400	432,000	- -	- -	ND	Phyllitic calcareous sandstone (Ss) - Contains gossan associated with 1-ft (0.3-m) zone of massive sulfide mineralization
2547	3,340	29	ND	ND	1.7	8	ND	2	ND	930	13,500	262,000	- -	- -	ND	Mafic diabase (Tim) - Contains 2.5-ft (0.75-m) zone of massive sulfide mineralization
2548	2,820	36	24	ND	4.8	4	ND	3	ND	182	2,590	97,300	- -	- -	196	Mafic diabase (Tim) - Contains minor sulfide mineralization
2549	2,250	27	46	ND	3.5	3	ND	2	ND	101	1,810	67,700	- -	- -	166	Mafic diabase (Tim) - Contains 25- to 30-pct disseminated sulfide mineralization
2550	627	28	28	ND	0.9	4	ND	2	ND	55	747	48,800	- -	- -	209	Mafic diabase (Tim) - Contains minor disseminated sulfide mineralization
2551	5,650	35	ND	ND	2.1	10	ND	2	ND	1,470	22,100	376,000	- -	- -	ND	Massive sulfide mineralization

[a] All samples analyzed by DGGS Minerals Laboratory unless otherwise noted.
[b] Samples KW19458, KW19459, and KW19460 collected by W.S. Roberts, U.S. Bureau of Mines, 1981. Samples 2542 through 2551 collected by T.E. Smith, M.A. Albanese, and W.G. Gilbert (DGGS), 1982, from 40-ft-long channel across mineralized contact between mafic diabase (Tim) of Tertiary age and phyllitic calcareous sandstone (Ss) of Devonian age.
[c] Analyzed with atomic absorption spectrometry by Bondar-Clegg, Inc., Lakewood, Colorado.
[d] Analyzed with atomic absorption spectrometry by TSL Laboratories, Spokane, Washington.
[e] Analyzed with inductively coupled plasma spectrometry by W. Barry, U.S. Bureau of Mines, Reno Research Center.
[f] Analyzed with X-ray fluorescence spectroscopy by W.S. Roberts, U.S. Bureau of Mines, Juneau.
ND = Not detected.
- - = Not analyzed.

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