RECONNAISSANCE GEOLOGIC MAP OF THE LOWER YUKON RIVER REGION, ALASKA

By

William W. Patton, Jr., Frederic H. Wilson, and Keith A. Labay

INTRODUCTION

This map and accompanying digital files represent part of a systematic effort to release geologic data for the United States in a uniform manner. All the geologic data in this series will be published as parts of the U.S. Geological Survey Data Series. The geologic data in this series have been compiled from a wide variety of sources, ranging from state and regional geologic maps to large-scale field mapping. The data are presented for use at a nominal scale of 1:500,000, although individual datasets may contain data suitable for use at larger scales. The metadata associated with each release will provide more detailed information on sources and appropriate scales for use. Associated attribute databases accompany the spatial database of the geology and are uniformly structured for ease in developing regional- and national-scale maps.

The 1:500,000-scale geologic map of the Lower Yukon River region covers a broad area in southwest Alaska that borders the Bering Sea and Norton Sound and includes the delta of the Yukon River (fig. 1). Much of the western and southern parts of the region is a delta plain standing less than 100 meters above sea level and covered by Quaternary surficial deposits. Exposures of bedrock are confined to small isolated mountain groups within the delta plain and to dissected uplands that border the delta plain in the eastern and northcentral parts of the map area.

The geologic map of the Lower Yukon River region was compiled from reconnaissance studies by J.M. Hoare, W.H. Condon, and W.L. Coonrad (1946-71) and from more recent investigations in the C-1 Russian Mission quadrangle by T.K. Bundtzen and G.M. Laird (1991), in the Kilbuck Mountains of the southern Russian Mission quadrangle by S.E. Box and others (1993), and near and along the Yukon River in the Holy Cross and Russian Mission quadrangles by Patton and others (1987) and by Miller and others (1996, 1998). Sources of geologic map data for each of the seven 1:250,000-scale quadrangle maps that make up this 1:500,000 scale map area as well as sources of general geologic information pertaining to the entire map area are listed in the “Sources of Information” section.

GEOLOGY

The map units are divided into overlap assemblages and lithotectonic terranes. The overlap assemblages are composed of undeformed to highly deformed sedimentary, volcanic, and plutonic rocks that range in age from Quaternary to late Early Cretaceous and unconformably overlie or intrude the lithotectonic terranes. The lithotectonic terranes range in age from Early Cretaceous to Mississippian and consist of complexly deformed

displaced fragments of island-arc and oceanic rocks that were accreted to the North American(?) continental margin by the Early Cretaceous (Patton and others, 1994).

Overlap assemblages

Sedimentary rocks

Surficial deposits

Large parts of the map area are covered by surficial deposits of Quaternary age that have been mapped almost entirely from aerial photographs. The delta plain and the broad valleys of the Yukon and Kuskokwim rivers and their tributaries are mantled chiefly by alluvial, and colluvial deposits (unit Qac) and by floodplain deposits (unit Qf). Unit Qac also includes small deposits of glacial drift in the Askinuk, Kilbuck, and Russian mountains and unit Qf locally includes tidal flats and estuarine deposits near and along the coast. Stabilized windblown deposits (unit Qw), recognizable in aerial photographs by their modified dune and blowout morphology, are mapped separately on south and southeast sides of the Yukon and Kuskokwim rivers and active and recently stabilized beach and lagoonal deposits (unit Qbl), also identifiable in aerial photographs, are mapped separately along the Bering Sea and Norton Sound coast.

Yukon-Koyukuk Basin

The Cretaceous sedimentary rocks in the Holy Cross, Kwiguk, and St. Michael quadrangles represent the southern end of the Yukon-Koyukuk Basin, a broad sedimentary trough that extends across western Alaska from the Brooks Range to the Yukon River delta plain (fig. 2). Aeromagnetic data suggest that the Cretaceous rocks continue beneath the delta plain at least as far as the central part of the Marshall quadrangle (Texas Instruments, Inc., 1977; Godsen, 1994). Exposures of the Cretaceous rocks in the map area are sparse and ground observations were limited to scattered ridgetop rubble crops and a few cutbanks along the major drainages. The descriptions of their lithologic and sedimentary features are taken in part from more detailed study of these rocks in the adjoining Unalakleet, Norton Bay, and Nulato quadrangles to the north where they are better exposed (Patton and others, 2009).

The Cretaceous sedimentary deposits filling the Yukon-Koyukuk Basin are divided into three broad groups based on their depositional environment: deltaic, submarine fan, and marginal shelf and slope deposits. The deltaic deposits (unit Kys), composed of fluvial, delta-plain, and shallow-marine beds, are exposed on the eastside of the basin. The submarine fan deposits crop out on the west side of the basin and are in probable fault contact with the deltaic deposits. The submarine fan deposits consist of two compositionally different units: graywacke sandstone and mudstone turbidites that are highly calcareous (unit Kygc) and graywacke sandstone and mudstone turbidites that are rich in volcanic debris (unit Kygv). Owing to poor exposure the two units cannot be mapped separately along the margin of the Yukon River delta plain and have been lumped together in unit Kyg. Marginal shelf and slope deposits (unit Kym) are limited a few scattered exposures along the eastern and western margins of the basin. On the eastern margin they crop out along the Yukon River between the villages of Holy Cross and Paimut and in the Innoko River drainage, 20 to 30 kilometers east of Holy Cross. On the western margin exposures of the

marginal shelf and slope deposits are limited to small outcrops within the delta plain in the southern St. Michael and northern Kwiguk quadrangles.

Kuskokwim Basin

Cretaceous sedimentary rocks (unit Kks) in the southeast corner of the map area lie at the western edge of the Kuskokwim Basin, a broad sedimentary trough that extends from the upper Kuskokwim River region to near Bristol Bay. The sedimentary section includes both deltaic and submarine fan deposits, but ground observations are insufficient to separate the two different deposit types at this map scale.

Volcanic and intrusive rocks

Volcanic and intrusive rocks, which are widely distributed in the map area, are divided into three age groups—Quaternary and late Tertiary, early Tertiary and latest Cretaceous, and Late and Early Cretaceous.

The Quaternary and late Tertiary group form nearly flat-lying, basalt lava fields (units Qb and QTb) in the eastern St. Michael quadrangle bordering Norton Sound and at isolated localities on the Yukon River delta plain in the Kwiguk, Marshall, and Hooper Bay quadrangles. The flows are part of the Bering Sea basalt province, which extends over a broad area from the Seward Peninsula southward to the Yukon River Delta and westward to the islands of the Bering Sea (Moll-Stalcup and others, 1994). Also included in this age group are several slightly older fields of basalt (unit Tb) in the Russian Mission quadrangle.

The early Tertiary and latest Cretaceous age group (units TKa, TKd, TKad, TKi, and TKg) is widely exposed in the eastern part of the map area. The volcanic rocks consist of mildly deformed lava flows, volcaniclastic rocks, and associated shallow intrusive bodies. Also included in this age group are granitic plutons (unit TKg) that form circular domal complexes in the Russian Mountains and Fox Hills along the eastern border of the map area and several irregular shaped granitic plutons in the northwestern part of the Russian Mission quadrangle.

The Late and Early Cretaceous age group (unit Kg) is composed chiefly of granite and granodiorite and forms several large plutons in the Kilbuck Mountains in the southern part of the Russian Mission quadrangle and in the Askinuk Mountains in the Hooper Bay quadrangle.

Lithotectonic terranes

Koyukuk terrane

The Koyukuk terrane is interpreted to be an accreted volcanic arc assemblage composed of three map units: andesitic and basaltic volcaniclastic rocks and lava flows, chert, and mudstone (KJv); trondhjemite, tonalite, and gabbro (Jt); and serpentinized ultramafic rocks (MzPzum). The age of the upper two units is established as Early Cretaceous and Jurassic, but the age of the lower unit is uncertain and may be as old as Paleozoic. Stratigraphic relationships and lithologic descriptions for these three units are based largely on observations in the Unalakleet quadrangle, which adjoins the Lower Yukon River map area on the north (Patton and Moll-Stalcup, 1996). Unit

KJv is exposed at a number of widely distributed localities in the Holy Cross quadrangle and northern part of the Russian Mission quadrangle. Exposure of unit Jt; however, is limited to a single plutonic body that intrudes unit KMu in the north central part of Holy Cross quadrangle and exposures of unit MzPzum are confined to four small fault blocks located a short distance to the northeast of the unit Jt plutonic body.

Angayucham-Tozitna terrane

The Angayucham-Tozitna terrane (unit TrMv) is a predominately oceanic assemblage composed of altered basalt, chert, argillite, tuff, graywacke, and limestone and is assigned a Triassic to Mississippian age based largely on fossils collected from small limestone bodies in the Russian Mission and Holy Cross quadrangles (table 2). The best exposures of the terrane are in the northwestern part of the Russian Mission quadrangle north of the Yukon River and in the east central part of the Russian Mission quadrangle north of the Kuskokwim River. Elsewhere the Angayucham-Tozitna terrane is poorly exposed and for mapping purposes has been lumped with the Koyukuk terrane in undivided unit Kmu.

Structure

Yukon-Koyukuk basin

The Yukon-Koyukuk basin covers a broad area of western Alaska from the Brooks Range on the north to the Yukon River delta plain on the south (fig 2). It is divided into two sub-basins, Lower Yukon and Kobuk-Koyukuk, which are separated by a structural high composed of Koyukuk and Angayucham-Tozitna terranes. The extent of the two sub-basins beneath the delta plain in the Lower Yukon region is uncertain. The northwestern edge of the Lower Yukon sub-basin can be traced in the subsurface of the delta plain by aeromagnetic profiles (Texas Instruments Inc., 1977) as far as the southwestern corner of the Kwiguk quadrangle and may extend into the Marshall and Hooper Bay quadrangles where Hoare and Condon (1968; 1971) report exposures of Cretaceous sedimentary deposits at isolated localities in the Kusilvak and Askinuk Mountains. The southeastern edge of the Lower Yukon sub-basin also can be traced by aeromagnetic profiles beneath the delta plain south of the Yukon River as far as the central part of the Marshall quadrangle. The profiles over the sub-basin are relatively smooth and free of large amplitude anomalies in contrast to the profiles over the adjoining lithotectonic terranes, which are characterized by closely spaced large amplitude anomalies.

It is uncertain how far the Kobuk-Koyukuk sub-basin extends southward into the Lower Yukon River region (fig. 2). Exposures of rocks belonging to this sub-basin are limited to two small bands of deltaic deposits in the north central part of the Holy Cross quadrangle and to a small area of marginal shelf and slope deposits at the bend of the Yukon River near the village of Paimuit. The Cretaceous sedimentary deposits in this sub-basin may extend beneath the cover of Quaternary surficial deposits and early Tertiary and latest Cretaceous volcanic rocks in the central part of the Holy Cross quadrangle, but the sub-basin does not extend as far in the southwestern part of the Holy Cross quadrangle and in the northwestern part of the Russian Mission quadrangle where a broad structural uplift exposes rocks of the underlying Koyukuk and Angayucham-Tozitna terranes.

Aniak Fault

The Aniak Fault, located near the eastern edge of the Lower Yukon region map area, can be traced from the Kuskokwim River near the village of Aniak in the Russian Mission quadrangle to the northern part of the Holy Cross quadrangle. On the north side of the Kuskokwim River the fault juxtaposes deposits of the Kuskokwim Basin (unit Kks) on the east with the undivided Koyukuk and Angayucham-Tozitna terranes (KMu) on the west. Further north the fault is buried beneath the alluvial deposits at the eastern edge of the Yukon River valley, but is clearly traceable by aeromagnetic and isostatic residual gravity data to the northern part of the Holy Cross quadrangle (Saltus and Morin, 1992). The west side of the fault trace is marked by a series of gravity lows, which together with the featureless character of the aeromagnetic profiles, suggest that the east side of the Yukon River valley is underlain by a thick down-faulted wedge of Quaternary surficial deposits and (or) Cretaceous sedimentary rocks of the Kobuk-Koyukuk sub-basin.

Volcanic structures

Three prominent circular topographic features are shown by hachured lines in the central part of the Holy Cross quadrangle. These features occur within broad fields early Tertiary and latest Cretaceous volcanic rocks (units TKa and TKad) and may be remnants of ancient volcanic collapse structures (calderas?).

SOURCES OF INFORMATION

GENERAL

Coonrad, W.L., 1957, Geologic reconnaissance of the Yukon-Kuskokwim delta region, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-223, scale 1:500,000.

Condon, W.H., 1962, 1963, 1966, Unpublished field notes and maps, Holy Cross, St Michael, Hooper Bay, and Russian Mission quadrangles.

Elder, W.P. and Miller, J.W., 1991, Maps showing fossil localities and checklists of Jurassic and Cretaceous macrofauna of western Alaska: U.S. Geological Survey Open-File Report 91-629, 71 p., 3 plates., scale 1:500,000.

Godson, R.H. editor, 1994, Composite magnetic anomaly map of Alaska, *in* Plafker G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, plate 10, scale 1:2,500,000.

Hoare, J.M., 1961, 1962, 1966, Unpublished field notes and maps, Holy Cross, St. Michael, and Russian Mission quadrangles.

Miller, T.P., 1963, Unpublished field notes and maps, Holy Cross, Hooper Bay, and Russian Mission quadrangles.

Moll-Stalcup, E.J., Brew, D.A., and Vallier, T.L., 1994, Latest Cretaceous and Cenozoic magmatic rocks of Alaska, *in* Plafker, G., and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, plate 5.

Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, G., and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 241-269.

Patton, W.W., Jr., Miller, M.L., Murphy, J.M., Box, S.E., and Bundtzen, T.K., 1987, Unpublished field notes, maps, and fossil collections, Holy Cross, Marshall, and Russian Mission quadrangles.

Patton, W.W., Jr., Wilson, F.H., Labay, K.A., and Shew, Nora, 2009, Geologic map of the Yukon-Koyukuk Basin, Alaska: U.S. Geological Survey Scientific Investigations Map S-2909, scale 1:500,000, 2 sheets.

Texas Instruments, Inc. 1977, National uranium resource evaluation aerial gamma ray and magnetic survey of the Bethel and Yukon areas, Alaska: U.S. Energy and Development Administration, Grand Junction Office, Report GJBX5(77),v.2, scale 1:500,000.

Wilson, F.H., Shew, Nora, and Dubois, G.D., 1994, Map and table showing isotopic age data in Alaska, *in* Plafker G. and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, plate 8, 1 sheet, scale 1:2,500,000.

BLACK

Hoare, J.M. and Condon, W.H., 1966, Geologic map of the Kwiguk and Black quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-469, scale 1:250,000.

HOLY CROSS

Csejtey, Béla, Jr., 1992, Geology of the Holy Cross quadrangle, Alaska *in* Csejtey, Béla, Jr. and Keith, W.J., eds., Pre-assessment report on the Holy Cross quadrangle, Alaska, U.S. Geological Survey Administrative report, 52 p., 3 plates, scale 1:250,000.

Harrington, G.L., 1918, The Anvik-Andreafsky region, Alaska: U.S. Geological Survey Bulletin 683, 70 p.

Hoare, J.M., 1961, Preliminary geology along the lower Yukon River, Alaska: U.S. Geological Survey Open-file Report 61-64, scale 1:500,000.

Miller, M.L., Bundtzen, T.K., Keith, W.J., Bailey, E.A., and Bickerstaff, Damon, 1996, Geology and mineral resources of the Stuyahok area, part of the Holy Cross A-4 and A-5 quadrangles, Alaska: U.S. Geological Open-File Report 96-505-A, 30 p.

Miller, M.L, Bundtzen, T.K., and Keith, W.J., 1998, Geology and gold resources of the Stuyahok area, southwestern Alaska *in* Gray, J.E. and Riehle, J.R., eds., Geologic studies in Alaska by the U.S. Geological Survey, 1996: U.S. Geological Survey Professional Paper 1595, p, 31-49.

Miller, M.L., Tucker, R.D., Layer, P.W., and Bundtzen, T.K, 1998, Isotopic ages from intrusive rocks near the Stuyahok gold placer deposits, south-central Holy Cross quadrangle, Alaska, *in* Kelley, K.D., and Gough, L.P., eds., Geologic studies in Alaska by the U.S. Geological Survey, 1998: U.S. Geological Survey Professional Paper 1615, p. 179-188.

Patton, W.W., Jr, and Moll-Stalcup, E.J., 1996, Geologic map of the Unalakleet quadrangle: U.S. Geological Survey Miscellaneous Investigations Map I-2559, scale 1:250,000.

Saltus, R.W., and Morin, R.L., 1992, Geophysics of the Holy Cross quadrangle, Alaska *in* Csejtey, Bela, Jr. and Keith, W.J., eds., Pre-assessment report on the Holy Cross quadrangle, Alaska, U.S. Geological Survey Administrative report, p. 14-20, 3 plates, scale 1:250,000.

HOOPER BAY

Hoare, J.M. and Condon, W.H., 1968, Geologic map of the Hooper Bay quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-523, scale 1:250,000.

KWIGUK

Hoare, J.M. and Condon, W.H., 1966, Geologic map of the Kwiguk and Black quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-469, scale 1:250,000.

MARSHALL

Hoare, J.M. and Condon, W.H., 1971, Geologic map of the Marshall quadrangle, western Alaska: U.S. Geological Survey Miscellaneous Geologic Map I-668, scale 1:250,000.

RUSSIAN MISSION

Box, S.E., Moll-Stalcup, E.J., Frost, T.P., and Murphy, J.M., 1993, Preliminary geologic map of the Bethel, and southern Russian Mission quadrangles, southwestern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 2226-A, scale 1:250,000.

Bundtzen, T.K., and Laird, G.M., 1991, Geology and mineral resources of the Russian Mission C-1 quadrangle, southwest Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 109, 24 p., 1 plate, scale 1:63,360.

Elder, W.P. and Box, S.E., 1992, Late Cretaceous Inoceramid bivalves of the Kuskokwim Basin, southwestern Alaska, and their implications on basin evolution: Journal of Paleontology, vol. 26, no. 2, (Mem. 26), 39 p.

Hoare, J.M., 1960, Preliminary geology along the lower Yukon River, Alaska: U.S. Geological Survey Open-File Report 61-64, 1 sheet, scale 1:500,000.

Hoare, J.M. and Coonrad, W.L., 1959, Geology of the Russian Mission quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Map I-292, scale 1:250,000.

Miller, M.L., Belkin, H.E., Blodgett, R.B., Bundtzen, T.K., Cady, J.W., Goldfarb, R.J., Gray, J.E., McGimsey, R.G., and Simpson, S.L., 1989, Pre-field study and mineral resource assessment of the Sleetmute quadrangle, southwestern Alaska: U.S. Geological Survey Open-File Report 89-363, 115 p., scale 1:250,000, 5 sheets.

Miller, M.L and Bundtzen, T.K., 1994, Generalized geologic map of the Iditarod quadrangle, Alaska, showing the potassium-argon, major-oxide, trace-element, fossil, paleocurrent, and archaeological sample localities: U.S. Geological Survey Miscellaneous Field studies Map MF-2219A, scale 1:250,000.

Silberling, N.J., Grant-Mackie J.A., and Nichols, K.M., 1997, The Late Triassic bivalve *Monotis* in accreted terranes of Alaska: U.S. Geological Survey Bulletin 2151, 21 p.

ST. MICHAEL

Hoare, J.M. and Condon, W.H., 1971, Geologic map of the St. Michael quadrangle: U.S. Geological Survey Miscellaneous Geologic Map I-682, scale 1:250,000.

Patton, W.W., Jr, and Moll-Stalcup, E.J., 1996, Geologic map of the Unalakleet quadrangle: U.S. Geological Survey Miscellaneous Geologic Map I-2559, scale 1:250,000.

Turner, R.F., and 6 others, 1983, Geological and operational summary Norton Sound COST No. 2 well, Norton Sound, Alaska: U.S. Geological Survey Open-File Report 83-557, 154 p.

DESCRIPTION OF MAP UNITS

OVERLAP ASSEMBLAGES

Sedimentary Rocks

SURFICIAL DEPOSITS

Qf **Floodplain, tidal flats, and estuarine deposits (Quaternary)**

Location and physiographic expression—Deposits form broad swaths along the Yukon and Kuskokwim Rivers and their major tributaries and include tidal flats and estuarine deposits along the shores of the Bering Sea and Norton Sound. The floodplain deposits are characterized physiographically by bars, oxbow lakes, meander scrolls, abandoned channels, and other evidence of recent floodplain building

Description—Unit composed chiefly of silt, fine sand, and peat. Some gravel and coarse sand deposits occur locally along the tributary streams draining upland areas. The tidal flats and estuarine deposits consist of fluvial silt and sandy silt that have been reworked and redeposited by brackish-water tidal currents

Qbl **Beach and lagoonal deposits (Quaternary)**

Location and physiographic expression—Scattered localities along the Norton Sound and Bering Sea coast in the St. Michael, Kwiguk, Black, and Hooper Bay quadrangles. Unit includes active offshore bars, spits, and beaches ridges and former beach ridges that have been recently stabilized by a thin vegetation cover

Description—Silt and sandy silt

Qw **Wind-blown deposits (Quaternary)**

Location and physiographic expression—Deposits form broad partly dissected stabilized dune fields in the lowlands of the Yukon and Kuskokwim Rivers. They compose sheet-like bodies as much as 100 feet thick that are characterized by modified dunes and blowouts. The dune fields overlie the alluvial and colluvial deposits of unit Qac and predate the floodplain deposits of unit Qf

Description—Silt and sandy silt

Qac **Alluvial, colluvial, and glacial drift deposits, undivided (Quaternary)**

Location—Alluvial deposits cover wide areas of the Yukon and Kuskokwim lowlands and delta plain; colluvial deposits make up the bulk of the unconsolidated deposits on the uplands slopes. Unit includes glacial drift at higher elevations in the Russian and Kilbuck Mountains

in the Russian Mission quadrangle and in the Askinuk Mountains in the Hooper Bay quadrangle

Description—Alluvial and colluvial deposits consist mainly of silt, sandy silt, and peat. Alluvium is chiefly fluvial in origin, but locally includes reworked windblown deposits. Glacial drift composed of sand, gravel, and boulder morainal and outwash deposits

VOLCANIC AND INTRUSIVE ROCKS

QTb **Basalt lava flows (Quaternary and latest Tertiary)**

Location-Unit is exposed chiefly in the St. Michael quadrangle where it forms the western end of a broad volcanic field that extends eastward into the adjoining Unalakleet quadrangle. Smaller volcanic fields belonging to this unit also are present on the delta plain in the Marshall, Kwiguk, and Hooper Bay quadrangles.

Description—Vesicular tholeiitic and alkali basalt lava flows, cones and maar craters. The flows are interlayered with thinner pyroclastic deposits that range from fine ash to coarse breccia. The lava flows are overlain locally by younger cinder cones and short flows, which have little or no vegetation cover. Samples collected from the volcanic field in the adjoining Unalakleet quadrangle yield whole-rock K-Ar ages ranging from 3.25Ma to 0.19 Ma (Patton and Moll-Stalcup, 1996

Qb **Young scoriaceous tholeiitic basalt lava flows and cones (Quaternary)**

Mapped separately on the western half of Stuart Island in the St Michael quadrangle. The flows and cones are unmodified by erosion suggesting a Holocene or late Pleistocene age

Tb **Basalt lava flows (late Tertiary)**

Location—Three small areas of basalt lava flows in the Russian Mission quadrangle: two on the Yukon River in the northwestern part of the quadrangle and one on the Owhat River in the northeastern part of the Russian Mission quadrangle

Description—Flat-lying vesicular basalt yielding whole-rock K/Ar ages of 19.35 Ma and 6.19 Ma (table 1)

TKg **Granite, granodiorite, syenite, and monzonite (early Tertiary and latest Cretaceous)**

Location —Unit forms the core of a domal volcano-plutonic complex in the Russian Mountains in the northeastern part of the Russian Mission quadrangle and a similar domal complex in the Fox Hills in the southeastern part of the Holy Cross quadrangle. Unit also composes two large plutonic bodies and a number of small stocks in the northwestern part of the Russian Mission quadrangle and one small stock in the Kilbuck Mountains at the southern edge of the Russian Mission quadrangle

Description—Unit is composed of plutonic rocks that have been assigned various petrographic names based largely on field inspection and examination of only a few thin sections. The most common rock type appears to be biotite granite, but other rock types include granodiorite, quartz diorite, syenite, quartz monzonite, monzonite, monzodiorite, and diorite. The only detailed chemical data come from the domal complex in the Russian Mountains, which according to Bundtzen and Laird, (1991) is composed of an outer rim of syenite, monzonite, and quartz monzonite and a core of quartz syenite and porphyritic quartz monzonite. A large pluton located in the northwest corner of the Russian Mission quadrangle and extending into the eastern edge of the Marshall quadrangle locally displays a strong gneissic banding. Seven K/Ar cooling ages from this unit range from 70.9 to 60.9 Ma (table 1)

TKi **Shallow intrusive rocks of intermediate and silicic composition (early Tertiary and latest Cretaceous)**

Location—Unit forms numerous large sills, dikes, and domes intruding Cretaceous sedimentary rocks in the northwestern Holy Cross quadrangle, in the northeastern Kwiguk quadrangle, and in the Kusilvak Mountains in the southwestern part of the Kwiguk quadrangle. Elsewhere the unit occurs as small isolated bodies most of which are too small to be shown separately on the map

Description—Unit composed of rhyolite, dacite and lesser amounts of trachyte and andesite. The typical rock is composed of a fine-grained felsic groundmass with phenocrysts of plagioclase, quartz, biotite, and hornblende. A felsic to intermediate dike in the southern part of the Holy Cross quadrangle has a U/Pb zircon age of 63.6 Ma and a $^{40}Ar/^{39}Ar$ age of 67.3 Ma. A dike of similar composition from the same general region has a $^{40}Ar/^{39}Ar$ age of 60.4 Ma (table 1)

TKa **Andesite and basalt flows and volcaniclastic rocks (early Tertiary and latest Cretaceous)**

Location—Unit is widely exposed in the central part of the Holy Cross quadrangle and in a small area in the north-central part of the Russian Mission quadrangle between the Yukon and Kuskokwim Rivers

Description—Unit composed predominately of andesite and basalt lava flows and volcaniclastic rocks. Flows are generally porphyritic and composed of phenocrysts of plagioclase and pyroxene in a groundmass of plagioclase microlites. Some of the flows are columnar jointed and locally vesicular. Volcaniclastic rocks in this unit include breccia, tuffs, and agglomerates. The andesitic and basaltic rocks commonly are interlayered with or intruded by small bodies of dacite and rhyolite belonging to units TKi and TKd. Two basalt samples from outcrops on the Yukon River near the northern edge of the map area yield K/Ar isotopic ages of 50.8 and 42.9 Ma (table 1). No other age data are available from the map area, but in

the adjoining Unalakleet quadrangle to the north similar basaltic rocks yield five K/Ar isotopic ages that range from 65.2 to 51.9 Ma (Patton and Moll-Stalcup, 1996)

TKd **Dacitic and rhyolitic flows, domes, ash-flow tuffs, and hypabyssal rocks (early Tertiary and latest Cretaceous)**

Location—Unit forms a large volcanic field in the southeastern part of the Holy Cross quadrangle and is widely distributed elsewhere in the Holy Cross and Russian Mission quadrangles as small bodies that intrude or are interlayered with andesite and basalt belonging to unit TKa. Most of these bodies are too small or too poorly known to be mapped separately

Description—Dacite, rhyolite, and subordinate trachyandesite lava flows, sills, dikes, and interlayered tuffs, ash-flow tuffs, and breccias. Flows generally are porphyritic and composed of phenocrysts of plagioclase, sanidine, quartz, and biotite in a fine-grained felsic groundmass

TKad **Dacite, rhyolite, andesite, and basalt lava flows, and volcaniclastic and hypabyssal rocks, undivided (Tertiary and latest Cretaceous)**

Location—Confined to the Holy Cross quadrangle and northern part of the Russian Mission quadrangle where field data are insufficient to map units TKa and TKd separately. May locally include basalt lava flows as young as late Tertiary (unit Tb)

Age—Two samples, one from a rhyolite flow, and the other from a devitrified tuff, yielded sanidine isotopic K/Ar ages of 67.0 Ma and 64.7 Ma (table 1). Both samples are from an area mapped as unit TKad, an undivided assemblage of dacite, rhyolite, andesite, and basalt flows, and volcaniclastic and hypabyssal rocks in the northeastern corner of the Holy Cross quadrangle

Kg **Granodiorite and granite (Late and Early Cretaceous)**

Location—Unit forms two large plutons that intrude the Nyac terrane in Kilbuck Mountains of the southern Russian Mission quadrangle and a large pluton that forms the Askinuk Mountains in the Hooper Bay quadrangle

Description—Unit is composed chiefly of biotite granite and hornblende-biotite granodiorite. Samples from plutons in the Kilbuck Mountains processed for isotopic ages yielded K/Ar and $^{40}Ar/^{39}Ar$ cooling ages ranging from 101 to 120Ma and a U/Pb zircon crystallization age of between 104 and 129 Ma (upper Concordia intercept). A single sample from the Askinuk Mountains pluton yielded a biotite K/Ar cooling age of 80.6±4.0 Ma (table 1)

CONTACT METAMORPHIC ROCKS

TKhf **Hornfels (early Tertiary and latest Cretaceous)**

Location—On the margins of circular volcano-plutonic structures that compose the Fox Hills in the southeastern part of the Holy Cross quadrangle and the Russian Mountains in the northeastern part of the Russian Mission quadrangle

Description—Formed in the thermal aureole bordering the granitic cores of the Fox Hills and Russian Mountains. Consists of metasiltstone, metasandstone, metaconglomerate and subordinate amounts of metavolcanic rocks

YUKON-KOYUKUK BASIN

Deltaic deposits

Kys **Sandstone and siltstone (Cretaceous)** Dot pattern where intruded by numerous small hypabyssal bodies of rhyolite and dacite **(**TKi**)**

Location—Unit is widely exposed in a broad belt that extends from the northwestern Holy Cross quadrangle through the eastern Kwiguk quadrangle and into the northern edge of the Marshall quadrangle. A few scattered exposures also occur in the southeastern part of Holy Cross quadrangle

Description—Fluvial and shallow marine deltaic deposits of sandstone, siltstone, and shale. Locally crossbedded and ripple marked. Unit contains abundant plant debris and fresh- and brackish–water mollusks. Shallow water marine mollusks of mid-Cretaceous age found in the Kwiguk quadrangle (table 2)

Submarine fan deposits

Kyg **Graywacke sandstone and mudstone turbidites, undivided (Cretaceous)**

Location—Unit poorly exposed along the eastern margin of the Yukon River delta plain in the southeastern St. Michael quadrangle and adjoining Kwiguk quadrangle. Also crops out in the Kusilvak Mountains in southwestern Kwiguk quadrangle and adjoining Marshall quadrangle

Description—Sparse field data on this sedimentary rock unit suggests unit composed largely of graywacke turbidites including both highly calcareous graywacke as in unit Kygc and graywacke containing abundant volcanic debris as in unit Kygv

Kygc **Highly calcareous graywacke sandstone and mudstone turbidites (Cretaceous)**

Location—Extends in a broad belt from the southeast corner of St. Michael quadrangle and the northwest corner of Holy Cross quadrangle to south-central Kwiguk quadrangle. Unit is infolded with and locally intertongues with unit Kygv

Description—Turbidites composed of highly calcareous sandstone interbedded with noncalcareous micaeous siltstone and shale. No fossils found in unit, but elsewhere in the

Yukon-Koyukuk Basin similar assemblages have yielded marine mollusks of probable late Early or early Late Cretaceous age (Patton, and others, 2009)

Kygv **Graywacke sandstone and mudstone turbidites containing abundant laumontitized volcanic debris (Cretaceous)**

Location—Unit widely exposed in a broad belt extending from the southeastern corner of the St. Michael quadrangle to south-central Kwiguk quadrangle. Unit is infolded with and locally intertongues with unit Kygc

Description—Hard, well-indurated, fine- to medium-grained, locally tuffaceous sandstone and micaceous mudstone. Some sandstone beds have a distinctly mottled appearance owing to presence of laumontite, most commonly in tuffaceous-rich layers. No fossils reported in the map area, but elsewhere in the Yukon-Koyukuk basin, a lithologically similar unit has yielded marine mollusks of late Early Cretaceous age (Patton, and others, 2009)

Marginal shelf and slope deposits

Kym **Polymict conglomerate, sandstone, siltstone, and shale (Cretaceous)**

Location—Unit poorly exposed along the eastern and western margins of the Yukon-Koyukuk Basin. On the eastern margin unit crops out at scattered localities in southern Holy Cross and northern Russian Mission quadrangles. On the western margin exposures of this unit are confined to a few small isolated outcrops on the coastal plain in northern Kwiguk and southeastern St. Michael quadrangles

Description—Pebble and cobble conglomerate interbedded with sandstone, siltstone, and shale. Conglomerate contains clasts of chert, greenstone, quartz, and schist in variable amounts. Sandstone varies from poorly-sorted graywacke turbidite to well-washed quartz-rich sandstone. Strata along western margin commonly are rich in carbonate debris. Some conglomerate beds on the eastern margin contain abundant granitic rock clasts. Well-preserved leaf impressions of Cretaceous (Albian-Cenomanian?) age occur in shale beds the along the eastern margin of the basin in the Holy Cross quadrangle (table 2)

KUSKOKWIM BASIN

Deltaic and submarine fan deposits, undivided

Kks **Sandstone, siltstone, and shale (Cretaceous)**

Location—Exposures confined to the eastern margin of map area in the northeastern Russian Mission quadrangle and adjoining parts of Holy Cross quadrangle and in Kilbuck Mountains in southeastern Russian Mission quadrangle. These deposits form the western margin of the Kuskokwim Basin, a broad Cretaceous sedimentary trough that extends from central Alaska nearly to Bristol Bay

Description—Composed of both deltaic and submarine fan deposits. Deltaic deposits consist of well-sorted, quartz-rich, cross-bedded sandstone interbedded with siltstone and shale. Submarine fan deposits composed of turbiditic sequences that grade from fine- to medium-grained graywacke to laminated mudstone. Marine mollusks collected from unit in the Russian Mission quadrangle are of Late Cretaceous (Cenomanian-Turonian) age (table 2)

LITHOTECTONIC TERRANES

KOYUKUK TERRANE

KJv **Andesitic and basaltic volcaniclastic rocks and lava flows, chert, and mudstone (Early Cretaceous and Jurassic)**

Location—Scattered localities in Holy Cross quadrangle and the northern part of Russian Mission quadrangle. Unit also includes several small exposures along the faulted western boundary of the Yukon-Koyukuk basin in Kwiguk quadrangle and adjoining St Michael quadrangle

Description—Highly disrupted assemblage of mafic to intermediate tuff, breccia, agglomerate, volcanic-rich conglomerate and graywacke, cherty tuff, chert, mudstone, and andesitic and basaltic pillow lava. Unit locally intruded by sills and dikes of diabase, diorite, and gabbro. Tuffs commonly are laumontitized. Some conglomerate beds east of the Yukon River in Holy Cross quadrangle contain clasts of altered granitic rocks. Unit is assigned an Early Cretaceous to Jurassic age based on sparse isotopic and fossil data and on its stratigraphic position below late Early Cretaceous sedimentary rocks of the Yukon-Koyukuk basin and above Triassic rocks of the Angayucham-Tozitna terrane. In the area east of the Yukon River a diorite intrusion into this unit yielded a K/Ar amphibole cooling age of 128 Ma (Early Cretaceous) and an andesite porphyry clast from a volcanic conglomerate gave a K/Ar amphibole age of 164 Ma (Middle Jurassic) (table 1). On Yukon River in the western part of the Russian Mission quadrangle, thin beds of calcareous tuffs contain mollusks of Early Cretaceous (Hauterivian and Valanginian) age (table 2)

Jt **Trondhjemite, tonalite, and gabbro (Jurassic)**

Location—Unit confined to the north-central part of the Holy Cross quadrangle where it intrudes a fault-bounded belt of undivided Koyukuk and Angayucham-Tozitna terranes (KMu)

Description—Chiefly trondhjemite and tonalite plutonic bodies that locally have been metasomatized by potassium-rich fluids to a pink granite and granodiorite. Also includes subordinate amounts of quartz diorite, diorite, and gabbro. Some of plutonic bodies have been cataclastically deformed. Unit is assigned a Jurassic age based on data from the adjoining Unalakleet quadrangle where similar plutonic bodies yield K/Ar isotopic cooling ages that range from 173 to 130 Ma (Patton and Moll-Stalcup, 1996)

MzPzum **Serpentinized ultramafic rocks (Mesozoic and Paleozoic?)**

Location—Unit confined to four small bodies distributed along the eastern side of a fault-bounded belt composed of units KMu and Jt in the north-central part of the Holy Cross quadrangle. Although the four bodies were mapped entirely by aerial reconnaissance, their appearance and erosional characteristics are similar to small bodies of ultramafic rocks which were mapped on the ground a short distance to the north in the Unalakleet quadrangle (Patton and Moll-Stalcup, 1996)

Description—Unit presumed to be composed of partly serpentinized harzburgite and dunite. May also include some gabbro. Unit probably Mesozoic in age, but may be as old as Paleozoic

ANGAYUCHAM-TOZITNA TERRANE

KMu **Andesitic and basaltic volcaniclastic rocks, lava flows, chert, and mudstone (KJv) and altered basalt, chert, chert breccia, argillite, tuff, volcaniclastic graywacke, and limestone (TrMv), undivided (Cretaceous to Mississippian)**

TrMv **Complexly deformed assemblage of altered basalt, chert, chert breccia, argillite, tuff, volcaniclastic graywacke, and limestone (Triassic to Mississippian)**

Location—Unit widely distributed in the Holy Cross and Russian Mission quadrangles where it is complexly infolded and faulted with the Koyukuk terrane. Best exposures occur in southwestern Holy Cross quadrangle, northwestern Russian Mission quadrangle, and in a small area between the Kuskokwim and Yukon Rivers in the east-central Russian Mission quadrangle. Owing to lack of continuous exposures and the reconnaissance nature of the field data, the unit cannot be mapped separately over much of the Holy Cross and Russian Mission quadrangles and is included with the Koyukuk terrane in undivided unit KMu

Description—Unit composed of a wide variety of mafic and intermediate volcanic and intrusive rocks including basalt, andesite, diabase, gabbro, and volcaniclastic rocks that are weakly metamorphosed to prehnite-pumpellyite and locally to greenschist facies assemblages. The volcanic and intrusive rocks are interbedded with varicolored radiolarian chert, chert breccia, chert pebble conglomerate, argillite, graywacke, and small limestone bodies. The chert, argillite, graywacke, and limestone are locally metamorphosed to metachert, slate, pelitic schist and marble. Unit assigned a Triassic to Mississippian age based on locally abundant fossils, chiefly from scattered limestone bodies (shown on map as unit ls) in southwestern Holy Cross and northwestern Russian Mission quadrangles (table 2). A small body of amphibolite from near the northwestern border of the Russian Mission quadrangle yielded a K/Ar isotopic cooling age of 349.27±10.48 Ma (early Mississippian) (table 1)

NYAK TERRANE

(from Box and others, 1993)

KJb **Basalt and andesite lava flows (Early Cretaceous and (or) Late Jurassic)**

Location—Unit confined to Kilbuck Mountains, southeastern Russian Mission quadrangle

Description—Variably altered basalt and andesite. Conformably(?) overlies unit Jab and unconformably(?) overlain by unit TJb. Assigned an Early Cretaceous to latest Jurassic age

Jvc **Volcaniclastic conglomerate, sandstone, and shale (Late and Middle Jurassic)**

Location—Unit confined to Kilbuck Mountains, southeastern Russian Mission quadrangle

Description—Tuffaceous marine sandstone, shale, and conglomerate. Minor basaltic and andesitic lava flows. Felsic pyroclastic rocks locally near base of unit. Unit rests conformably(?) on unit Jab and is conformably(?) overlain by unit KJb. Mollusks collected from this unit are of Late Jurassic (late Kimmeridgian to early Tithonian) age (table 2). Middle Jurassic (Bajocian) mollusks are reported by Box and others (1993) from this unit in the adjoining Bethel quadrangle south of the Russian Mission quadrangle

Jab **Andesitic and basaltic lava flows and marine volcaniclastic rocks (Middle Jurassic)**

Location—Unit confined to Kilbuck Mountains, southeastern Russian Mission quadrangle

Description—Andesitic and basaltic lava flows and flow breccias. Tuffaceous sandstone and conglomerate containing abundant clasts of mafic and intermediate volcanic and intrusive rocks. Unit altered to low-grade metamorphic facies by variable replacement of primary minerals by chlorite, calcite, epidote, albite, and quartz. Unit assigned a Middle Jurassic (Bajocian) age based on the presence of marine mollusks

VOLCANIC AND INTRUSIVE ROCKS OF UNCERTAIN AGE AND AFFINITY

TJb **Whitefish Lake Volcanic Field (early Tertiary? to Jurassic?)**

Location— Unit confined to Kilbuck Mountains, southeastern Russian Mission quadrangle

Description—Altered basaltic lava flows and subordinate altered andesite, dacite, rhyolite, and gabbro. Inferred to be the extrusive equivalent of the mafic intrusive rocks of unit TJm. Regional relationships suggest unit could be as old as Jurassic or as young as Tertiary

TJm **Altered mafic plutonic rocks (early Tertiary? to Jurassic?)**

Location—Small scattered bodies in the Russian Mission and southern Holy Cross quadrangles

Description—Altered gabbro and diorite bodies. Intrudes units Jab, Jvc, KJv, and KMu. Age of unit is uncertain, but not older than Jurassic. Some or all of the unit may be as young as Tertiary

TJi **Hyabyssal felsic intrusive rocks (early Tertiary? to Jurassic?)**

Location—Confined to a single body in the Kilbuck Mountains, southeastern Russian Mission quadrangle

Description—Altered rhyolite and dacite porphyries. Age of unit is uncertain, but not older than Jurassic. May be as young as Tertiary

Table 1. Radiometric age determinations from the Lower Yukon region, southwest Alaska

[Quadrangles listed are the 1:250,000-scale sheets, all ages have been calculated using constants of Steiger and Jager, 1977; references listed at end of table]

Sample	Quadrangle	Latitude (degrees)	Longitude (degrees)	Age, Ma	Analytical Error, Ma	Method	Rock type	Mineral	Comment	Reference
61AHr 91	Hooper Bay	61.7500	-165.1500	80.6	4.0	K/Ar	Granodiorite	Biotite		Hoare and Condon, 1966, 1968
62AHr 77	Holy Cross	62.7553	-159.0917	64.7	3.0	K/Ar	Rhyolite	Sanidine		Marvin and Cole, 1978
62AHr 79	Holy Cross	62.6750	-159.1695	128	4.5	K/Ar	Diorite	Hornblende	Shageluk diorite, location corrected	Marvin and Cole, 1978
63ACo 254	Russian Mission	61.8817	-161.4778	70.9	3.3	K/Ar	Quartz monzonite	Biotite	Base Hill quartz monzonite	Marvin and Cole, 1978
63ACo 414	Russian Mission	61.0333	-160.0000	120	3.3	K/Ar	Granodiorite	Biotite	Nyac pluton	Wilson, 1977; Marvin and Cole, 1978; Decker and others, 1984; Frost and others, 1988; Box and others, 1993
82MR 300	Russian Mission	61.1310	-159.8288	101.1	3.0	K/Ar	Granodiorite	Hornblende		Decker and others, 1984; Frost and others, 1988; Robinson and Decker, 1986; Box and others, 1993
				108.5	3.3	K/Ar	Granodiorite	Biotite		
82MR 307	Russian Mission	61.0392	-159.6755	66.6	2.0	K/Ar	Granodiorite	Biotite	Minimum age, Fox Creek	Frost and others, 1988; Robinson and Decker, 1986
85AM 16a	Holy Cross	65.7500	-159.0833	67	2.0	K/Ar	Tuff	Sanidine	Devitrified tuff	Miller and Bundtzen, 1994
85Bt 174	Russian Mission	61.7000	-159.2000	70.3	2.1	K/Ar	Quartz monzonite	Biotite		Bundtzen and Laird, 1991
87APa 113	Holy Cross	62.4138	-159.5112	164.19	4.93	K/Ar	Conglomerate	Amphibole	Andesite porphyry clast in volcanic conglomerate	This report
87APa 147	Russian Mission	61.7250	-161.9458	19.35	0.58	K/Ar	Basalt	Whole rock		This report

Sample	Quadrangle	Latitude (degrees)	Longitude (degrees)	Age, Ma	Analytical Error, Ma	Method	Rock type	Mineral	Comment	Reference
87APa 60	Russian Mission	61.9147	-161.9283	69.29	2.08	40/39	Granite porphyry	Biotite		Miller and others, 2000
87APa 62	Russian Mission	61.8833	-161.9388	60.85	1.83	K/Ar	Granite gneiss	White mica		This report
				67.1	2.01	K/Ar		Biotite		This report
87ASb 228	Russian Mission	61.8237	-161.9833	349.27	10.48	K/Ar	Amphibolite	Amphibole		This report
87Bt 115	Holy Cross	62.2138	-159.1278	62.9	1.9	K/Ar	Alkali granite	Amphibole		This report
88ATf 32	Russian Mission	61.1050	-159.7745	110.0	3.3	40/39 Total Fusion	Granodiorite	Biotite		Box and others, 1993
88Bt 113	Russian Mission	61.6917	-159.3612	6.19	0.19	K/Ar	Basalt	Whole rock		Bundtzen and Laird, 1991
91BT210	Russian Mission	61.9053	-161.4688	69.4	2.1	40/39	Alaskite	White Mica	Alaskite dike	Miller and others, 2000
95Bt 245	Holy Cross	62.0597	-160.9708	67.3	0.9	40/39 Total Fusion	Granite porphyry	Biotite	Dike	Miller and others, 2000
95Bt 259	Holy Cross	62.0472	-161.0280	60.4	1.1	40/39 Plateau	Granodiorite	Amphibole	Dike	Miller and others, 2000
DT83-24	Holy Cross	62.9800	-159.9700	50.8	1.5	K/Ar	Basalt	Whole rock		Harris, 1985; Harris and others, 1987
DT83-25	Holy Cross	62.9800	-159.9900	42.9	1.3	K/Ar	Basalt	Whole rock		Harris, 1985; Harris and others, 1987

Table references cited:

Box, S.E., Moll-Stalcup, E.J., Frost, T.P., and Murphy, J.M., 1993, Preliminary geologic map of the Bethel and southern Russian Mission quadrangles, southwestern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2226-A, scale 1:250,000.

Bundtzen, T.K., and Laird, G.M., 1991, Geology and mineral resources of the Russian Mission C-1 quadrangle, southwest Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 109, 24 p., 1 plate, scale 1:63,360.

Decker, John, Reifenstuhl, R.R., and Coonrad, W.L., 1984, Compilation of geologic data from the Russian Mission A-3 quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 84-19, 1 sheet, scale 1:63,360.

Frost, T.P., Calzia, J.P., Kistler, R.W., and Vivit, D.V., 1988, Petrogenesis of the Crooked Mountains pluton, Bethel quadrangle, *in* Galloway, J.P., and Hamilton, T.D., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1987: U.S. Geological Survey Circular 1016, p. 126-131.

Harris, R.A., 1985, Paleomagnetism, geochronology, and paleotemperature of the Yukon-Koyukuk Province, Alaska: Fairbanks, University of Alaska M.S. thesis, 139 p., 1 plate.

Harris, R.A., Stone, D.B., and Turner, D.L., 1987, Tectonic implications of paleomagnetic and geochronologic data from the Yukon-Koyukuk province, Alaska: Geological Society of America Bulletin, v. 99, p. 362-375.

Hoare, J.M., and Condon, W.H., 1966, Geologic map of the Kwiguk and Black quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I-469, scale 1:250,000.

Hoare, J.M., and Condon, W.H., 1968, Geologic map of the Hooper Bay quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I-523, scale 1:250,000.

Marvin, R.F., and Cole, J.C., 1978, Radiometric ages: Compilation A, U.S. Geological Survey: Isochron/West, no. 22, p. 3-14.

Miller, M.L, and Bundtzen, T.K., 1994, Generalized geologic map of the Iditarod quadrangle, Alaska, showing potassium-argon, major-oxide, trace-element, fossil, paleocurrent, and archaeological sample localities: U.S. Geological Survey Miscellaneous Field Studies Map MF-2219A, scale 1:250,000, 48 p.

Miller, M.L., Tucker, R.D., Layer, P.W., and Bundtzen, T.K, 2000, Isotopic ages from intrusive rocks near the Stuyahok gold placer deposits, south-central Holy Cross quadrangle, Alaska, *in* Kelley, K.D, and Gough, L.P., eds., Geologic studies in Alaska by the U.S. Geological Survey, 1998: U.S. Geological Survey Professional Paper 1615, p. 179-188.

Robinson, M.S., and Decker, John, 1986, Preliminary age dates and analytical data for selected igneous rocks from the Sleetmute, Russian Mission, Taylor Mountains, and Bethel quadrangles, southwestern Alaska: Alaska Division of Geological and Geophysical Surveys Public Data-file 86-99, 7 p.

Wilson, F.H., 1977, Some plutonic rocks of south-western Alaska, a data compilation: U.S. Geological Survey Open-File Report 77-501, 4 plates, 7 p.