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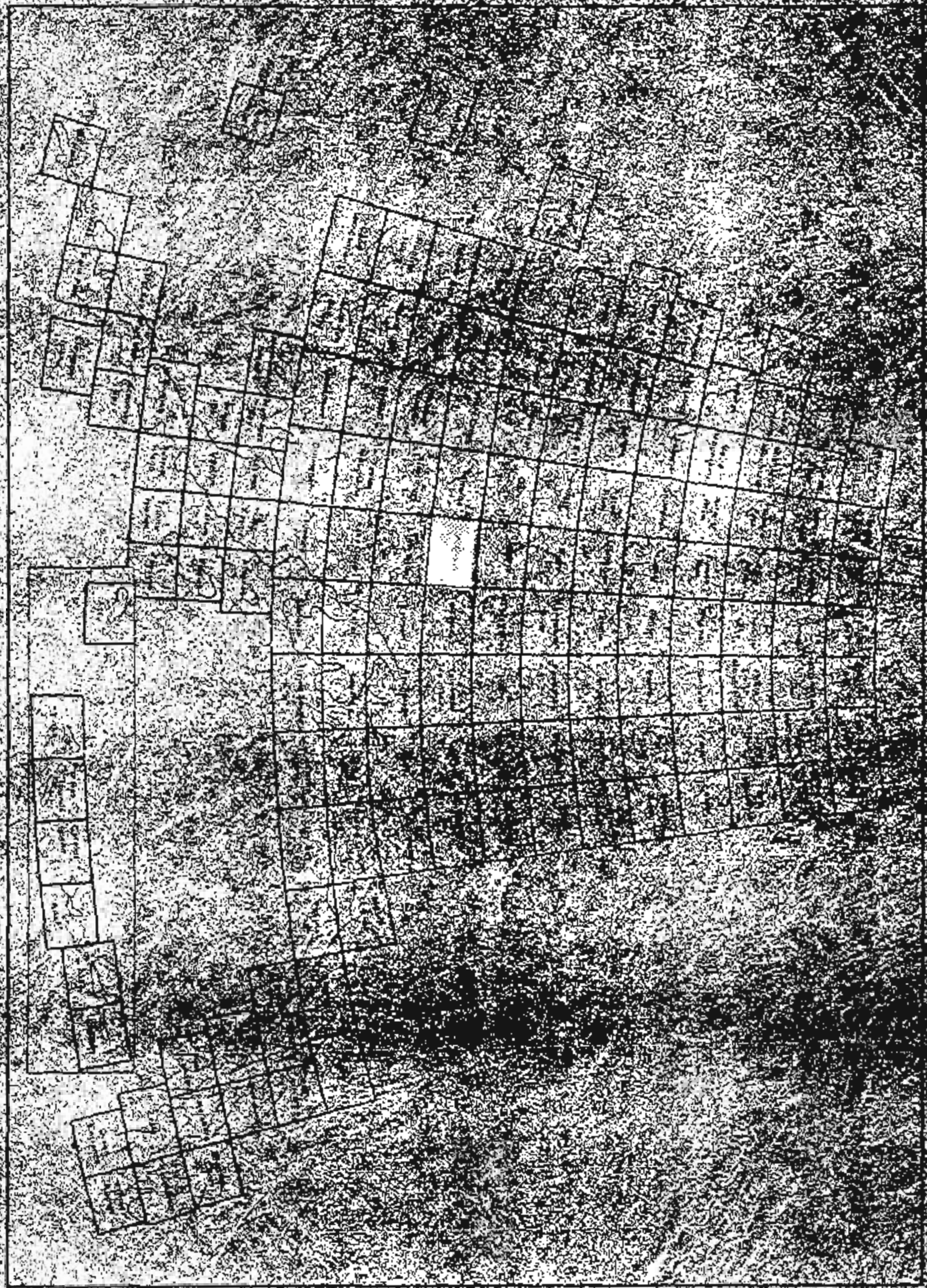

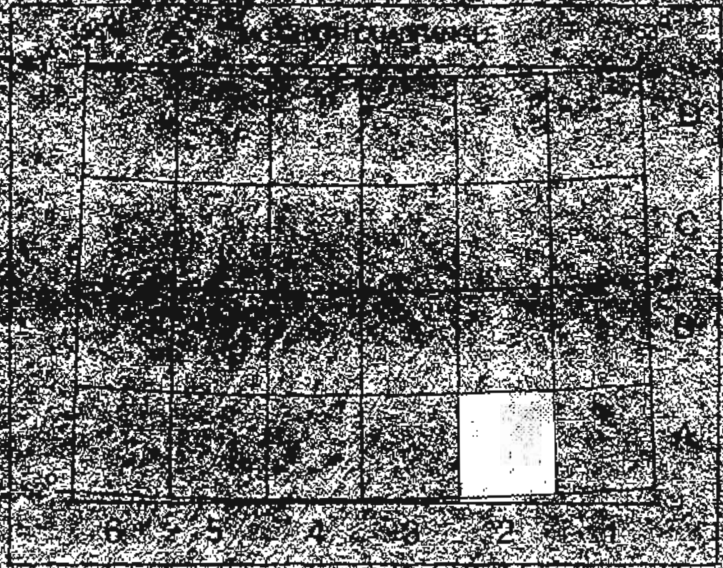

GEOLOGY OF THE MCGRATH A-2 QUADRANGLE, ALASKA

By T.K. Bundtzen, J.T.Kline, T.E. Smith, and M.D. Albanese

PROFESSIONAL REPORT 91

A summary of the stratigraphy, lithology, and mineral resources of a structurally deformed 450 km² (175 mi²) region on the north flank of the western Alaska Range, Alaska

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INTRODUCTION

The McGrath A-2 Quadrangle is composed of rugged mountains with numerous glacier-scoured, U-shaped valleys on the northwest flank of the southern Alaska Range. Elevations range from 1,750 ft (534 m) at Post River to 7,880 ft (2,402 m) in the west-central part of the quadrangle. No roads exist in the area; however, a 1,700-m-long gravel airstrip is maintained at the Farewell Federal Aviation Administration station 35 km to the north. Fixed-wing airplanes can also land on an unmaintained airstrip at Bowser Creek, on gravel flood plains, and on Post Lake.

Sedimentary rocks of the McGrath area form irregular, rolling hillslopes; igneous plutons, dike swarms, and thermally altered rocks form prominant, rugged, circular massifs. Valley floors and hillslopes below 4,000-ft (1,220 m) elevation are mantled with surficial deposits and vegetation. Colluvium covers many hillslopes, and bedrock exposures are concentrated on ridge tops and cirque headwalls and in steep canyons. Bedrock and surficial control is generally excellent. Although the metric system is used in this report, elevations are also expressed in feet to be consistent with the published topographic maps.

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BEDROCK GEOLOGY

Sixteen mappable rock units that range in age from Cambrian(?) to Cretaceous are exposed in the McGrath A-2 Quadrangle. Figure 1 (map inset) shows a simplified version of the bedrock geology. Most layered units were originally described by Brooks (1911) as the Tatina Group after exposures on the Tatina River in the McGrath B-1 Quadrangle 12 km northeast of Post Lake. Armstrong and others (1977) later referred to these rocks as the 'sedimentary rocks of the Dillinger River.' Jones and others (1982) assigned the term 'Dillinger terrane' to those deepwater rocks of lower to mid-Paleozoic age in the study area; Bundtzen and Gilbert (1983) used the term 'Dillinger group' for these same rock units.[1] Gilbert and Bundtzen (1984) referred to most pre-Jurassic layered rocks south of the Farewell fault in the southern Alaska Range as the 'Dillinger-Mystic succession.' The Dillinger terrane consists of Cambrian and Ordovician limestone turbidite deposits (OЄls) with minor greenstone sills (OЄg); Ordovician and Lower Silurian interbedded shale, chert, and minor limestone (SOsh, lSl); Middle to Upper Silurian laminated limestone (mSl, uSl, uSsl), sandstone turbidite (Ss, mSs), and shale (mSa); and Upper Silurian to Lower Devonian limestone (DSl) and limestone breccia and calcareous sandstone (DSls). Bundtzen and Gilbert (1983) suggested that the Dillinger terrane reflects a shallowing-upwards marine regime that includes basinal, turbidite-fan, and foreslope depositional environments on a Paleozoic continental margin. Limited paleocurrent data (table 1) and probable facies relationships with the Nixon Fork terrane (Bundtzen and Gilbert, 1983) indicate that during the Paleozoic Era, a shoreline existed northwest of the study area. Bearings of the paleocurrents are dominantly southeasterly in lower Paleozoic units, but are dominantly northeasterly in the Silurian turbidite fan. The latter bearing was probably derived from a paleocurrent that was directed down the axes of a sedimentary trough parallel to the continental margin. The Dillinger group ranges in thickness from 2,750 to 3,000 m in the study area; the base is not exposed.

The Dillinger terrane is overlain by a 1,000-m-thick section of sublithic quartz sandstone, limestone, and fluvial(?) conglomerate (ℙDs,ℙDl, ℙDc) of probable Middle Devonian through Late Pennsylvanian age. Gilbert and Bundtzen (1984) suggested that these units form a southwestern extension of the Mystic terrane as described by Jones and others (1982) in the Talkeetna Quadrangle. Gilbert and Bundtzen (1984) also suggested that the Mystic terrane is a continuation of the sedimentary basin that formed in early Paleozoic time (Dillinger terrane).

A deformed package of lithic sandstone, siltstone, and conglomerate (KJs) of Late Jurassic to Early Cretaceous age is in tectonic contact with Paleozoic rocks. The deformed unit is part of a 50,000-km^2 turbidite-dominated basin that trends from southcentral Alaska near Cantwell (Smith, 1981, p. 15-17) 300 km west-southwest to Lake Clark (Eakins and others, 1978). Jones and others (1982) referred to this flysch sequence as the Kahiltna terrane after exposures in the Talkeetna Quadrangle to the east.

Seven units of hypabyssal rocks crop out in the study area (Tim, Tif, Tids, Tqm, Tqp, Tia, Td). They include the Bowser and Post River intrusive complexes and an extensive east-west-trending dike swarm in the westcentral

[1] For descriptive convenience only, the following text uses the term 'Dillinger terrane.'

Table 1. Paleocurrent data[a] from Paleozoic sedimentary rocks in the McGrath A-2 Quadrangle, Alaska.

Map no.	Field no.	Rock unit	Flow regime[b]	Azimuth in ° (corrected for tilt)	Grand mean
1	82BT233	DSls	upper	25	25.0
2	82BT166	SOsh	upper	24	
				355	
				352	08.0
3	82BT163	mSs	upper	24	
				29	26.5
4	82BT188	mSs	upper	183	
				202	192.5
5	82BT494	mSs	upper	322	
				321	321.5
6	83BT300	uSsl	upper	25	
				40	
				50	
				26	
				40	36.2
7	83BT304	Ss	upper	25	
				32	28.5
8	83BT303	mSs	upper	45	45.0
9	83BT311	mSs	upper	25	
				15	20.0
10	83BT311	uSsl	upper	0	
				25	
				40	21.7
11	83BT148	OЄls	lower	120	
				130	
				119	133.0
12	83BT147	OЄls	lower	125	
				118	
				109	117.3
13	82BT264	OЄls	lower	225	
				250	
				235	
				240	237.5
14	82BT281	ℙDc	lower	220	
				210	215.0
15	83BT123	mSs	upper	332	
				312	
				355	313.0

[a] Measurements taken and interpreted by T.K. Bundtzen. Churkin and others (1977) also present paleocurrent data from study area.

[b] Upper flow-regime structures include flutes, striation casts, and longitudinal ripples. Lower flow-regime structures include cross-beds.

part of the map area. The Bowser complex consists of igneous breccia with a quartz monzonite core and quartz porphyry intrusive rocks that cut the igneous lithologies. The Post River pluton is a porphyritic quartz monzonite. Both plutons have sharp high-angle contacts with host rock units.

Prominant dike swarms and scattered dikes of augite basalt, andesite, and rhyolite cut layered rocks in the area; basaltic and andesitic dikes are most abundant. Rhyolite dikes consistently cut the more mafic varieties.

Two K-Ar analyses from intrusive rocks in the study area (table 2) yield early Tertiary ages consistent with those reported by Reed and Lanphere (1972). However, some dikes in adjacent map areas yield ages as young as 20 m.y. (Bundtzen and others, in preparation). Solie and others (1982) believed that all igneous rocks are part of at least two calc-alkaline subduction-related suites active during Tertiary time (table 3).

Table 2. Analytical data for ^{40}K-^{40}Ar age determinations.[a]

Sample	1[b]	2[c]
Rock type	Quartz porphyry	Quartz monzonite
Mineral dated	Biotite	Biotite
K_2O (wt %)	5.287	5.412
Sample wt (g)	0.1600	0.1277
$^{40}Ar(rad)$ moles/g) x 10^{-11}	46.76	49.00
$\frac{^{40}Ar(rad)}{^{40}K \times 10^{-3}}$	3.57	3.65
$\frac{^{40}Ar(rad)}{^{40}Ar(total)}$	0.534	0.477
Age (m.y.)	60.4 + 1.8	61.8 + 1.9

[a]Constants used: $= 0.581 \times 10^{-10}\ yr^{-1}$, $= 4.962 \times 10^{-10}\ yr^{-1}$.

[b]Analyzed by Daniel Krummenacher, San Diego State University, San Diego, California.

[c]Analyzed by J.D. Blum, DGGS-University of Alaska Cooperative Geochronology Laboratory, Fairbanks, Alaska.

QUATERNARY GEOLOGY

Eleven Quaternary units were mapped in the McGrath A-2 Quadrangle; these units include Wisconsin and Holocene drift, ice-contact, outwash, and till deposits and Holocene colluvium and alluvium. Multistoried cross-valley profiles, perched side-glacial notches, faceted spurs, high level erratic boulders, and multiple lateral and end moraines demonstrate that the study area underwent several major episodes of glaciation. A more complete glacial chronology of the general Farewell area is summarized in Kline and Bundtzen (1986). Before late Wisconsin time, most of the McGrath A-2 Quadrangle was overlain by an extensive ice field with only a few nunataks protruding above ice. Two major glacial episodes of Wisconsin age are primarily responsible for the current morphology and unconsolidated surficial deposits.

Evidence for pre-Wisconsin glaciation in the McGrath A-2 Quadrangle consists of scattered erratics that are found at elevations above 4,500 ft (1,372 m) and relict valley morphology; however, most older deposits have been eroded from the rugged terrain. The oldest extensive glacial deposits in the McGrath A-2 Quadrangle (Odt in high-level terraces) are inferred to be roughly correlative with early Wisconsin deposits of Knik age in the upper Cook Inlet basin (Karlstrom, 1964) and Talkeetna Quadrangle (Nelson and Reed, 1978) based on morphology, degree of weathering, and extent. These glacial deposits may also correlate with deposits of Selatna age along the Big River to the northwest and of Farewell I age along the South Fork Kuskokwim River (originally described by Fernald, 1960). The apparent discrepancy in the latter correlation with previously mapped drift units is due to a recent reevaluation of Fernald's earlier valley-to-valley correlations of drift limits (Kline and Bundtzen, 1986).

In the McGrath A-2 Quadrangle, late Wisconsin drift is roughly correlative with Naptowne-age deposits of the upper Cook Inlet basin (Karlstrom, 1964) and Talkeetna Quadrangle (Nelson and Reed, 1978) and with Farewell II age drift (Fernald, 1960) that occurs along the mountain front in adjacent quadrangles.

Multiple recessional moraines that occur in major southerly tributaries to the Post River resemble the latest Wisconsin and early Holocene deposits of the upper Cook Inlet basin and Kenai Peninsula that Karlstrom (1964) referred to as Skilak and Tanya readvances of late Naptowne time. Late Holocene moraines that extend a few kilometers down-valley from cirque headwalls throughout the study area were deposited well after the main trunk-glacier systems collapsed. Nested neoglacial moraines indicate at least two, and possibly more, late Holocene pulses of glacier activity.

Modern alluvial units (Qa, Qat, Qaf) include terrace, fan, and modern-stream deposits. Colluvial processes and vigorous stream erosion caused by

Table 3. Major-oxide analyses and CIPW norms of igneous rocks.

Map no.	1	2	3	4	5	6	7
Field no.	82BT184	82BT165	82BT183	83BT300	82BT323	82BT275	82BT181
Rock type	Olivine gabbro	Gabbro dike	Rhyolite	Andesite dike	Dacite	Quartz monzonite	Rhyolite
SiO	45.53	52.02	77.31	56.01	67.00	68.98	77.58
Al_2O_3	14.06	17.04	12.84	15.18	16.81	14.39	14.16
Fe_2O_3	3.45	4.09	0.13	3.19	2.04	0.96	0.14
FeO	5.94	3.61	1.33	7.32	0.71	1.80	1.26
MnO	0.16	0.16	0.05	0.19	0.03	0.05	0.02
MgO	6.15	4.77	0.12	1.53	1.71	0.69	0.15
CaO	8.77	6.69	1.34	4.80	5.05	2.55	0.36
Na_2O	3.31	3.78	3.43	4.28	3.61	3.07	0.15
K_2O	4.28	0.89	2.06	3.38	0.93	4.18	2.80
TiO_2	1.95	0.95	0.10	1.69	0.54	0.46	0.03
P_2O_5	0.70	0.29	0.10	0.85	0.33	0.17	0.03
H_2O	0.34	0.16	0.65	0.30	0.40	0.32	0.00
LOI	4.77	4.81	1.32	0.94	1.04	0.88	3.16
TOTAL	99.41	99.26	100.78	99.66	100.21	98.50	99.84
Norms							
Quartz	0.000	4.201	46.710	5.503	30.006	28.275	67.317
Orthoclase	25.291	5.259	12.173	19.973	5.495	24.700	17.114
Albite	6.975	31.983	29.022	36.214	30.545	25.976	1.313
Anorthite	10.866	26.899	5.995	12.226	22.898	11.540	1.645
Diopside	22.497	3.561	0.000	5.128	0.000	0.000	0.000
Hypersthene	0.000	16.197	0.299	9.579	4.259	3.564	0.386
Olivine	6.951	0.000	0.000	0.000	0.000	0.000	0.000
Magnetite	5.002	3.552	1.260	4.625	0.824	1.392	1.448
Ilmenite	3.704	1.804	0.151	3.210	1.026	0.874	0.044
Corundum	0.000	0.000	2.771	0.000	1.472	0.586	10.654
Apatite	1.621	0.672	0.232	1.968	0.764	0.394	0.072
Nepheline	11.394	0.000	0.000	0.000	0.000	0.000	0.000
Differentiation index	43.65	41.44	87.90	61.68	66.05	78.95	85.74
Irvine and Baragar (1971) classification	Alkalic trachybasalt	Subalkalic andesite	Subalkalic rhyolite	Tholeiitic andesite	Subalkalic andesite	Subalkalic adamellite (quartz monzonite)	Low-calcium rhyolite

uplift and lowering of local base level by glacial scour continue to modify surficial and bedrock units of the landscape.

STRUCTURE

Layered rocks of the study area have undergone isoclinal to subisoclinal folding and synkinematic thrusting (see cross sections A, B, C, D). The Terra Cotta and Sheep Creek anticlines can be traced south and north of the study area for at least 100 km and 70 km along strike, respectively (fig. 1, map inset). Most subisoclinal folds trend N. 10^{o}-40^{o} E., plunge to the northeast, and are locally overturned to the northwest. However, west of the Sheep Creek fault (fig. 1), fold asymmetry is reversed, and axes plunge to the southwest and are overturned to the southeast. The trend of fold axes sharply turns 20^{o} E. near Bowser Creek (fig. 1). Three major overturned folds in the McGrath A-2 Quadrangle are responsible for an estimated 20 to 25 km of crustal shortening. Locally, minor slip has occurred along thrust faults. Isoclinal folding and thrust faulting occurred after Lower Cretaceous units (KJs) were deposited and before rocks were intruded by plutons and dikes during Paleocene time. These plutonic rocks apparently were intruded during extensional processes in early Tertiary time. Later, east-west to northeast broad warping locally steepened thrust faults and isoclinal folds. The Tatina fault (after Reed and Lanphere, 1972) separates the Mesozoic flyschoid rocks from the Dillinger terrane; the fault trace is obscured by Quaternary deposits throughout the map area.

Northwest-trending, high-angle faults, such as the Bowser Creek fault, cut bedrock units and older structures; however, lateral and vertical displacement along these youthful faults only amounts to a few hundred meters.

ECONOMIC GEOLOGY

Mineralization in the McGrath A-2 Quadrangle consists of lead-zinc-silver-copper skarn replacement bodies in limestone; veins and stockwork that contain zinc, tungsten, tin, and silver in igneous rocks; cobalt- and nickel-bearing massive pyrrhotite replacement deposits; and anomalous lead, zinc, and silver in shale (SOsh). The assay data in table 4 are not derived from channel samples and hence do not necessarily show average metal values of mineral deposits in the area.

Base-metal skarns at Bowser Creek (table 4) are typical of low-temperature, fracture-controlled lead-zinc skarns described by Einaudi and Burt (1982). Reed and Elliott (1968a,b) described the Bowser Creek occurrences and presented assay and prospect map information in addition to that reported here. The main Bowser Creek deposit (table 4, map no. 2) consists of replacement deposits of pyrrhotite, sphalerite, galena, and chalcopyrite in a hedenbergite-johannsenite skarn next to a felsite dike. The main pyrrhotite-sphalerite occurrences are in a johannsenite-rich exoskarn in the marble front; however, important fissure-controlled, silver-rich, galena-tetrahedrite-pyrrhotite-calcite mineralization occurs in the marble 5 to 25 m from the marble front. The fissure deposits have been mined for silver, and modest amounts of ore were marketed before 1973. Some metasomatic fluids have replaced felsic dikes with anhedral garnet and pyroxene and produced a small area of endoskarn. Skarn deposits northeast of Bowser Creek (table 4, map no. 3) are apparently associated with quartz monzonite porphyry. A sphalerite-pyrrhotite-johannsenite skarn zone 3 to 10 m thick continues at distances of 14 to 40 m within the marble away from the intrusive contact. Assay data (table 4) for both deposits show positive correlation of silver with lead content.

Fracture-controlled, cobalt-and-nickel-bearing massive pyrrhotite deposits cut hornfelsed shale (SOsh) in a bedrock canyon near Post Lake (table 4, map no. 5). Several massive pyrrhotite zones 0.5 to 2 m thick and 20 to 80 m long trend N. 15^{o}-25^{o} W. and parallel the joint-cleavage set in the host rock. A small quartz monzonite plug is exposed 1 km north of the occurrences. Skarn mineralogy is notably absent. Pyrrhotite samples contain up to 570 ppm copper, 156 ppm cobalt, and 637 ppm nickel, well below commercial assay levels. However, the occurrences are similar to the Chip-Loy nickel-cobalt deposit (McGrath A-3 Quadrangle) that contains up to 2.25 percent nickel and 0.18 percent cobalt (Herreid, 1968; Gilbert and Solie, 1983).

Veins and stockwork in igneous rocks occur at the head of Bowser Creek and in the Post River pluton. The Bowser mineralization (table 4, map no. 4, fig. 2, and map inset) occurs as 3- to 20-cm-thick veins of pyrrhotite, sphalerite, and minor chalcopyrite in a felsic intrusion (Tqp) that is similar in composition to the felsic dike exposed in the skarn described above. Sulfide-bearing veins in the intrusion are localized along steeply dipping joints that trend N. 65-70^{o} W. Skarn mineralogy is notably absent. Occurrences in the Post River pluton (table 4, map no. 6a,b) consist of pyrite ± scheelite-chalcopyrite-quartz-calcite veinlets in hornfelsed roof pendants, in fracture zones in the intrusion, or in the contact zones between intrusions and country rock. The mineralized areas are poorly exposed and of unknown extent. A sample of mineralized vein found in the rubble yielded 1.1 percent copper, 0.089 percent tin, 98 ppm silver, and 0.028 percent tungsten. Scheelite occurs in pan concentrates from ravines that drain the south side of the intrusion. The Post River intrusion is similar to a tungsten-bearing quartz monzonite plug in the McGrath B-2 Quadrangle (Bundtzen and others, in preparation) and is also similar to tungsten-bearing intrusions that cut identical Paleozoic rock units (Rabbit Kettle Formation) in the Selwyn Basin, Canada (Anderson, 1982).

Table 4. Descriptions and analytical results of selected mines and minerals prospects and occurrences in the McGrath A-2 Quadrangle, Alaska (sample data in ppm).

Map no.	Field no.	Au	Ag	Cu	Pb	Zn	Mo	Sb	W	Sn	As	Co	Ni	Cr	Remarks
1	82MK92	ND	0.4	83	38	453	10	ND	2	ND	ND	ND	52	64	Random chip channel; geochemical
	82MK93	ND	0.6	38	19	335	17	28	2	ND	ND	ND	24	74	samples of sulfurous (SOsh) shale.
Main Bowser Creek															
2	82BT237	0.02	140.0	3,060	3,300	93,560	ND	ND	1	1	209	157	13	13	Skarn with disseminated sulfides.
	82BT238	0.11	2,510.0	1,510	237,600	34,430	ND	ND	1	10	816	3	7	9	Average of six high-grade samples of massive pyrrhotite-galena ores.
	82BT235	0.30	3.7	652	69	35,500	13	ND	1	6	17	57	14	7	Sphalerite-rich ores; contain 0.10 and
	2527	ND	10.6	990	377	110,000	-	-	-	-	ND	42	36	64	0.11% cadmium, respectively. (See map inset, fig. 2).
Northeast Bowser Creek															
3	83BT117a	ND	391.0	200	240,000	1,600	-	-	-	-	-	-	-	-	Selected sample of galena-pyrrhotite ore.
	83BT117b	0.7	98.0	5,500	2,600	221,000	-	-	-	-	-	-	-	-	Sphalerite-rich vein in marble.
Headwaters of Bowser Creek															
4	82BT236	ND	83.0	550	2,780	34,800	-	ND	1	1	469	55	102	108	Selected samples from pyrrhotite-
	2507	ND	6.2	78	358	1,070	-	ND	2	1	23	ND	ND	39	sphalerite-chalcopyrite quartz vein in quartz
	2508	ND	9.5	110	202	1,210	-	ND	3	ND	44	10	10	50	porphyry body; sphalerite-rich ores contain
	2514	ND	50.0	10,900	2,060	123,000	-	ND	3	ND	83	169	30	52	up to 0.12% cadmium and 0.2% barium.
Post Lake prospect															
5	83BT158	-	-	244	-	ND	10	ND	1	1	240	156	154	-	Grab sample of pyrrhotite 'ore.'
	83BT158a	0.7	0.1	182	23	28	2	20	2	1	378	60	104	61	Selected 0.5-m-long chip channel.
	83BT158b	-	-	570	10	170	21	ND	1	1	ND	139	167	10	1-m-long chip channel; massive pyrrhotite contains 33.5% Fe.
	83BT158c	-	-	429	-	294	20	ND	1	1	25	38	183	137	0.5-m-long chip channel; contains 13.1% Fe.
	83BT158d	ND	ND	230	840	302	14	ND	2	1	40	118	637	-	Grab sample of massive pyrrhotite. (See map inset, fig. 3).
Post River pluton															
6a	82BT269	ND	0.8	759	10	41	ND	ND	4	ND	ND	45	76	77	1-m-wide pyrite zone in skarn.
	83MSL62	0.9	98.0	11,500	67	413	49	ND	275	890	ND	ND	66	134	Chalcopyrite-quartz-scheelite vein.
6b	83BT119	ND	13.7	5	6	14	3	ND	3	3	91	10	20	105	Sulfide vein in intrusive rock (Tqm).
	83BT120	ND	ND	35	16	76	18	ND	3	26	56	ND	77	90	Contact zone between Tqm and SOsh.
	83BT122a	ND	8.1	47	1,820	191	19	117	125	5	38	11	51	137	Quartz vein in Tqm; 0.1-m-wide chip sample.
	83BT122b	ND	59.0	29	24	114	9	41	3	8	ND	ND	31	80	Concentrate sample below Tqm-SOsh contact in creek ravine.
7a	82BT316	ND	ND	155	6	709	5	ND	2	ND	-	37	196	62	Random chip samples of sulfur-rich shale
7b	82BT486	0.3	13.6	1,220	-	13,700	3	1	1	1	ND	14	11	25	(contains SOsh).
8	83BT303	0.3	1.2	28	41	700	31	ND	2	1	52	4	30	56	Three 10-cm-thick stratiform pyrite layers with disseminated sphalerite.
9	82MK203a	ND	4.5	33	186	8,660	2	ND	3	13	ND	13	52	65	Chip samples of sulfur-rich shale (SOsh).
	82BT321	ND	2.0	104	61	172	5	ND	3	ND	ND	ND	-	145	Same as above.

Analyses by M.R. Ashwell, T.A. Benjamin, and M.K. Polly using X-ray fluorescence and atomic-absorption spectrophotometry, DGGS Minerals Laboratory.
ND = Not detected.
- = Not analyzed.

Composite grab samples of sulfur- and iron-rich shale (SOsh) locally contain anomalous lead, zinc, silver, and molybdenum (table 4, map no. 1, 7a,b, 9). The occurrence at map number 9 (table 4) is coincident with a significant barium anomaly reported in stream-sediment sample data by Aamondt and others (1979).

Selected shale samples were analyzed for Rock-Eval pyrolysis geochemistry. Four samples of shale (SOsh) contain 1.20 to 1.93 percent total organic carbon and 0.05 mill/g free hydrocarbons. Three samples of Silurian shale (mSs) average only 0.37 percent total organic carbon and 0.03 mill/g free hydrocarbon. Hence, the shale (SOsh) has fair to good potential as a hydrocarbon source. However, all Paleozoic units are overmature and contain conodonts with maturation indexes that range from 3 to 5.

REFERENCES CITED

Aamondt, P.L., Jacobsen, S.I., and Hill, D.E., 1979, Uranium hydrogeochemical and stream sediment reconnaissance of the McGrath and Talkeetna NTMS Quadrangles, Alaska, including concentrations of 43 additional elements: Los Alamos, New Mexico, Los Alamos Scientific Laboratory Report LA-7350, 214 p., scale 1:250,000, 12 sheets.

Anderson, R.G., 1982, The relationship of the southeastern Selwyn plutonic suite to tungsten skarn mineralization in southeastern Selwyn Basin: Geological Survey of Canada Paper 83-13, 22 p.

Armstrong, A.K., Harris, A.G., Reed, B.L., and Carter, Claire, 1977, Paleozoic sedimentary rocks in the northwest part of Talkeetna Quadrangle, Alaska Range, Alaska, *in* Blean, K.M., ed., The U.S. Geological Survey accomplishments during 1976: U.S. Geological Survey Information Circular 751-B, p. 61-62.

Blusson, S.L., 1976, Selwyn Basin, Yukon and district of MacKenzie: Report of activities: Geological Survey of Canada Paper 764, p. 131-133.

Brooks, A.H., 1911, The Mt. McKinley region, Alaska: U.S. Geological Survey Professional Paper 70, p. 69-77.

Bundtzen, T.K., and Gilbert, W.G., 1983, Outline of geology and mineral resources of upper Kuskokwim region, Alaska, *in* Reed, K.M., and Mull, C.G., eds., Western Alaska geology and resource potential: Journal of the Alaska Geological Society, v. 3, p. 101-117.

Bundtzen, T.K., Kline, J.T., and Clough, J.G., 1982, Preliminary geology of McGrath B-2 Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-file Report 149, 22 p., scale 1:63,360, 1 sheet.

Bundtzen, T.K., Kline, J.T., and Clough, J.G., Geologic map of McGrath B-2 Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys unpublished report [in preparation].

Churkin, Michael, Jr., Reed, B.L., Carter, Claire, and Winkler, G.R., 1977, Lower Paleozoic graptolite section in Terra Cotta Mountains: U.S. Geological Survey Circular 751-B, p. 37-38.

Dickinson, W.R., and Suczek, C.A., 1979, Plate tectonics and sandstone compositions: American Association of Petroleum Geologists Bulletin, v. 63, no. 12, p. 2164-2182.

Eakins, G.R., Gilbert, W.G., and Bundtzen, T.K., 1978, Preliminary bedrock geology of west-central Lake Clark Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-file Report 118, 15 p., scale 1:63,360, 2 sheets.

Einaudi, M.T., and Burt, D.M., 1982, Introduction to terminology, classification, and composition of skarn deposits: Economic Geology, v. 77, no. 4, p. 745-755.

Fernald, A.T., 1960, Geomorphology of upper Kuskokwim region, Alaska: U.S. Geological Survey Bulletin 1071-B, p. 191-275.

Folk, R.L., 1968, Petrology of sedimentary rocks: Austin, Texas, Hemphills Book Store, 170 p.

Gabrielse, H., Blusson, S.L., and Roddick, J.A., 1973, Geology of Flat River, Glacier Lake, and Wrigley Lake map areas: District of Mackenzie and Yukon Territory: Geological Survey of Canada Memoir 366, in portfolio (text, figs., and sheet at 1:250,000).

Gilbert, W.G., and Bundtzen, T.K., 1984, Stratigraphic relationship between Dillinger and Mystic terranes, western Alaska Range, Alaska [abs.]: Geological Society of America, Cordilleran Section, Abstracts with Programs, v. 16, no. 5, p. 286.

Gilbert, W.G., and Solie, D.N., 1983, Preliminary bedrock geology of McGrath A-3 Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-7, scale 1:40,000, 1 sheet.

Gilbert, W.G., Solie, D.N., and Dickey, D.B., 1982, Preliminary geologic map of the McGrath B-3 Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-file Report 148, scale 1:40,000, 1 sheet.

Hantzschel, Walter, 1975, Trace fossils and problematics (2nd ed.), *in* Treatise on invertebrate paleontology, part W, supplement 1: Geological Society of America, 269 p.

Herreid, Gordon, 1968, Geological and geochemical investigations southwest of Farewell, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 26, 24 p., scale 1:75,000, 2 sheets.

Irvine, T.N., and Barager, W.R.A., 1971, A guide to the chemical classification of common volcanic rocks: Canadian Journal of Earth Sciences, v. 8, no. 6, p. 523-548.

Karlstrom, T.N.V., 1964, Quaternary geology of the Kenai lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 443, 69 p.

Kline, J.T., and Bundtzen, T.K., 1986, Two glacial records from west-central Alaska, *in* Hamilton, T.D., Reed, K.M., and Thorson, eds., Glaciation in Alaska - The geologic record: Alaska Geological Society, p. 123-150.

Jones, D.L., Silberling, N.J., Gilbert, W.G., and Coney, P.N., 1982, Character, distribution, and tectonic significance of accretionary terranes in central Alaska Range, Alaska: Journal of Geophysical Research, v. 87, no. B5, p. 3709-3717.

MacDonald, K.M., 1983, Stratigraphy of the Ordovician and Silurian 'Black Shale' unit of McGrath Quadrangle [abs.], *in* New developments in the Paleozoic geology of Alaska and the Yukon: Alaska Geological Society Symposium, Anchorage, 1983, Program and Abstracts, p. 19.

Nelson, S.W., and Reed, B.L., 1978, Surficial deposits map of the Talkeetna Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 870-J, scale 1:250,000, 1 sheet.

Reed, B.L., and Elliott, R.L., 1968a, Lead, zinc, and silver deposits at Bowser Creek, McGrath A-2 Quadrangle, Alaska: U.S. Geological Survey Circular 559, 17 p.

Reed, B.L., and Elliott, R.L., 1968b, Geochemical anomalies and metalliferous deposits between Windy Fork and Post River, southern Alaska: U.S. Geological Survey Circular 596, 22 p.

Reed, B.L., and Lanphere, M.A., 1972, Generalized geologic map of the Alaska - Aleutian Range batholith showing potassium-argon ages of plutonic rocks: U.S. Geological Survey Miscellaneous Field Studies Map MF-372, scale 1,000,000, 2 sheets.

Reed, B.L., and Nelson, S.W., 1980, Geologic map of the Talkeetna Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-1174, scale 1:250,000, 1 sheet.

Smith, T.E., 1981, Geology of the Clearwater Mountains, south-central Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 60, 72 p., scale 1:63,360, 3 sheets.

Solie, D.N., Bundtzen, T.K., and Gilbert, W.G., 1982, Upper Cretaceous - Lower Tertiary volcanic rocks near Farewell, Alaska [abs.], *in* Science in the North: Alaska Science Conference, 33rd, Fairbanks, 1982, Proceedings, American Association for the Advancement of Science, Arctic Division, p. 138.

Table 5. Fossil identifications from the McGrath A-2 Quadrangle, Alaska.

Map no.	Field no.	University of Alaska Museum no.	Description
1	82BT152	A-1841	Graptolites in calcareous sandstone of mSl. *Pristiograptus* cf. *P. dubius*, Wenlockian (Middle Silurian) age.
2	82BT190	--	Poorly preserved, ribbed atrypaccan brachiopod in mSl; suggests Silurian to early Late Devonian range.
3	82BT175	A-1864	Graptolites midway through SOsh; mixed collection of *D. decoratus* and *C. bicornis* zones, Middle Ordovocian age; *D. decoratus* zone contains *Pterograptus* cf. *P. elegans* (f), *Cryptograptus schaferi* (r), *Didymograptus* sp. (r), *Glossograptus* cf. *G. acanthus* (f), *G. ciliatus* (c), *G. ciliatus* cf. subsp. *antennatus* (r), *Phyllograptus* cf. *P. angustifolius elongatus* (r). *C. bicornis* zone contains *Climacograptus bicornis* (c), *Dicellograptus* cf. *D. divaricatus divaricatus* (r), *D.* cf. *D. divaricatus salopiensis* (c).
4	82BT176A	A-1874	Graptolite collection made at top of SOsh 6 m stratigraphically below lSl; contains *Monograptus* cf. *M. planus* (r), late Llandoverian (late Early Silurian) age.
5	82BT174	A-1851	Collection made midway through SOsh section contains graptolites of *P. tentaculatus* zone, late Early Ordovician age. Includes *Isograptus forcipiformis latus* (r), *Brachiograptus etaformis* (f), *Cryptograptus schaferi* (r), *Phyllograptus nobilis* (c). *Glyptograptus* cf. *G. austrodentatus* (r). *Glyptograptus* sp. (f), *Didymograptus* sp. (f).
6	82BT173	A-1846	Collection made near core of Sheep Creek anticline on west side of SOsh; contains graptolites of *Oncograptus* zone, Early Ordovician age. Include *Isograptus forcipiformis* (r), *Didymograptus* cf. *D. v-deflexus* (r), *Didymograptus* sp. (r).

Table 5. (con.)

Map no.	Field no.	University of Alaska Museum no.	Description
7	82BT170	A-1970	Collection made in axis of Sheep Creek anticline in SOsh; graptolites are of *T. approximatus* and *T. fruticosus* zones, earliest Ordovician age, includes *Tetragraptus approximatus* (r).
8	82BT172	A-1862	*Phyllograptus*? sp. (r) in SOsh east of axis of Sheep Creek anticline.
9	82BT169	A-1948	Graptolite collection from SOsh near lSl contact; contains poorly preserved diplograptids including *Climacograptus*? and *Glyptograptus*?, Middle or Late Ordovician age.
10	82BT168	A-1848	Graptolite collection from mSl contains *Pristiograptus* cf. *P. dubius* (a), retiolitid (r), Wenlockian (Middle Silurian) age.
11	82BT186	- -	Graptolite collection from lSl contains *Crytograptus centrifugus*, late Early Silurian age.
12	82BT185	A-1861	Scree slope in SOsh contains *Cyrtograptus* sp. (r), *Dicellograptus*? sp., Middle Ordovician age.
13	82BT301	- -	*Pristiograptus* dubius, Wenlockian (Middle Silurian) age.
14	82BT362	A-1845	Scree slope in SOsh contains undiagnostic diplograptid graptolites, Middle or Late Ordovician age.
15	82MK209	A-1938	SOsh contains graptolites *Climacograptus caudatus* (c), *Glyptograptus*? sp. (r), *Orthograptus* aff. *O calcaratus* s.l. (r), *Didymograptus*? sp. (r) of *C. tubuliferus* zone, late Middle Ordovician age.
16	82BT258	A-1907	Small limestone unit 20 m above lSl contains *Crytograptus* sp. (r), *Monograptus* sp. aff. *M. firmus* (c), *M.* sp. (*priodon* type) (c), *Monoclimacis* sp., earliest Wenlockin (Middle Silurian) age.

Table 5. (con.)

Map no.	Field no.	University of Alaska Museum no.	Description
17	82BT335	A-1935	Collection in SOsh contains *Climacograptus bicornis* (c), *Orthograptus* aff. *O. calcaratus* s.l. (r), *Glyptograptus* sp. (f), *Dicellograptus* cf. *D. divaricatus salopiensis* (c), *Dicranograptus*? sp.(r) of *C. bicornis* zone, Middle Ordovician age.
18	82MKTC1	A-1856	Base of SOsh contains *Tetragraptus* cf. *T. quadribrachiatus* (r), Early Ordivician age.
19	82MKTC2	A-1857	Upsection from map no. 18 in SOsh; contains *Glossograptus* sp. (r), *Phyllograptus* sp. (r), *Climacograptus* sp. (c), *Glyptograptus* sp. (f), *Didymograptus*? sp. (r) of *D. decoratus* zone, early Middle Ordovician age.
20	82MKTC3	A-1858	Fragments of *Didymograptus*? sp. indicates Early to Middle Ordovician age.
21	82MKTC4	A-1859	Upper portion of SOsh section yields *Pristiograptus* sp. (r), *Monograptus* aff. *M. exiguus* (r), *Monograptus* sp. (f), Llandoverian (Early Silurian) age.
22	82MKTC5	A-1860	Collection in carbonate layer above lSl yields *Monograptus* aff. *M. priodon*, Early to Middle Silurian age.
23	83BT132	- -	mSl contains compressed orthocone nautiloid shells, probable Silurian age.
24	83BT147	- -	O€ls contains abundant branching trace fossils on shale partings similar to *Thalassinoides* and *Torrowangea* from basinal deposits in Australia, Europe, and North America.
25	83BT148	- -	Lowest carbonaceous shale horizon in SOsh yields *Tetrograptus* cf. *T. approximatus*? and *Didymograptus latus aequalis* of *T. fruiticosis* zone, Early Ordovician age.

Table 5. (con.)

Map no.	Field no.	University of Alaska Museum no.	Description
26	82MK182B	A-1876a-b	SOsh yields *Glossograptus* cf. *G. ciliatus* (f), *Amplexograptus fallax* (r), *Orthograptus calcaratus acutus* (r), *Climacograptus* sp. (r), *Orthograptus calcaratus acutus* (r). *Climacograptus* sp. (r), and *Glyptograptus* sp. *Didymograptus*? sp. (r) of *C. bicornis* zone, Middle Ordovician age.
27	82MK193	A-1910	Carbonate unit in mSs yields *Monograptus* of *priodon* type; Middle Silurian(?) age.
28	82BT272	--	*Climacograptus bicornis*, Middle Ordovician age.
29	82BT492	A-1961	SOsh yields *Tetragraptus quadribrachiatus* (c), Early Ordovician age.
30	82MA320	A-1843	SOsh yields *Climacograptus bicornis*, Middle Ordovician age.
31	82BT321	--	Uppermost part of SOsh below ISl yields *Monograptus spiralis*, Early Silurian age.
32	82MSL61	--	KJs yields *Inoceramus* sp. with ribbing similar to *Inoceramus pelliformis pochialaynen* of Early Cretaceous (Hauterivian) age.
33	82MA300	--	*Thalassinoides*(?) trace fossil; very similar to map no. 24.

Fossils collected by T.K. Bundtzen (BT), K.M. MacDonald (MK), M.S. Lockwood (MSL), and M.D. Albanese (MA). Graptolite identifications by Claire Carter, U.S. Geological Survey. Pelecypod (map no. 32) identified by J.W. Miller, U.S. Geological Survey. Other megafossil examinations by R.B. Blodgett, Oregon State University. Trace-fossil identifications by Bundtzen after Hantzschel (1975). Most fossil collections are archived at the University of Alaska Museum in Fairbanks.

(a) = abundant

(f) = frequent

(c) = common

(r) = rare