Generalized bedrock geologic map, Yukon Flats region, east-central Alaska

by

Alison B. Till, Julie A. Dumoulin,
U.S. Geological Survey, Anchorage Alaska

Jeffrey D. Phillips,
U.S. Geological Survey, Denver, Colorado

Richard G. Stanley, and Jesse M. Crews
U.S. Geological Survey, Menlo Park, California

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INTRODUCTION

This 1:500,000-scale generalized geologic map of the Yukon Flats basin and its borderlands covers a large part of interior Alaska adjacent to the Canadian border. The basin is a vast, forested lowland that contains numerous lakes and streams. The borderlands are generally densely vegetated low rolling hills. The vegetative cover is predominantly trees and shrubs in the southern areas, and shrubs and tundra on the northern flank of the basin. Typically, bedrock exposures are found in limited numbers on ridgelines and banks of rivers and streams.

This geologic map is intended to show major geologic features that surround the Yukon Flats basin. Geologic units were generalized to highlight significant boundaries and relationships so that the general geologic setting of the basin would be more clearly evident and the subsurface basin geology could be more easily inferred.

The map was compiled largely from existing geologic maps, most of them based on field data collected between 1948 and 1974 (Fig. 1). Mapping in the Livengood and Circle quadrangles, and parts of the Bettles and Wiseman quadrangles, was done more recently in the 1970s and 1980s. Field data for larger-scale geologic maps in the Charley River and Tanana quadrangles was collected in the 1980s and 1990s, and field data from 2002-2003 were used to compile parts of the Tanana quadrangle. Published and unpublished paleontologic data were used to assign ages to the map units.

GEOLOGIC OVERVIEW

The geologic units that underlie the flanks of the Yukon Flats basin can be divided into three main provinces based on their histories (Fig. 2). The rocks contained in each province share significant aspects of their formation and their subsequent deformation. For example, an important factor in definition of the provinces is the paleogeographic affinity of the oldest rocks in an area. Some of the older rocks in the map area clearly formed on the margin of the North American continent, as they contain fossils known to be restricted to North America. Others of the older rocks contain fossils that have affinities with both North America and Siberia; they may have formed on landmasses adjacent to both continents (but not necessarily part of either continent). The lithologic nature of the rock succession and most importantly the nature of the contained fossil fauna and flora are clues to paleogeographic affinities. This information and the deformational history of an area are important factors in definition of the geologic provinces.

Structural geology

This simplified geologic map does not show all faults that have been mapped in the map area. The faults shown are major faults and fault zones, many of which mark boundaries between the generalized units used in the map. Many of the faults shown have had protracted histories and some are known or suspected to have accommodated different types of displacement at different times. At least four phases of deformation have been documented along the Kobuk-Malamute fault zone, for example, including periods of thrusting, extensional, and strike-slip displacement (Avé-Lallement and others, 1998). In the central and northern parts of the Porcupine province, very little is known about fault displacements. Because of these two factors, a number of faults on the map are shown without symbols indicating the nature of displacement.

Brooks Range province

The northern and western flanks of the basin are underlain by rocks that participated in an ancient collisional or mountain-building event. Those rocks are grouped herein under the heading "Brooks Range province" and include rocks that underly the Brooks Range, Ruby Geanticline, Rampart area, Yukon-Koyukuk basin, and the western part of the Yukon Flats basin. The rocks of this province record the collision of oceanic rocks with an ancient continental margin (Moore and others, 1994) during Jurassic and Cretaceous time. Rocks that lie along the northern margin of this map, in the central Brooks Range, are remnants of the continental margin, which is thought to have characteristics of both the North American and Siberian continents (Dumoulin and others, 2002). The core of the Ruby Geanticline and the southern part of the Brooks Range contain rocks that were once part of that continental margin, but were subducted, metamorphosed to blueschist-facies, and deformed in the early stages of the collision (Pzp€b). Oceanic rocks of the Angayucham-Tozitna terrane (JDat) represent the initial material that collided with the margin, and include remnants of a Jurassic arc and older oceanic crustal rocks. The Yukon-Koyukuk basin is underlain by andesitic volcanic and volcaniclastic rocks of the Koyukuk arc and marine and younger non-marine sedimentary rocks (Kkyu), which represent an arc and basin related to the latter part of the collisional event. The boundary between the Brooks Range province and the adjacent Yukon-Tanana province is marked by the Victoria Creek fault zone, a major fault zone that connects the Tintina and Kaltag fault systems (Dover, 1994 and references therein).

Porcupine province

The eastern flank of the Yukon Flats basin is underlain by rocks of the ancient North American continental margin (Tatonduk area) and rocks that are the most poorly understood in the map area (Porcupine platform). These rocks are herein grouped under the heading "Porcupine province" (Fig. 2). The southern part of this province, the Tatonduk area, is relatively well studied (see Dover, 1994, and references therein; Van Kooten and others, 1996). Here, rock units and their contained fossil fauna that range from Precambrian to Cretaceous age have close affinities to ancestral North America. The central and northern parts of the province, the Porcupine platform, are among the most poorly known rocks in Alaska. The Black River quadrangle has never been systematically mapped, and the Coleen quadrangle was mapped in the 1960s. Although these rocks are known to be deformed, we know little about the style of deformation and how it compares to that of similarly-aged rocks in adjacent parts of Canada. Based on known lithologic characteristics of the rocks, however, some have an apparent affinity with rocks in the Brooks Range. Therefore, the poorly known geology of the Porcupine platform could hold a crucial link between the ancient continental margin of the Brooks Range and that of ancient North America.

Some workers have shown the boundary between the Porcupine province and the adjacent Brooks Range province as a major strike-slip fault called the Porcupine lineament or megashear (see discussion in Moore and others, 1994). However, no fault corresponding to this structure was mapped in the Coleen quadrangle, where it should be evident, and no geophysical evidence exists for a major geologic transition or fault where the structure traverses the area (Brosgé and Reiser, 1969; Lane, 1997; Saltus and others, 2004). In addition, the apparent close lithologic relationship between some rocks of the Porcupine platform and sequences in the Brooks Range argues against the existence of the structure. We have no evidence that the boundary we show between the Brooks Range and Porcupine provinces is a significant structural boundary; we defined it strictly to organize the information in this map.

The southern boundary of the Porcupine province is the Tintina fault zone and trace of the Yukon River. The Tintina fault zone is a significant crustal boundary that has accommodated 450 or more kilometers of right lateral strike-slip movement (Dover, 1994; Mortensen and others, 2000). Rocks south of the fault zone, therefore, originated 100s of kilometers to the southeast, and are not directly related to the rocks of the Porcupine province.

Yukon-Tanana province

The Yukon-Tanana province underlies the southern flank of the Yukon Flats basin. The province is bounded on the northeast by the Tintina fault zone and Yukon Flats basin and on the northwest by the Victoria Creek fault zone and an unnamed thrust fault (Fig. 2). The main geologic unit in this province is the vast Yukon-Tanana terrane (PzpꞒy), which lies south of the Tintina fault system and stretches hundreds of kilometers to the southeast into Canada. The Yukon-Tanana terrane contains several packages of rocks originally formed on and near the North American continental margin far south of their present position. It is thought that they represent oceanic and continental margin rocks that, like those in the Brooks Range province, record a collisional event at the continental margin (Dusel-Bacon and others, 2002, and references therein). This collisional event, though broadly synchronous with the collision recorded in the Brooks Range province, occurred many hundreds of kilometers to the south. Rocks of the Yukon-Tanana terrane record several phases of deformation from the Triassic to the Cretaceous and were subsequently translated northward along the Tintina fault system into their present position (Mortensen and Jilson, 1985; Dusel-Bacon and others, 2002).

On the northwest margin of the Yukon-Tanana terrane (PzpꞒy), several packages of weakly metamorphosed to unmetamorphosed rocks sit between the terrane and the Victoria Creek fault. Three of the packages contain Late Proterozoic to Paleozoic sequences of dominantly sedimentary rocks (PzZs, PzZl, PzZw); delineation of the packages follows subdivisions established by Weber and others (1992) in the Livengood quadrangle geologic map. The Late Proterozoic and earliest Paleozoic rocks in all three packages are clastic rocks of the Wickersham unit, largely argillite and grit, but later Paleozoic rocks differ in character and paleogeographic affinity from package to package. The Wickersham unit is interpreted as slope sediments that formed on the Late Proterozoic to Cambrian North American continental margin and has been correlated with the Windemere Supergroup, a Late Proterozoic sequence exposed in Canada that has a clear depositional relationship to North America (Weber and others, 1985; Grantz and others, 1991). No consensus exists about the relationships of each Paleozoic sequence to the underlying Wickersham unit or to the ancient North American margin. A package of deformed and weakly metamorphosed Mesozoic marine sedimentary rocks (KJmu) sits between units PzZl and PzZw, and is called the Wilber Creek unit (Weber and others, 1992) or the Manley terrane (Silberling et al., 1994). These sedimentary rocks have been correlated with those in the Kandik basin, although fossil control in that basin is poor (Kku; Dover, 1994).

North of the Yukon-Tanana terrane, between the Yukon Flats basin and the Tintina fault system, Paleozoic and older rocks of continental affinities are juxtaposed with the oceanic Angayucham-Tozitna terrane (JDat). The continental rocks include a unit also found in the Porcupine province (Pzqs) and another that may be correlative with part of the Brooks Range province (DSc). Thus, this area contains units that have affinities to all of the provinces; their present juxtaposition is likely related to movement on the Tintina fault system and related, older fault systems.

Angayucham-Tozitna terrane

One major unit, the Angayucham-Tozitna terrane (JDat), is found in all provinces. The mafic igneous and related sedimentary rocks that make up the terrane are all of oceanic origin, but from at least two oceanic settings. Along the southern flank of the Brooks Range thick sections of weakly metamorphosed pillow basalt are thought to have originated as oceanic plateaus (Pallister and others, 1989); along the western flank of the Ruby Geanticline, high-grade metamorphic mafic rocks are thought to be the roots of an island arc (Ghent and others, 2001). Aeromagnetic, gravity, and seismic data indicate that the Yukon Flats basin is largely underlain by rocks of the Angayucham-Tozitna terrane (Saltus and others, 2005). The depth-to-basement contours on the geologic map represent the thickness of sedimentary rocks that may sit on the Angayucham-Tozitna terrane and are based on geophysical modeling (Phillips and Saltus, 2005). The wide distribution of the Angayucham-Tozitna terrane in the map area is the result of multiple deformational episodes, the first of which was the early phase (Jurassic) of the Brooks Range orogeny. Later, during the middle part of the Cretaceous, parts of the terrane were thrust eastward over the continental margin in the Tatonduk area (Underwood and others, 1996; Johnsson, 2000). In addition, Tertiary movement on the Tintina fault system likely deformed rocks of the Angayucham-Tozitna terrane along the southern boundary of the Yukon Flats basin (Dover, 1994).

Yukon Flats basin

The time of initial subsidence of the modern Yukon Flats basin is unknown but must have occurred after the mid-Cretaceous thrusting event in the Tatonduk area. Based on the age of sedimentary rocks exposed around the basin margin, initial subsidence may have started in the latest Cretaceous or earliest Tertiary time (Kirschner, 1994). Tectonic models of the basin link its formation to movement on the Kobuk-Malamute and Tintina fault zones (Kirschner, 1994; Dover, 1994). Timing on the movement of both fault systems is poorly constrained. Based on interpretation of seismic data, Till and others (2005) proposed that the more deeply subsided parts of the basin were formed before the Miocene, when thin, laterally continuous units were deposited over broad areas in the basin. The deeper parts of the basin, represented by the contours on the geologic map, likely formed in Late Cretaceous to Early Tertiary time.

The Yukon Flats basin is thought to be prospective for petroleum (Kirschner, 1994), but no deep exploratory wells have been drilled and no commercial production of petroleum has occurred. Direct indications of petroleum in the vicinity of Yukon Flats include small amounts of biogenic methane that were found in a 700-m-deep coalbed methane test well drilled in 2005 at Fort Yukon (Barker and others, 2005), and scattered occurrences of tasmanite, a type of oil shale, in pre-Tertiary rocks located in the uplands north of Yukon Flats (Troutman and Stanley, 2003). Seismic reflection surveys conducted by the oil industry during the 1970s and 1980s, along with more recent studies of gravity and magnetics by the U.S. Geological Survey, indicate that low-density sedimentary strata in the Yukon Flats basin are as thick as 8 kilometers (Phillips and Saltus, 2005). Shallow core hole penetrations and nearby outcrops suggest that the low-density basin fill consists mainly of Tertiary fluvial and lacustrine deposits (Stanley and others, 2005). Potential source rocks of petroleum are thought to include Tertiary nonmarine coal, mudstone, and shale, whereas potential reservoirs include Tertiary nonmarine sandstone and conglomerate (Lillis and Stanley, 2005).

An assessment by the U.S. Geological Survey (Stanley and others, 2004) concluded that the amount of undiscovered, technically recoverable oil resources in the Yukon Flats basin could range from zero to almost 600 million barrels (MMBO) with a mean of 173 MMBO and that the amount of undiscovered, technically recoverable gas resources could range from zero to almost 15 trillion cubic feet (TCF) with a mean of about 5.5 TCF.

REFERENCES CITED

Aleinikoff, J.N., Moore, T.E., Walter, M., and Nokleberg, W.J., 1993, U-Pb ages of zircon, monazite, and sphene from Devonian metagranites and metafelsites, central Brooks Range, Alaska: U.S. Geological Survey Bulletin 2068, p.59-70.

Athey, J.E., Layer, P.W., and Drake, J., 2004, ^{40}Ar/^{39}Ar ages of rocks collected in the Livengood C-3, C-4, and B-5 quadrangles, Alaska: Alaska Division of Geological and Geophysical Surveys Raw Data File 2004-1, 12p.

Avé Lallement, H.G., Gottschalk, R.R., Sisson, V.B., and Oldow, J.S., 1998, Structural analysis of the Kobuk fault zone, north-central Alaska, *in* Oldow, J.S, and Avé Lallement, H.G., eds., Architecture of the Central Brooks Range Fold and Thrust Belt, Arctic Alaska: Boulder, Colorado, Geological Society of America Special Paper 324, p. 261-268.

Barker, C.E., Clark, A.C., Clough, J.G., Maclean, E.A., Ogbe, D.O., Clautice, K.H., Weeks, E.P., and Fisk, R.F., 2005, Shallow coalbed gas assessment at Fort Yukon, Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 4, p. 95.

Blodgett, R.B., Rohr, D.M., and Boucot, A.J., 2002, Paleozoic links among some Alaskan accreted terranes and Siberia based on megafossils, *in* Miller, E.L., Grantz, A., and Klemperer, S.L., eds., Tectonic Evolution of the Bering Shelf-Chukchi Sea-Arctic Margin and Adjacent Landmasses: Boulder, Colorado, Geological Society of America Special Paper 360, p. 273-290.

Brabb, E.E., 1969, Six New Paleozoic and Mesozoic Formations in East-Central Alaska: U.S. Geological Survey Bulletin 1274-I, 26p.

Brabb, E.E., 1970, Preliminary geologic map of the Black River quadrangle, east-central Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-601, 1 sheet, scale 1:250,000.

Brabb, E.E. and Churkin, Michael, Jr., 1969, Geologic map of the Charley River quadrangle, east-central Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-573, 1 sheet, scale 1:250,000.

Brabb, E.E., and Grant, R.E., 1971, Stratigraphy and paleontology of the revised type section for the Tahkandit Limestone (Permian) in East-Central Alaska: U.S. Geological Survey Professional Paper 703, 26 p.

Bradley, D.C., Dumoulin, J.A., Layer, P.W., Sunderlin, D., Roeske, S.M., McClelland, W.C., Harris, A.G., Abbott, G., Bundtzen T.K., and Kusky, T., 2003, Late Paleozoic orogeny in Alaska's Farewell terrane: Tectonophysics, v. 372, p. 23-40.

Bradley, D.C., McClelland, W., Wooden, J., Till, A., Roeske, S., Miller, M., Karl, S., and Abbot, Grant, in press, Detrital zircon geochronology of some Neoproterozoic to Triassic rocks in interior Alaska, *in* Ridgway, K.D., Trop, J.M., O'Neill, Michael, and Glen, J.M.,eds., Tectonic growth of a collisional continental margin: Crustal evolution of southern Alaska: Boulder, Colorado, Geological Society of America Special Paper.

Brosgé, W.P. and Reiser, H.N., 1964, Geologic map and section of the Chandalar quadrangle, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-375, 1 sheet, scale 1:250,000.

Brosgé, W.P. and Reiser, H.N., 1969, Preliminary geologic map of the Coleen quadrangle, Alaska: U.S. Geological Survey Open-File Map 69-25, 1 sheet, scale 1:250,000.

Brosgé, W.P. and Reiser, H.N., 2000, Geologic map of the Christian quadrangle, Alaska: U.S. Geological Survey Open-File Map 00-192, 14 p., 1 sheet, scale 1:250,000.

Brosgé, W.P., Reiser, H.N., Dutro, J.T., Jr., and Churkin, Michael, Jr., 1966, Porcupine River Canyon, Alaska: U.S. Geological Survey Open-File Report 263, 4 sheets, scale 1:63, 360.

Brosgé, W.P., Lanphere, M.A., Reiser, H.N., and Chapman, R.M., 1969, Probable Permian age of the Rampart Group, central Alaska: U.S. Geological Survey Bulletin 1294-B, 18 p.

Brosgé, W. P. and Reiser, H. N., and Yeend, Warren, 1973, Reconnaissance geologic map of the Beaver quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-525, 1 sheet, scale 1:250,000.

Chapman, R.M., Yeend, Warren, Brosgé, W.P., and Reiser, H.N., 1982, Reconnaissance geologic map of the Tanana quadrangle, Alaska: U.S. Geological Survey Open-File Report OFR 82-734, 20 p., scale 1:250,000.

Churkin, M., Jr. and Brabb, E. E., 1965, Ordovician, Silurian, and Devonian biostratigraphy of east-central Alaska: American Association of Petroleum Geologists Bulletin, v. 49, p. 172-185.

Churkin, Michael, Jr., and Brabb, E.E.,1967, Devonian rocks of the Yukon-Porcupine Rivers area and their tectonic relation to other Devonian sequences in Alaska, *in* Oswald, D.H., ed., International Symposium on the Devonian System: Alberta Society of Petroleum Geologists, Calgary, Alberta, Canada, p. 227-258.

Coleman, D.A., 1985, Shelf to basin transition of Silurian-Devonian rocks, Porcupine River area, east-central Alaska: M.S. thesis, University of Alaska, Fairbanks, Alaska, 162 p.

Dillon, J.T., Brosgé, W.P., and Dutro, J.T., 1986, Generalized geologic map of the Wiseman quadrangle, Alaska: U.S. Geological Survey Open-File Report OFR 86-219, scale 1:250,000.

Dover, J.H., 1992, Geologic map and fold- and thrust-belt interpretation of the southeastern part of the Charley River quadrangle, east-central Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-1942, 1 pamphlet, 14 p., 2 sheets, scale 1:100,000.

Dover, J.H., 1994, Geology of part of east-central Alaska, *in* Plafker, George, and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 153-204.

Dover, J.H., and Miyaoka, R.T., 1988, Reinterpreted geologic map and fossil data, Charley River quadrangle, east-central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2004, scale 1:250,000, 2 sheets.

Dumoulin, J. A., and Harris, A.G., 1994, Depositional framework and regional correlation of pre-Carboniferous metacarbonate rocks of the Snowden Mountain Area, Central Brooks Range, Northern Alaska: U.S. Geological Survey Professional Paper 1545, 66 p.

Dumoulin, Julie A., Harris, A.G., Gagiev, Mussa, Bradley, Dwight C., and Repetski, J.E., 2002, Lithostratigraphic, conodont, and other faunal links between lower Paleozoic strata in northern and central Alaska and northeastern Russia, *in* Miller, E.L., Grantz, A., and Klemperer, S.L., eds., Tectonic Evolution of the Bering Shelf-Chukchi Sea-Arctic Margin and Adjacent Landmasses: Boulder, Colorado, GSA Special Paper 360, p. 291-312.

Dumoulin, J.A., Harris, A.G., Blome, C.D., and Young, L.E., 2004, Depositional settings, correlation, and age of Carboniferous rocks in the western Brooks Range: Economic Geology, v. 99, no. 7, p. 1355-1384.

Dusel-Bacon, Cynthia, Brosgé, W.P, Till, A.B., Doyle, E.O., Mayfield, C.F., Reiser, H.N., and Miller, T.P., 1989, Distribution, facies, ages, and proposed tectonic associations of regionally metamorphosed rocks in northern Alaska: U.S. Geological Survey Professional Paper 1497-A, 2 pls., 44 p.

Dusel-Bacon, Cynthia, Lanphere, M.A., Sharp, W.D., Layer, P.W., and Hanson, V.L., 2002, Mesozoic thermal history and timing of structural events for the Yukon-Tanana Upland, east-central Alaska—$^{40}Ar/^{39}Ar$ data from metamorphic and plutonic rocks: Canadian Journal of Earth Sciences, v. 39, no. 6, p. 1013-1051.

Dusel-Bacon, Cynthia, Wooden, J.L., and Hopkins, M., 2004, U-Pb zircon and geochemical evidence for bimodal mid-Paleozoic magmatism and syngenetic base-metal mineralization in the Yukon-Tanana terrane, Alaska: Geological Society of America Bulletin, v. 116, no 7/8, p. 989-1015.

Eberlein, G.D., and Lanphere, M.A., 1988, Precambrian rocks of Alaska: U.S. Geological Survey Professional Paper 1241-B, 18 p.

Farmer, E.T., Ridgway, K.D., Bradley, D.C., and Till, A.B., 2003, Cretaceous-early Eocene two stage basin development, Yukon Flats basin, north-central Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 560.

Foster, H.L., compiler, 1992, Geologic map of the eastern Yukon-Tanana region, Alaska: U.S. Geological Survey Open-File Report 92-313, 1 sheet, scale 1:500,000, 26 p.

Foster, H.L., Laird, J., Keith, T.E.C., Cushing, G.W., and Menzie, W.D., 1983, Preliminary geologic map of the Circle quadrangle, Alaska: U.S. Geological Survey Open-File Report OFR 83-170A, 32 p., 1 sheet, scale 1:250,000.

Fouch, T.D., Carter, L.D., Kunk, M.J., Smith, C.A.S., and White, J.M., 1994, Miocene and Pliocene lacustrine and fluvial sequences, upper Ramparts and Canyon village, Porcupine River, east-central Alaska: Quaternary International, v. 22/23, p. 11-29.

Ghent, E.D., Roeske, S.M., Stout, M.Z., Bradshaw, J.Y., and Snee, L.W., 2001, Mesozoic granulite-facies metamorphism of the Pitka mafic-ultramafic complex, northern Alaska [abs.]: Geological Society of America Abstracts with Programs v. 33 no. 6. p. 249-250.

Gottschalk, R.R., Oldow, J.S., and Ave Lallement, H.G., 1998, Geology and Mesozoic structural history of the south-central Brooks Range, Alaska, *in* Oldow, John S., and Ave Lallement, Hans G., eds., Architecture of the Central Brooks Range Fold and Thrust Belt, Arctic Alaska: Geological Society of America Special Paper 324, p. 195-223.

Grantz, Arthur, Moore, T.E., and Roeske, S.M., 1991, A-3 Gulf of Alaska to Arctic Ocean: Boulder, Colorado, Geological Society of America Centennial Continent/Ocean Transect, n. 15, 72 p., 3 sheets, scale 1:500,000.

Johnsson, M.J., 2000, Tectonic assembly of east-central Alaska: Evidence from Cretaceous-Tertiary sandstones of the Kandik River terrane: Geological Society of America Bulletin, v. 112, no. 7, p. 1023-1042.

Jones, D.L., Silberling, N.J., Coney, P.J., and Plafker, G., 1987, Lithotectonic terrane map of Alaska, west of the 141^{st} meridian; Folio of the lithotectonic terrane maps of the North American Cordillera: U.S. Geological Survey Miscellaneous Field Studies Map MF-1874-A, scale 1:2,500,000.

Jones, D.L., Coney, P.J., Harms, T.A., and Dillon, J.T., 1988, Interpretive geologic map and supporting radiolarian data from the Angayucham terrane, Coldfoot area, southern Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1993, scale 1:63,360.

Karl, S.M., and Aleinikoff, J.N., 1990, Proterozoic U-Pb zircon age of granite in the Kallarichuk Hills, western Brooks Range, Alaska: U.S. Geological Survey Bulletin 1946, p. 95-100.

Kirschner, C.E., 1994, Interior basins 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, p. 469-493.

Kunk, M. J., Rieck, Hugh, Fouch, T. D., and Carter, L.D. , 1994, $^{40}Ar/^{39}Ar$ age constraints on Neogene sedimentary beds, Upper Ramparts, Half-Way Pillar and Canyon Village sites, Porcupine River, East-Central Alaska: Quaternary International, v. 22/23, p. 31-42.

Lane, L. S., 1997, Canada Basin, Arctic Ocean; evidence against a rotational origin: Tectonics, v. 16, no. 3, p. 363-387.

Lillis, P.G., and Stanley, R.G., 2005, Evaluation of petroleum source rocks from Yukon Flats, east-central Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 4, p. 94.

McClelland, W. C., Schmidt, J.M., and Till, A.B., 2006, New U-Pb SHRIMP ages from Devonian felsic volcanic and Proterozoic plutonic rocks of the southern Brooks Range, Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 38, no. 5, p.12.

Mertie, J.B., Jr., 1930, Geology of the Eagle-Circle district, Alaska: U.S. Geological Survey Bulletin 816, 169p.

Miyaoka, Ronny T., 1990, Fossil locality map and fossil data for the southeastern Charley River quadrangle, East-Central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2007, 46 p., 1 sheet, scale 1:100,000.

Moll-Stalcup, Elizabeth, and Arth, J.G., 1989, The nature of the crust in the Yukon-Koyukuk province as inferred from the chemical and isotopic composition of five Late Cretaceous to Early Tertiary volcanic fields in western Alaska: Journal of Geophysical Research, v. 95, no. B11, p. 15,989-16,020.

Moore, T.E., Wallace, W.K., Bird, K.J., Karl, S.M., Mull, C.G., and Dillon, J.T., 1994, Geology of northern Alaska, *in* Plafker, George, and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, p. 49-140.

Moore, T.E., Aleinikoff, J.N., and Harris, A.G., 1997, Stratigraphic and structural implications of conodont and detrital zircon U-Pb ages from metamorphic rocks of the Coldfoot terrane, Brooks Range, Alaska: Journal of Geophysical Research, v. 102, no. B9, p. 20,797-20,820.

Mortenson, J.K., and Jilson, G.A., 1985, Evolution of the Yukon-Tanana terrane: evidence from the southeastern Yukon Territory: Geology, v. 13, p. 806-810.

Mortenson, J.K., Hart, C.J.R., Murphy, D.C., and Heffernan, S., 2000, Temporal evolution of Early and mid-Cretaceous magmatism in the Tintina Gold Belt, *in* Tucker, T. .L, and Smith, M.T., chairs, The Tintina Gold Belt: concepts, exploration, and discoveries, Special Volume 2: Vancouver, British Columbia, British Columbia and Yukon Chamber of Mines, Cordilleran Roundup, p. 49-57.

Newberry, R.J., 2000, Mineral deposits and associated Mesozoic and Tertiary igneous rocks within interior Alaska and adjacent Yukon portions of the 'Tintina gold belt': a progress report, *in* Tucker, T. .L, and Smith, M.T., chairs, The Tintina Gold Belt: concepts, exploration, and discoveries, Special Volume 2: Vancouver, British Columbia, British Columbia and Yukon Chamber of Mines, Cordilleran Roundup, p. 59-88.

Oliver, W.A., Jr., Merriam, C.W., and Churkin, Michael, Jr., 1975, Ordovician, Silurian, and Devonian corals of Alaska: U.S. Geological Survey Professional Paper 823-B, p. 13-44.

O'Sullivan, P.B., Murphy, J.M., and Blythe, A.E., 1997, Late Mesozoic and Cenozoic thermotectonic evolution of the central Brooks Range and adjacent North Slope foreland basin, Alaska: Including fission-track results from the Trans-Alaska Crustal Transect (TACT): Journal of Geophysical Research, v. 102, no. B9, p. 20,821-20,845.

Pallister, J.S., Budahn, J.R., and Murchey, B.L., 1989, Pillow basalts of the Angayucham terrane; oceanic plateau and island crust accreted to the Brooks Range: Journal of Geophysical Research, B., Solid Earth and Planets, v. 94, no. 11, p. 15,901-15,923.

Patton, W.W., Jr., and Miller, T.P., 1973, Bedrock geologic map of Bettles and southern part of Wiseman quadrangles, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-492, scale 1:250,000.

Patton, W.W., Jr., Stern, T.W., Arth, J.G., and Carlson, C., 1987, New U/Pb ages from granite and granitic gneiss in the Ruby geanticline, and southern Brooks Range, Alaska: Journal of Geology, v. 95, p. 118-126.

Patton, W.W., Jr., Box, S.E., Moll-Stalcup, E.J., and Miller, T.P., 1994, Geology of west-central Alaska, *in* Plafker, George, 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., Wilson, F.H., Labay, K.A., and Shew, Nora, in press, Reconnaissance geologic map and digital data for the Yukon-Koyukuk basin, Alaska: U.S. Geological Survey Scientific Investigations Map SIM-2909, XX p., 1 sheet, scale 1:500,000.

Phillips, J.D., and Saltus, R. W., 2005, Thickness of sedimentary rocks in the Yukon Flats basin, east-central Alaska, as estimated using constrained iterative gravity inversion [abs.]: Geological Society of America Abstracts with Programs v. 37, no. 4, p. 94.

Rainbird, R.H., Jefferson, C.W., and Young, G.M., 1996, The early Neoproterozoic sedimentary succession B of northwestern Laurentia: correlations and paleogeographic significance: Geological Society of America Bulletin v. 108, no. 4, p. 454-470.

Reifenstuhl, R.R., Dover, J.H., Newberry, R.J., Clautice, K.H., Liss, S.A., Blodgett, R.B., Bundtzen, T.K., and Weber, F.R., 1997a, Interpretive geologic bedrock map of the Tanana B-1 quadrangle, central Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations RI 97-15b, 1 sheet, 1:63,360, 15 p. text.

Reifenstuhl, R.R., Layer, P.W., and Newberry, R.J.,1997b, Geochronology ($^{40}Ar/^{39}Ar$) of 17 Rampart-area rocks, Tanana and Livengood quadrangles, east-central Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 97-29, 21p.

Reifenstuhl, R., Dover, J.H., Newberry, R.J., Clautice, K.H., Pinney, D.S., Liss, S.A., Blodgett, R.B., and Weber, F.R., 1998, Interpretive geologic bedrock map of the Tanana A-1 and A-2 quadrangles, central Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations RI 98-37a, 1 sheet, 1:63,360, 18 p. text.

Reiser, H.N., Lanphere, M.A., and Brosgé, W.P., 1965, Jurassic age of a mafic igneous complex, Christian quadrangle, Alaska: U.S. Geological Survey Professional Paper 525-C, p. 668-671.

Rohr, D.M. and Blodgett, R.B., 1994, *Palliseria* (Middle Ordovician Gastropoda) from east-central Alaska and its stratigraphic and biogeographic significance: Journal of Paleontology, v. 68, p. 674-675.

Roeske, S.M., Till, A.B., Layer, P.W., and Harms, T.A., 2003, Kobuk fault zone of the southern Brooks Range, Alaska, preserves Paleocene exhumation of amphibolite grade rocks along a dextral strike-slip fault system [abs.]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 474.

Saltus, R.W., Phillips, J.D., Till, A.B., Stanley, R.G., and Morin, R.L., 2004, Geophysical evidence that oceanic rocks underlie the Yukon Flats basin, Alaska [abs.]: Geological Society of America Abstracts with Programs v. 36, no. 5. p. 495.

Saltus, R.W., Phillips, J.D., Stanley, R.G., Till, A.B., and Morin, R.L., 2005, Geophysical characterization of pre-Cenozoic basement for hydrocarbon assessment, Yukon Flats, Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 4, p. 94.

Silberling, N.J., Jones, D.L., Monger, J.W.H., Coney, P.J., Berg, H.C., and Plafker, George, 1994, Lithotectonic terrane map of Alaska and adjacent parts of Canada, *in* Plafker, George, and Berg, H.C., eds., The Geology of Alaska: Boulder, Colorado, Geological Society of America, The Geology of North America, v. G-1, Plate 3, scale 1:2,500,000.

Stanley, R.G., Ahlbrandt, T.S., Charpentier, R.R., Cook, T.A., Crews, J.M., Klett, T.R., Lillis, P.G., Morin, R.L., Phillips, J.D., Pollastro, R.M., Rowan, E.L., Saltus, R.W., Schenk, C.J., Simpson, M.K., Till, A.B., and Troutman, S.M., 2004, Oil and gas assessment of Yukon Flats, east-central Alaska, 2004: U.S. Geological Survey Fact Sheet 2004-3121, 2 p., online at http://pubs.usgs.gov/fs/2004/3121/

Stanley, R.G., Till, A.B., Simpson, M.K., Schenk, C.J., Saltus, R.W., Rowan, E.L., Phillips, J.D., Morin, R.L., Lillis, P.G., and Crews, J.M., 2005, Assessment of undiscovered oil and gas resources in Yukon Flats, east-central Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 4, p. 95.

Tempelman-Kluit, D.J.,1984, Counterparts of Alaska's terranes in Yukon; Cordilleran geology and mineral exploration status and future trends [abs.]: Vancouver, B.C., Canada, Geologic Association of Canada Cordilleran Section abstracts, p. 41-44.

Till, A.B., 1989, Proterozoic rocks of the western Brooks Range, *in* Dover, J.H., and Galloway, J.P., eds., Geologic Studies in Alaska by the U.S. Geological Survey, 1988: U. S. Geological Survey Bulletin 1903, p. 20-25.

Till, A.B., Schmidt, J.M., and Nelson, S.W., 1988, Thrust involvement of metamorphic rocks, southwestern Brooks Range, Alaska: Geology, v. 16, p. 930-933.

Till, A.B., Stanley, R.G., O'Sullivan, P.B., Saltus, R.W., and Crews, J., 2005, Tectonic events leading to establishment of the Yukon Flats basin, Alaska [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 4, p. 94.

Troutman, S.M., and Stanley, R.G., 2003, Maps showing sedimentary basins, surface thermal maturity, and indications of petroleum in the Central Alaska Province: U.S. Geological Survey Miscellaneous Field Studies Map MF-2428, scale 1:2,500,000, 20 p., CD-ROM, online at http://geopubs.wr.usgs.gov/map-mf/mf2428/

Underwood, M.B., Howell, D.G., Johnsson, M.J., and Pawlewicz, M.J., 1996, Thermo-tectonic evolution of suspect terranes in the Kandik region of east-central Alaska, *in* Johnsson, M.J., and Howell, D.G., eds., Thermal evolution of sedimentary basins in Alaska: U.S. Geological Survey Bulletin 2142, p. 81-110.

Van Kooten, G.K., Watts, A.B., Coogan, J., Mount, V.S., Swenson, R.F., Daggett, P.H., Clough, J.G., Roberts, C.T., and Bergman, S.C., 1996, Geologic investigations of the Kandik area, Alaska, and adjacent Yukon Territory, Canada: Alaska Division of Geological and Geophysical Surveys Report of Investigations RI 96-61, 3 sheets, scale 1:125,000.

Weber, F.R., Smith, T.E., Hall, M.H., and Forbes, R.B., 1985, Geologic guide to the Fairbanks-Livengood area, east-central Alaska: Anchorage, Alaska Geological Society, 45 p.

Weber, F.R., Wheeler, K.L., Rinehart, C.D., Chapman, R.M., and Blodgett, R.B., 1992, Geologic map of the Livengood quadrangle, Alaska: U.S. Geological Survey Open-File Report OFR 92-562, 20 p., 1 sheet, scale 1:250,000.

Weber, F.R., Blodgett, R.B., Harris, A.G., and Dutro, J.T. Jr.,1994, Paleontology of the Livengood quadrangle, Alaska: U.S. Geological Survey Open-File Report 94-215, 23 p., 1 sheet, scale 1:250,000.

Williams, J. R., 1962, Geologic reconnaissance of the Yukon Flats District, Alaska: U.S. Geological Survey Bulletin 1111-H, 42p., 1 plate, scale 1:500,000.

Wilson, F.W., Shew, N., and DuBois, G.D., 1994, Map and table showing isotopic age data in Alaska, *in* Plafker, George, 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, with tables

Wiltse, M.A., Reger, R.D., Newberry, R.J., Pessel, G.H., Pinney, D.S., Robinson, M.S., and Solie, D.N., 1995, Geologic map of the Circle mining district, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations RI 95-2a, scale 1:63,630.

Young, G.M., 1982, The Late Proterozoic Tindir Group, east-central Alaska: Evolution of a continental margin: Geological Society of America Bulletin, v. 93, p. 759-783.

Young, G.M., 1992, Late Proterozoic stratigraphy and the Canada-Australia connection: Geology, v. 20, p. 215-218.

UNIT DESCRIPTIONS

UNITS PRESENT IN MORE THAN ONE PROVINCE

Qu Unconsolidated and poorly consolidated sediments, undivided (Quaternary) – Surficial material deposited by water, wind, freeze-thaw cycles, and glaciers

Tb Basalt flows and rare cinder cones (Tertiary) – Vesicular, massive olivine basalt flows that range from 20 to 300 m thick exposed in the northeastern and northwestern parts of the map area, in the Brooks Range and Porcupine provinces. The best exposed and studied localilties are in the northeast (Coleen quadrangle; Fouch and others, 1994), where flows are interlayered with sedimentary rocks and have yielded $^{40}Ar/^{39}Ar$ ages that range from 15.7+/-0.1 to 14.4+/-0.1 Ma (Miocene; Kunk and others, 1994)

Tg Granitic rocks (Tertiary) – Quartz monzonite, biotite granite, and alaskite exposed in the Rampart area of the Brooks Range province and in the Yukon-Tanana province. The two bodies in the Rampart area exposed between the Yukon River and Victoria Creek fault locally have igneous lineations (aligned long axes of crystals) and strongly deformed contact aureoles, indicating deformation occurred during intrusion. The pluton on the Yukon River yielded a U-Pb zircon age of 60.5 +/- 0.2 Ma; the Manley pluton, on the southern boundary of the map area in the Tanana quadrangle, yielded a U-Pb zircon age of 60.9 +/- 1.0 Ma (A.B.Till, unpub. data). $^{40}Ar/^{39}Ar$ ages have been obtained from these and other plutons in this unit and range from 54 to 64 Ma (Reifenstuhl and others, 1997b, Wilson and others, 1994). Two 66-Ma plutons in the Yukon-Tanana province at the boundary of units Pzp€w and Pzp€y are included in Kg, but have geologic similarities to adjacent plutons mapped as Tg

Ts Clastic sedimentary rocks (Tertiary) – Mudstone, coal, sandstone, and conglomerate deposited in lacustrine and fluvial environments exposed in the southern, western, and northeastern part of the map area. In the southern and western part of the map area, sandstone and conglomerate are common, siltstone and shale are less common, and many localities have minor plant fossils and debris or thin (<2m thick) layers of lignite. Conglomerates have clasts as large as boulder-sized (Chapman and others, 1982; Weber and others, 1992). Paleocene, Eocene, Oligocene and Miocene pollen have been recovered from several sites (Weber and others, 1994, Chapman and others, 1982, unpublished oil industry data, written commun., 2002). In the northeastern map area, the sequence contains basalt as well as mudstone, sandstone, gravels, and silt and is Miocene and Pliocene in age (Fouch and others, 1994)

TKs Sedimentary rocks (Tertiary and Cretaceous) – Sandstone, mudstone, thin coal seams, and conglomerate exposed in the Tatonduk and Rampart areas. In the Tatonduk area, the unit occurs just east of the Kandik basin and along the Tintina fault zone. Late Cretaceous, Paleocene, and Eocene pollen have been recovered from exposures within and immediately south of the map area (Miyaoka, 1990), and from shallow core holes (unpublished oil industry data, written commun., 2002). In the western Rampart area, along the Victoria Creek fault zone, quartz- and chert-rich fluvial conglomerate, sandstone, and mudstone are typical, and palynofloras of probable Maastrichtian (latest Cretaceous) age (Farmer and others, 2003) as well as those of early Tertiary age (Chapman and others, 1982) have been collected. Younger part of the unit likely correlative to unit Ts

Kg Granitic rocks (Cretaceous) – Small plugs to large, batholithic plutons, largely of mid-Cretaceous age, exposed in the Ruby geanticline, Manley basin, and Yukon-Tanana Upland. Ruby geanticline plutons are generally evolved and yield U-Pb zircon and K/Ar ages of 112-90 Ma (Patton and others, 1994). In the Manley basin and western Yukon-Tanana Upland, plutons are slightly younger; they have yielded K/Ar and $^{40}Ar/^{39}Ar$ ages that range from 110 to 88 Ma (Newberry, 2000; Mortensen and others, 2000). A belt of 90-88 Ma quartz-alkalic plutons in the western part of the province has been correlated with the Tombstone alkalic suite in the Yukon Territory (Dover, 1994; Mortensen and others, 2000)

TRPgt Glenn Shale, lower part, and Tahkandit Limestone, undivided (Triassic and Permian) – Thin-bedded fossiliferous limestone, calcareous shale and rare thin oil shale of the lower part of the Glenn Shale, and massive bioclastic limestone, glauconitic sandstone, and minor chert pebble conglomerate of the Tahkandit Limestone. Most of the exposures of this unit are in the southern part of the Porcupine province, but two small lenses (equivalent to lower Glenn Shale only) occur in the central Yukon-Tanana province, along a fault that separates KJmu from PzpꞒw ("Beaver Creek thrust" of Weber and others, 1992). Combination of the two units into one follows the detailed mapping of Dover (1992) and Dover and Miyaoka (1988). Reasons for separating the lower from the upper part of the Glenn Shale on this map are given in the description of the upper part of the Glenn Shale (KJg). In the central Yukon-Tanana province, exposures of this unit are lithologically similar to the lower part of the Glenn Shale and have yielded Permian to Triassic conodonts (Weber and others, 1994). In the southern part of the Porcupine province, the lower part of the Glenn Shale yielded Middle to Late Triassic megafossils, and the limestone of the Tahkandit yielded Permian megafossils and conodonts (Brabb and Grant, 1971; Miyaoka, 1990; A.G. Harris, USGS Emeritus, written commun., 2000)

JDat Angayucham-Tozitna terrane, undivided (Early Jurassic to Devonian) – Lithologically diverse, structurally imbricated igneous and sedimentary rocks of oceanic affinity exposed on all flanks of the Yukon Flats basin. Igneous rocks include ultramafic, mafic extrusive and intrusive, andesitic, and rare dacitic to rhyolitic igneous rocks. Mafic igneous rocks are most characteristic of the unit and locally contain minor amounts of interbedded chert and limestone. Sedimentary rocks are typically volumetrically subordinate to the igneous rocks. Chert is the most common sedimentary lithology, but the presence of argillite, shale, and graywacke is characteristic; rare limestone and oil shale are known. Sedimentary rocks are volumetrically significant in the large exposure of the unit in the northeastern part of the map area (Coleen quadrangle; Brosgé and Reiser, 1969). Both igneous and sedimentary rocks are partially to fully recrystallized to low-grade metamorphic assemblages (Dusel-Bacon and others, 1989; A.B. Till, unpub. data); one exposure in the Beaver quadrangle records amphibolite to granulite facies metamorphism (Ghent and others, 2001). In the southern Brooks Range and Ruby geanticline, the terrane structurally overlies metamorphosed sedimentary rocks of unit DpЄs. Hornblendes from four exposures of gabbro in the Rampart area and Christian quadrangle have yielded K-Ar ages that range from 207 to 174 Ma (Brosgé and others, 1969; Brosgé and Reiser, 2000), but low potassium contents of the amphiboles (and low radiogenic yields in the geochronologic analysis) place the accuracy of these ages in question. A gabbro near Rampart yielded a U-Pb zircon age of 231-230 Ma (Triassic; R. Friedman, written commun., 2004). Radiolarians, conodonts, and pollen from sedimentary rocks interlayered with the mafic rocks and from the predominantly sedimentary sections yielded ages of Devonian, Mississippian, Pennsylvanian, Permian, Triassic, and Early Jurassic. Unit includes rocks previously assigned to the Angayucham and Tozitna terranes (Jones and others, 1987), Rampart Group (Brosgé and others, 1969), Circle Volcanics (Mertie, 1930; Foster and others, 1983), and Christian complex (Reiser and others, 1965)

BROOKS RANGE PROVINCE

Tv Volcanic rocks (Tertiary) – Locally thick packages that include basalt, andesite, dacite, and rhyolite flows and domes exposed in the southwestern part of the map area, all in the Brooks Range province. The largest accumulation of these rocks is on the west side of the Ruby geanticline, where a sequence as thick as 2 km, predominantly dacite in composition, depositionally overlies sedimentary rocks of the Yukon-Koyukuk basin in the west and rocks of the Angayucham-Tozitna terrane in the east (Moll-Stalcup and Arth, 1989). Andesite and rhyodacite are also present in the area. Hornblende and biotite K/Ar ages from exposures near the bottom of the sequence yielded ages of 59.5 +/- 1.7 and 59.6 +/- 1.8 Ma respectively (Patton and Miller, 1973); a flow in an uncertain position in the sequence yielded a U-Pb zircon age of 62.4 +/- 0.3 Ma (A.B. Till, unpub. data). In the Rampart area, rock compositions are limited to interbedded basalt and rhyolite flows, tuff-breccias, and ignimbrite (Reifenstuhl and others, 1997a). $^{40}Ar/^{39}Ar$ whole-rock ages on basalt dikes and flows range from 57.8 +/- 0.3 to 60.0 +/- 0.2 Ma (Reifenstuhl and others, 1997b). A rhyolite flow near the Yukon River yielded a U-Pb zircon age of 59.5 +/- 0.5 Ma (A.B.Till, unpub. data)

Kkyu Sedimentary rocks of the Yukon-Koyukuk basin, undivided (Cretaceous) – Marine volcanic-clast conglomerate, graywacke, sandstone, mudstone, shale, calcareous sandstone, siltstone and shale, and minor non-marine sandstone and shale. Exposed along the western boundary of the map. Mollusks from the marine part of the unit are Albian; rare plant fossils from the non-marine part of the section range from late Early Cretaceous to Late Cretaceous in age (Patton and others, in press). Marine rocks are thought to represent an oceanic basin that participated in the arc-continent collision that involved rocks of the Brooks Range province; non-marine rocks contain clasts of the Angayucham-Tozitna terrane (JDat) and quartz-rich rocks of units DpЄs and PzpЄb, and therefore record the unroofing of the southern Brooks Range and Ruby geanticline (Patton and others, 1994).

KDe Sedimentary rocks of the Endicott Mountains allochthon of Moore and others (1994) (Cretaceous to Devonian) – Thick marine and non-marine sedimentary sequence dominated by Devonian and Mississippian clastic and carbonate rocks of the Endicott and Lisburne Groups (Moore and others, 1994). Oldest parts of the Endicott Group are Middle Devonian (Moore and others, 1994)

TRPzd Metasedimentary, metavolcanic, and sedimentary rocks of the Doonerak area (Triassic to lower Paleozoic) – Fine-grained metasedimentary rocks that contain lenticular bodies of carbonate rocks; metavolcanic and metavolcaniclastic rocks of island arc affinity, and a thin sequence of shale, siltstone and limestone (Dillon and others, 1986; Moore and others, 1994). Exposed in the northwestern part of the map area. Cambrian, Ordovician, and Silurian fossils have been recovered from the metasedimentary rocks (Moore and others, 1994). Just below the fault on the northern contact of the unit, these lower Paleozoic rocks are depositionally overlain by a sequence of sedimentary rocks of Mississippian to Triassic age (Dillon and others, 1986). This unit represents rocks buried by faulting during the early phases of Brooks Range deformation and uplifted into an arch during the Tertiary (O'Sullivan and others, 1997). The older rocks in the core of the arch are thought to represent basement to the foreland of the Brooks Range (Moore and others, 1994)

Mbu Rocks of Brooks Range sequence of Brosgé and Reiser (2000), undivided, (Mississippian) —Consists of gray to brown, fine- to medium-grained, partly crinoidal limestone (Lisburne Group); black shale, laminated siltstone, chert, and orange-weathering limestone (Kayak Shale); and unnamed black siltstone and shaly phosphatic limestone (Brosgé and Reiser, 1969). Exposed in the northeastern part of the map area. The black siltstone and shaley phosphatic limestone may be correlative with the phosphatic “drowned platform” facies of the Lisburne Group (Dumoulin and others, 2004) in the central and western Brooks Range. Contains mega- and microfossils of Mississippian age

Pzvu Sedimentary rocks of the Venetie terrane of Silberling and others (1994), undivided (Paleozoic) – Lithic and quartz wacke, metamorphosed wacke, metasandstone, phyllite, slate, shale, quartzite, chert, and minor greenstone (Brosgé and Reiser, 2000). Devonian (?) plants and spores, Mississippian (?) Radiolaria, and Permian conodonts have been recovered from this unit. May be at least in part correlative with unit Dp€s, and may contain rocks older than Devonian. The unit was included in the Slate Creek subterrane by Moore and others (1994)

DZs Metamorphosed sedimentary rocks (Devonian to Proterozoic) – Variably metamorphosed and deformed shale, siltstone, fine- to medium-grained sandstone, graywacke, quartz and chert wacke, and minor conglomerate, carbonate, and mafic rocks. Quartz-rich rocks that contain chert clasts are common. Sedimentary structures are preserved locally, but the unit is penetratively deformed elsewhere, especially near the contacts with subjacent metamorphic rocks, where contacts appear gradational. In general, the unit has not been studied in any detail and may contain several sequences of sedimentary rocks, not necessarily of a common origin. Metamorphic grade is greenschist-facies in most parts of the unit but prehnite-pumpellyite facies on the west side of the Ruby geanticline (Dusel-Bacon and others, 1989). The unit sits structurally above large belts of metamorphosed continental margin sediments (unit PzpЄb) and structurally below the oceanic assemblage of the Angayucham-Tozitna terrane (JDat), and therefore may be composed of structurally juxtaposed sedimentary packages. Some age data are available. Five localities in the large exposure of the unit in the central Tanana quadrangle yielded Late Devonian (Famennian) conodonts (A.G. Harris, USGS Emeritus, written commun., 2000). Two detrital zircon samples from the same area have been analyzed; one contains populations of zircons similar to those contained in the Wickersham and Yukon-Tanana terranes, while the other contains a limited suite that lacks those populations (Bradley and others, in press). Therefore, it is possible that part of the unit in the Tanana quadrangle contains infolded rocks from the Wickersham or Yukon-Tanana terranes, which would extend the age of the unit into the Late Proterozoic. Early Devonian palynoflora were collected from exposures in the southern Brooks Range (Gottschalk and others, 1998); Early-Middle Devonian conodonts and Devonian brachiopods were recovered from exposures in the Beaver quadrangle (A.G. Harris, USGS Emeritus, written commun., 2000; Brosgé and others, 1973). Includes part of the Slate Creek subterrane of the Arctic Alaska terrane of Moore and others (1994), and the Slate Creek thrust panel of the Angayucham-Tozitna terrane of Patton and others (1994). Also informally called the phyllite-graywacke belt. May be in part correlative with Venetie terrane of the Brooks Range (unit Pzvu), and metasedimentary rocks exposed along the Tintina fault system on the southern flank of the Yukon Flats basin (DSc)

PzpЄm Metamorphic rocks (Paleozoic? and(or) Precambrian?) – Pelitic schist, amphibolite, metaquartzite, marble, and granitic orthogneiss that occur as three lenses in or near the Kobuk and Victoria Creek fault systems. Not all lithologies are found in all three lenses. Protolith ages are unknown. Metamorphic assemblages formed at amphibolite facies. The southern of two lenses along the Victoria Creek fault yielded three biotite and white mica $^{40}Ar/^{39}Ar$ ages of 61 Ma (Reifenstuhl and others, 1997a), which are interpreted as metamorphic cooling ages. One of the lenses along the Kobuk fault system yielded a $^{40}Ar/^{39}Ar$ age of 54.8 +/- 1.3 Ma (Roeske and others, 2003). Other rocks metamorphosed during the early Tertiary occur between the Tozitna fault and Yukon River but are too small to show on the map. The eastern of the two lenses associated with the Kobuk fault zone is equivalent to the Mosquito terrane of Jones and others (1988)

PzpЄb Metasedimentary and metaigneous rocks of the southern Brooks Range and Ruby geanticline, (Paleozoic and (or) Precambrian) – Quartz-mica schist and lesser calcareous schist, marble, mafic schist, and granitic orthogneiss, exposed along the southern Brooks Range and axis of the Ruby geanticline. Early Devonian microfossils were collected from marble in the Wiseman quadrangle (Moore and others, 1997). U-Pb zircon ages from orthogneisses, which occur in both the Brooks Range and the Ruby geanticline, are Middle Devonian (Aleinikoff and others, 1993; Patton and others, 1987), older than the Late Devonian orthogneisses of unit PzpЄy in the Yukon-Tanana province. Proterozoic orthogneisses are known in comparable units in the Brooks Range west of the map area (Karl and Aleinikoff, 1990). Most rocks in the unit are of unknown age; no rocks younger than Devonian have been identified, but may be present. Protoliths are thought to have had a continental affinity and undergone high-pressure metamorphism (blueschist-facies) and penetrative ductile deformation in the Middle Jurassic or earlier

PzpꞒh Metasedimentary and metaigneous rocks of the Hammond terrane (Paleozoic and (or) Precambrian) – Thick sequences of lower Paleozoic metacarbonate rocks commonly called the Skajit Limestone (Moore and others, 1994), thick sequences of metasiliciclastics, metamorphosed calcareous sedimentary rocks, and minor mafic metagabbro and metafelsite exposed immediately north of unit PzpꞒb. West of the map area, Late Proterozoic metamorphic rocks are known (Till, 1989; McClelland and others, 2006). Cambrian, Ordovician, Silurian, and Devonian fossils have been collected within the area shown on this map (Dumoulin and Harris, 1994); Mississippian rocks occur in the unit west of the map area (Moore and others, 1994). No rocks younger than Mississippian have been identified in the unit, but large expanses of rocks of unknown age are present. Lower Paleozoic rocks contain fauna that have North American and Siberian affinities (Dumoulin and others, 2002). A large volume of the rocks included in this terrane are of an unknown age. Multiple deformational events, both ductile and brittle, and multiple metamorphic events have affected these rocks (Till and others, 1988; O'Sullivan and others, 1997)

PORCUPINE PROVINCE

Kku- Sedimentary rocks of the Kandik basin, undivided (Cretaceous) – Carbonaceous shale, siltstone, quartz arenite, argillite, graywacke, sandstone, and conglomerate; parts of the section are rich in volcanic clasts. Early Cretaceous (Valanginian and Berriasian) megafossils have been identified. Although correlations have been made between units in the Kandik basin and units in the Manley basin that contain Albian fossils (e.g., Dover, 1994), no unequivocally Albian strata have been identified in the Kandik basin (Johnsson, 2000). Equivalent to the Kandik Group (Brabb, 1969)

KJg - Glenn Shale, upper part (Lower Cretaceous and Jurassic?) – carbonaceous shale that contains minor thin (up to 5m) beds of fine-grained sandstone, exposed in the southern part of the Porcupine province. Depositionally overlain by sedimentary rocks of the Kandik basin (Kku). Early Cretaceous megafossils have been collected from several localities within the unit (Miyaoka, 1990). The Glenn Shale is included in two units on this map, a division that is consistent with recent mapping. Brabb (1969), in his original description of the type section, noted that the section was faulted. The age assigned to the unit was based on collections in the type section (Triassic and Early Cretaceous) and from exposures elsewhere (probable Jurassic; Brabb, 1969). Dover and Miyaoka (1988) and Dover (1992) mapped the upper and lower parts of the unit separately, and show a fault between the two in the type section. Dover (1992) noted that the upper part of the Glenn Shale is structurally detached from underlying rocks in most places, and that the upper part overlies units other than the lower Glenn Shale in at least one area. No unequivocal Jurassic fossils have been identified in the upper Glenn Shale, nor has it been found in an unequivocally depositional relationship to the lower part of the Glenn Shale (Dover and Miyaoka, 1988; Johnsson, 2000)

<u>KJu</u> Sedimentary rocks, undifferentiated (Cretaceous? and Jurassic?) –Scattered occurrences of shale, argillite and quartzite up to 300m thick exposed in central and northern part of Porcupine province (Brosgé and Reiser, 1969; Brabb, 1970). Bivalves of Jurassic or Cretaceous age reported from one exposure in the Coleen quadrangle (Brosgé and Reiser, 1969)

<u>JMsu</u> Strangle Woman Creek sequence of Brosgé and Reiser (1969), undivided (Jurassic to Mississippian)—Rock types include very fine grained to conglomeratic sandstone; gray limestone and dolostone; dark gray, very fine grained, thin-bedded limestone and black chert; and coarse-grained, conglomeratic, quartz sandstone that contains minor potassium feldspar, exposed in the northern part of the Porcupine province. The carbonate rocks of this unit were assigned to the Lisburne Group by Brosgé and Reiser (1969). Dark, fine-grained quartzite contains Early Jurassic (Hettangian) ammonites (Brosgé and Reiser, 1969). Unit also contains Permian or Carboniferous brachiopods and corals and Late Mississippian corals (Brosgé and Reiser, 1969), as well as tightly dated Carboniferous conodonts. Conodont faunas range from late Kinderhookian-middle Osagean to latest Chesterian-early Atokan in age; they indicate chiefly shallow-water, locally high-energy depositional settings, but the oldest sample suggests a slope environment (A.G. Harris, USGS Emeritus, written commun., 2000). Juxtaposition of Lower Jurassic and Carboniferous-Permian strata seen in this unit is also seen in unit JMpu. The contact of this unit with the large granitic body, Cg, is not well exposed or understood

<u>Cg</u> - Granite (Carboniferous) – Granite and quartz monzonite, exposed in large body on the northeast boundary of the map. Northern contact with adjacent metamorphic rocks is intrusive; southern boundary is shown as a fault but is not well exposed nor well understood. K/Ar mica ages range from 354 to 302 Ma (Brosgé and Reiser, 1969)

<u>Pzcm</u> Metamorphic rocks (Paleozoic?) – Semischist, phyllite, and thin layers of mafic rock exposed in the extreme northeast corner of the Porcupine province. Rocks are generally fine grained, and the metamorphic assemblage locally includes biotite and garnet. Contact with adjacent granite is intrusive, but contact with sedimentary rocks is poorly exposed and not understood

<u>Pzqs</u> Sedimentary and igneous rocks (Paleozoic) – Quartz-rich sedimentary rocks, associated carbonate rocks and minor mafic volcanic rocks. The quartz-rich rocks are by far the most common lithologies and consist of chert arenite, quartz-chert wacke, quartzite, chert-pebble conglomerate, minor mudstone and siltstone; these rocks occur throughout the Porcupine province. The unit includes associated small bodies of Devonian, Carboniferous, and Permian carbonate rocks, mostly exposed in the southern part of the province. In the Charley River quadrangle the unit also includes shale, argillite, and limestone that contains Permian and Carboniferous brachiopods, and Devonian basalt, tuff, limestone, chert, argillite, and quartzite of the Woodchopper Volcanics (Brabb and Churkin, 1969). No direct age control is available from the widely distributed siliciclastic rocks in the unit. As noted by Dover (1992, 1994), in the Charley

River quadrangle the paucity of age data and lithologic similarities among siliciclastic rocks makes unit assignations difficult. There, siliciclastic rocks mapped as Permian Step Conglomerate by Brabb and Churkin (1969) were later mapped as Devonian Nation River Formation by Dover (1994). Since age control is lacking for the dominant lithology, and the minor lithologies for which age control is available are restricted to the southern part of the province, it is possible that the unit may include rocks older than Devonian

JMpu Younger strata of the Porcupine River sequence of Brosgé and Reiser (1969), undivided (Jurassic to Mississippian) – Main rock types are ferruginous, very fine grained sandstone; gray to black pyritic siltstone and silty shale; laminated, red and green chert; silty, shaly, and cherty limestone; coarse-grained to conglomeratic, locally feldspathic sandstone, mafic flows, and minor mafic conglomerate. Mafic rocks are geographically widespread within the unit (Brosgé and Reiser, 1969; Brosgé and others, 1966). Carboniferous, Permian, and Jurassic megafaunas are reported (Brosgé and Reiser, 1969). Lithologic and faunal similarities to the Siksikpuk and Kuna Formations (Dumoulin and others, 2004) suggest ties between JMpu and correlative rocks of northern Alaska, but faunal links to strata to the south (e.g., Tahkandit Limestone, units TRPgt and PꞒta) also exist

DꞒpu Older strata of the Porcupine River sequence of Brosgé and Reiser (1969), undivided (Devonian to Cambrian) — Succession includes dark gray limestone and lesser dolostone that contain Middle Devonian corals; the Salmontrout Limestone of Early Devonian age (Churkin and Brabb, 1965); and light to dark gray, locally mottled dolostone and limestone of Silurian and older age (Brosgé and Reiser, 1969). Subordinate lithologies are gray and black chert, black shale, red and green shale and sandstone, and limestone cobble conglomerate (Brosgé and others, 1966; Brosgé and Reiser, 1969). The unit is exposed in northern part of the Porcupine province. Most precise ages for older part of succession based on Late Silurian and Late(?) Ordovician corals and Cambrian(?) trilobites (Brosgé and Reiser, 1969). Conodonts of Early Silurian and middle Middle Ordovician ages also occur in these strata (A.G. Harris, USGS Emeritus, written commun., 2000). Brosgé and others (1966) describe this succession in the Porcupine River canyon, in the northern part of the Porcupine province on the boundary between the Black River and Coleen quadrangles. Less lithologic detail is available for unit in southern part of map area, but a similar suite of ages is indicated by corals, stromatoporoids, brachiopods, and gastropods (Brabb, 1970) as well as by conodonts (A.G. Harris, USGS Emeritus, written commun., 2000). Lithofacies and faunal data suggest that most of DꞒpu formed in a relatively shallow-water shelf or platform setting, but Upper Silurian and Lower Devonian graptolitic shale, limestone, and chert in the Porcupine River area (Churkin and Brabb, 1967; Coleman, 1985) accumulated in a slope or basin environment and may correlate with the Road River Formation (Churkin and Brabb, 1965; Brabb and Churkin, 1969), which is included in unit PꞒta in the southern part of the province. Conodonts and megafossils in DꞒpu have chiefly Laurentian (North American) affinities (Oliver and others, 1975; Rohr and Blodgett, 1994; Dumoulin and others, 2002; Blodgett and others, 2002)

PꞒta Sedimentary rocks of the Tatonduk area (Permian to Cambrian) – Limestone, argillite, shale, chert, quartz arenite and conglomerate exposed in the southern part of the Porcupine province. The sequence includes several formal stratigraphic units, which are not enumerated here (see Dover, 1994). Lower Paleozoic rocks include both basinal and shelf facies; youngest rocks include the Permian Step Conglomerate (Brabb, 1969) and parts of the Permian Tahkandit Limestone (Brabb and Churkin, 1969); other parts of the Tahkandit Limestone are mapped together with the lower Glenn Shale (TrPgt) due to the difficulty of showing the relatively thin unit on this regional-scale map. The Cambrian through Permian fauna contained in this unit have strong North American affinities (Blodgett and others, 2002)

ꞒPt Sedimentary rocks of the Tindir Group, (Cambrian? and Proterozoic) – Phyllite, slate, siltstone, argillite, quartzite, red beds, carbonate-clast conglomerate, dolostone, limestone, basalt, chert, and glacial diamictite exposed in the southeast part of the Porcupine province. See Dover (1994) for a summary of the formal units included in this sequence. Carbonate rocks, quartzite, and argillite are the most common and widespread lithologies (Dover, 1994). The Cambrian(?) age is based on several occurrences of the trace fossil *Oldhamia* (Miyaoka, 1990). The Proterozoic age is based on lithologic correlation with areally extensive successions of sedimentary rocks that were deposited on the ancient North American continental margin during and after rifting of its western margin (Eberlein and Lanphere, 1988; Dover, 1994). The lower part of the Tindir Group is considered correlative with the Mackenzie Supergroup, while the upper part of the Group is likely correlative with the Windemere Supergroup (Young, 1982, 1992; Rainbird and others, 1996)

YUKON-TANANA PROVINCE

KJmu Sedimentary rocks of the Manley basin, undivided (Cretaceous and Jurassic) – Quartzite, shale, siltstone, graywacke, polymictic conglomerate exposed in the western part of the province. Equivalent to the Minto, Wilber Creek, and Wolverine quartzite units of Weber and others (1992) and the Manley terrane of Jones and others (1987). Most of these rocks have been folded, faulted, and weakly metamorphosed, but most primary sedimentary textures are preserved. The Minto unit, a thin, less deformed package of limited extent is thought to lie unconformably on the older rocks and may be Late Cretaceous in age (Weber and others, 1994). Older parts of the unit contain marine megafauna of Jurassic and Early Cretaceous (including Albian) age and the Minto unit has yielded plant fossils of Late Cretaceous(?) age (Weber and others, 1994).

Mzmv Fine-grained sedimentary rocks and tuff (Mesozoic?) – Slate, shale, siltstone, argillite, tuff, and minor quartzite and conglomerate exposed just south of the Tintina fault system and immediately northeast of the Manley basin. No direct age control. Equivalent to the Vrain unit ("KJv") of Weber and others (1992) and "MzPzat" unit of Foster and others (1983). Parts of the unit thought to be correlative with the upper Glenn Shale (KJg) (Weber and others, 1992)

<u>TRPs</u> Sedimentary rocks (Triassic to Early Permian) – Argillite, siltstone, sandstone, shale, chert, limestone, conglomerate, and limestone debris flows exposed along the southwestern margin of the Manley basin. The unit is structurally imbricated with the sedimentary rocks of the Manley basin (KJmu). Conodonts, foraminifera, and megafossils yielded Permian and less definite late Paleozoic ages (Weber and others, 1994); Triassic Radiolaria were also recovered (Weber and others,1992)

<u>MzPza</u> Low-grade metamorphic rocks (Mesozoic? and (or) Paleozoic?) – Phyllite, argillaceous metachert, metalimestone, and associated mafic rocks. Exposed only in southeast part of the map area adjacent to Tintina fault. Includes some areas dominated by argillite, equivalent to "Mza" of Foster (1992), and other lithologically complex packages (their "PzPun") thought to include rocks with affinities both north and south of the Tintina fault zone. Equivalent to "MzPzm" of Dover (1992), which is described as "typically blastomylonitic". The age of the protoliths and metamorphic event(s) are unknown; age assignment based on age of lithologically similar rocks along the fault zone

<u>DSc</u> Metamorphosed sedimentary rocks (Devonian and Silurian) – Chert and chert-pebble conglomerate, calcarenite, conglomeratic metalimestone, metalimestone, metasiltstone and argillite, mafic intrusive rocks, and rare dolostone exposed between the Tintina fault zone and the Yukon Flats basin, in the northern part of the Yukon-Tanana province. Conodonts recovered from the unit have broad age ranges, are Late Devonian (Famennian) or are Silurian in age (A.G. Harris, USGS Emeritus, written commun., 2000). This unit may be in part correlative with Dp€s, which contains Famennian conodonts and similar lithologies in the central Tanana quadrangle. Silurian conodonts were collected along the northern contact of DSc and may be from a fault slice of older rocks

<u>Pzum</u> Ultramafic rocks (Paleozoic?) – Serpentinite and lesser gabbro and rodingite rubble limited to one small area in the southwest part of the province. Based on trace element data, Reifenstuhl and others (1998) considered these rocks to have formed originally in an oceanic arc or ridge setting; the unit likely marks the trace of a major structure within the deformed sedimentary rocks of the Manley basin (KJmu). Hornblende from gabbro has yielded a disturbed $^{40}Ar/^{39}Ar$ age spectrum suggestive of early Paleozoic age (Reifenstuhl and others, 1998)

<u>PzZs</u> Sedimentary and igneous rocks corresponding to older parts of the Schwatka - Rampart area sequence of Weber and others (1992) (Paleozoic to Proterozoic) – Includes grit, argillite, quartzite, siltite, graywacke, phyllite, and minor limestone; interlayered mafic volcanic rocks and limestone, minor associated greenstone, limestone, and limestone debris flows, and a group of fine-grained metamorphic and sedimentary rocks (Weber and others, 1992). The unit is exposed in belt immediately west of the Victoria Creek fault zone. It is equivalent to the Wickersham, Schwatka, and "PDms" ("metamorphic and sedimentary rocks") units of Weber and others (1992). The part of the sequence that includes the grit yielded the trace fossil *Oldhamia*, of probable Cambrian age; limestone interlayered with mafic volcanic rocks yielded Devonian

megafossils and Early and Middle Devonian conodonts (Weber and others, 1994). Late Devonian conodonts were obtained from clasts in limestone debris flows (Weber and others, 1994). Middle Devonian mafic volcanic rocks of the unit were correlated by Grantz and others (1991) and Dover (1994) with the Devonian Woodchopper Volcanics (Mertie, 1930) of the Charley River quadrangle. The Woodchopper Volcanics have been included in unit Pzqs on this map. Lacks rocks of Ordovician and Silurian age; contained Devonian rocks do not correlate with those present in units PzZw and PzZl

PzZl Sedimentary and igneous rocks corresponding to the Livengood area sequence of Weber and others (1992) (Paleozoic to Proterozoic) – Argillite, phyllite, quartzite, graywacke, siltite, grit and limestone of the Wickersham unit, mafic intrusive and extrusive rocks and fine grained sedimentary rocks interlayered with serpentinite, of the "PzZm" and "CZum" units; dolomite, chert, argillite, and minor greenstone, tuff, and volcanic graywacke and basalt flows of the Amy Creek unit; chert and lesser sedimentary breccia, siliceous slate, rare greenstone, tuff, limestone and mafic flows and sills of the Livengood Dome Chert; lime mudstone, wackestone, debris flows of the Lost Creek unit; shale, siltstone, graywacke, polymict conglomerate, and fossiliferous limestone of the Cascaden Ridge unit; cherty argillite, chert, siliceous slate, mafic intrusive and extrusive rocks of the Troublesome unit, and limestone associated with phyllite, quartzose sandstone, graywacke, and polymict conglomerate of the Quail unit. Gabbro associated with the serpentinite of "CZum" yielded a $^{40}Ar/^{39}Ar$ hornblende age of 535.3 +/- 2.7 Ma (Athey and others, 2004). Weber and others (1994) reported all paleontologic control on the age of the rocks in this unit. Late Ordovician graptolites were recovered from sedimentary rocks of the Livengood Dome Chert; megafossils from the lime mudstone of the Lost Creek unit are Silurian; fossiliferous siltstone and limestone of the Cascaden Ridge unit is Middle Devonian, based on a variety of megafossils and conodonts; biogenic lime mudstone and wackestone of the Quail unit are Late Devonian. Siliciclastic rocks of the Quail unit are thought to be correlative with the Devonian Nation River Formation (Weber and others, 1992). Parts of this unit have been correlated with Selwyn Basin and the Farewell terrane (Dover,1994; Grantz and others, 1991; Chapman and others,1982). Fauna contained in parts of the unit are similar to those in the Nixon Fork sequence of the Farewell terrane **(**Blodgett and others, 2002; Dumoulin and others, 2002), which is thought to have been located between North America and Siberia during the early Paleozoic (Bradley and others, 2003)

PzZw Sedimentary and igneous rocks corresponding to the older parts of the Fairbanks-White Mountains area sequence of Weber and others (1992) (Paleozoic to Proterozoic) – Includes argillite, grit, quartzite, graywacke, phyllite, limestone, and dolomite, of the Wickersham unit; alkali basalt, agglomerate, volcanic conglomerate, and associated limestone, sandstone and chert, of the Fossil Creek Volcanics; limestone and rare dolostone of the Tolovana Limestone; and conglomerate, graywacke, siltstone, and quartzite that is cut by mafic sills, of the Beaver bend and Globe units of (Weber and others, 1992). Exposed in a belt east of the Manley basin. All fossil ages for the unit are reported in Weber and others (1994). The part of the sequence that includes the grit contains the trace fossil *Oldhamia* of probable Cambrian age; sedimentary rocks associated with the alkali basalt yielded mega- and microfossils of Ordovician age; and

Silurian and Middle Devonian megafossils and Silurian conodonts were recovered from thick limestone. This unit contains Ordovician and Silurian rocks absent from unit PzZs and lacks the Devonian volcanics found in unit PzZs. Parts of this unit have been correlated with lithologically similar strata in the Selwyn basin and Cassiar platform of western Canada (Dover, 1994, Tempelman-Kluit, 1984)

PzpЄy   Metamorphic rocks of the Yukon-Tanana Upland, undivided (Paleozoic to Precambrian?) – Fault-bounded assemblages of lithologically and metamorphically distinct metaigneous and metasedimentary rocks that have Paleozoic and Precambrian(?) protoliths exposed in the south-central part of the map (Dusel-Bacon and others, 2002). Structurally lower assemblages, most with continental affinities, have been deformed in a ductile manner and metamorphosed to greenschist and amphibolite facies. A Late Devonian to Mississippian magmatic episode produced felsic (metavolcanic and metaplutonic) and mafic metaigneous rocks that are present in several of these assemblages (Dusel-Bacon and others, 2004). Recent efforts at U-Pb geochronology reveal that the Yukon-Tanana felsic metaigneous rocks are younger than felsic metavolcanic and metaplutonic rocks in the Brooks Range, although they were previously considered to be correlative (McClelland and others, 2006). Weakly metamorphosed oceanic rocks were tectonically emplaced over the higher-grade assemblages during the Mesozoic (Dusel-Bacon and others, 2002). This oceanic unit extends far into Canada where similar assemblages and histories have been observed (see references in Dusel-Bacon and others, 2004). Complex nomenclature regarding rocks in this unit is reviewed in Foster (1992) and Dusel-Bacon and others (2002). Small exposures of Cretaceous and Tertiary volcanic rocks and Tertiary sedimentary rocks are included in the unit as they can not be shown at this map scale (Foster, 1992)