EXPLANATION OF MAP UNITS: BEDROCK-GEOLOGIC MAP, ALASKA HIGHWAY CORRIDOR, TETLIN JUNCTION, ALASKA TO CANADA BORDER

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EXPLANATION OF MAP UNITS: BEDROCK-GEOLOGIC MAP, ALASKA HIGHWAY CORRIDOR, TETLIN JUNCTION, ALASKA TO CANADA BORDER

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DESCRIPTION OF GEOLOGIC MAP UNITS

(All map units may not appear on both map sheets)

This map shows the distribution of bedrock units exposed at or near the surface in the corridor along the Alaska Highway in parts of the Tanacross A-1, A-2, A-3, and B-3 and Nabesna C-1, D-1, and D-2 quadrangles. It is the easternmost of three bedrock-geologic maps along the Alaska Highway corridor (Werdon and others, 2019a; 2019b), and is part of a multi-year project conducted by the Alaska Division of Geological & Geophysical Surveys (DGGS) between 2006 and 2013. The project focused on investigating and reporting the geology and geologic hazards of the corridor. Bedrock units were mapped and structural elements were measured in the field. Where bedrock units are covered by surficial units and/or vegetation, units were interpreted using airborne magnetic and electromagnetic surveys published by DGGS in 2006 (Burns and others, 2006). Rock names were assigned based on field and petrographic observations, modal-mineral percentages, and interpretations of geochemical data (Werdon and others, 2014). Surficial-geologic map units are shown in Reger and others (2012). An evaluation of potentially active faults in the map area is presented in Koehler and Carver (2012). Ages are based on the International Commission on Stratigraphy's chronostratigraphic chart (2018). Where bedrock map units are shown with a pattern and queried label, unit designation is interpreted based on nearby geology and geophysical characteristics.

BEDROCK MAP UNITS

buk BEDROCK, UNKNOWN (Tertiary and older)—Identity of bedrock was not interpreted in areas of thick and widespread unconsolidated Quaternary and Recent fluvial, colluvial, and glacial deposits. Although geophysical data were acquired over the entire map area, field observations of exposed bedrock in buk areas were insufficient for reasonable interpretation of bedrock character. The extent of interpreted bedrock underlying the Quaternary is subjectively located and does not indicate a geologic contact. Surficial-geologic units are shown in Reger and others (2012).

b UNMAPPED BEDROCK (Tertiary and older)—Identifiable bedrock is present at or near surface but was not mapped because no field visits were possible during the course of this project.

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mb UNMAPPED MAGNETIC BEDROCK (Tertiary and older)—Identifiable bedrock is present at or near surface but was not mapped because no field visits were possible during the course of this project. This unit is distinguished by its distinctly high aeromagnetic signature (Burns and others, 2006). The unit could represent an extension of mapped Kgd or Ms. Alternatively, mb could possibly represent unobserved ultramafic rocks that separate lithologically different rock packages.

IGNEOUS DIKES

GRANITIC DIKES (Tertiary to Cretaceous)—Generally fine grained, ranging from equigranular to porphyritic. Dikes are typically less than 4 m thick, ranging from less than 1 cm to 7 m. Color is orange to gray to dark brown on weathered surfaces, gray to white on fresh surfaces. Compositions vary between monzogranite and granodiorite; mafic mineral content ranges from 10 to 30 percent of rock with common biotite ± less-abundant hornblende; rare white mica, tourmaline, and pyrite. Where present, phenocrysts account for less than 60 percent of the rock and variably include quartz, alkali feldspar, plagioclase, and less commonly biotite. Magnetic susceptibility varies from 0.01×10^{-3} to 7.1×10^{-3} SI, averaging 1.21×10^{-3} SI (Système International). Granitic dikes are likely comagmatic with the Cretaceous plutons they cut, but could be as young as Tertiary in age.

FELSIC PORPHYRY DIKES (Tertiary to Cretaceous)—Porphyritic with very-fine-grained to aphanitic, quartz-rich groundmass. Phenocrysts include feldspar (5–45 percent of rock, generally ≤4 mm in length, up to 1 cm in length), quartz (5–20 percent of rock, 1–5 mm in diameter) and biotite (2–10 percent of rock, ≤5 mm in diameter). Biotite may be present in groundmass; rare disseminated pyrite (≤3 percent of rock). Overall color ranges from gray to black to orange. The magnetic susceptibility varies from 0×10^{-3} to 40×10^{-3} SI with average value of 2×10^{-3} SI. Biotite from a black porphyry body, possibly a sill, with biotite and feldspar phenocrysts in an aphanitic groundmass (09MBW269A) yields a Cretaceous $^{40}Ar/^{39}Ar$ plateau age of 97.0 ± 0.7 Ma (map location A2; table 1; Solie and others, 2013). Some porphyry dikes may be Tertiary in age based on likely equivalency of these dikes with larger bodies of similar lithology (unit TKp) discussed below.

APLITE DIKES (Tertiary to Cretaceous)—Felsic aplite dikes crop out predominantly in or near Cretaceous plutonic bodies north of Gardiner Creek fault, though aplites were observed associated with metamafic rocks south of Gardiner Creek in the Nabesna D-1 Quadrangle. Light pinkish-gray to tan, very fine to fine grained, equigranular, with trace biotite (up to 5 percent). Minor to trace disseminated pyrite is mostly oxidized. Width of dikes ranges from 5 cm to less than 1 m. Several felsic pegmatitic dikes with centimeter-scale alkali feldspar crystals are included in this unit. The magnetic susceptibility varies from 0.01×10^{-3} SI to 7.2×10^{-3} SI, averaging 1.0×10^{-3} SI. Aplite dikes may be comagmatic with Cretaceous intrusions, but genetic relationships are unknown; they are assigned Tertiary to Cretaceous age.

MAFIC DIKES AND SILLS (Tertiary to Cretaceous)—Mafic dikes and sills are irregularly distributed from just south of Gardiner Creek fault to the north end of the map area. Unit includes fine-grained gabbro, microgabbro, lamprophyre, and diorite. Color ranges from black to dark green. Thickness varies from less than 1 m up to 4.5 m. Mineralogy includes plagioclase feldspar, and varying percentages of biotite, clinopyroxene, and hornblende; some chloritization was observed. A black, fine-grained lamprophyre dike with feldspar phenocrysts up to 4 mm in length (09MBW245A) yields an $^{40}Ar/^{39}Ar$ weighted-mean-average minimum age of 84.4 ± 1.5 Ma on biotite and a weighted-mean-average minimum age of 89.7 ± 1.2 Ma on hornblende (map location A1; table 1; Solie and others, 2013). Genetic relationships are unknown, and unit is assigned age from Tertiary to Cretaceous.

IGNEOUS MAP UNITS

TKf FELSIC CRYSTAL LITHIC TUFF (Tertiary to Cretaceous)—Weathered felsic volcaniclastic crystal lithic tuff crops out across three ridges northeast of Eliza Lake in the Nabesna D-2 and Tanacross A-2 quadrangles. Pale green to tan, breaks in slabs, plates, and blocks, with local flow banding. The aphanitic to cryptocrystalline groundmass comprises up to 50 percent of the rock. Slightly coarser-grained, angular to subangular lithic fragments ranging from less than 1 mm to 1 cm in diameter, locally clast supported, make up as much as 50 percent of the rock. Phenocrystic crystals up to 2 mm in diameter, predominantly quartz and feldspar, compose up to approximately 20–30 percent of the rock. Quartz is angular to round, commonly embayed. Feldspar, mostly plagioclase, is commonly altered. Primary mafic minerals have been completely altered to various combinations of epidote, iron oxide, opaque minerals, and minor chlorite. Minor tourmaline sprays (blue–tan pleochroic), pyrite, biotite, and garnet are present locally, along with spherulites and opaque-mineral-lined vesicles. Magnetic susceptibility of unit is low, ranging from essentially zero to 0.3×10^{-3} SI, averaging 0.08×10^{-3} SI. Unweathered samples might possess higher magnetic susceptibility. Age uncertain; may be correlative with mid-Cretaceous rhyolitic tuff caldera fill described by Bacon and others (1990) in the Tanacross Quadrangle north of the study area; also may be extrusive equivalent of unit TKp, discussed below.

TKp FELSIC PORPHYRY (Tertiary to Cretaceous)—Crops out as small bodies north of Gardiner Creek fault. Similar, and may be equivalent to the granite porphyry dikes described above. However, based on map distribution it appears to comprise more extensive bodies. Felsic porphyry is variably porphyritic with phenocrysts of quartz, feldspar, and/or biotite composing up to 60 percent of rock volume, hosted in an aphanitic, silicic, light tan, gray, or greenish groundmass. Quartz phenocrysts are common, some euhedral, up to 4 mm in diameter. Alkali feldspar or plagioclase feldspar phenocrysts are very common as subhedral crystals up to 5 mm long, locally altered. Biotite phenocrysts are also common and generally form small, brown to black flakes up to 3 mm in diameter. Remnants of oxidized pyrite are present but uncommon. Magnetic susceptibility is generally low, from essentially 0 to 7.0×10^{-3} SI, with an average value of 0.9×10^{-3} SI. Based on intrusive relationships, analytical age data, and interpreted geologic correlations, the ages of felsic porphyry bodies range from Cretaceous to Tertiary. Biotite from a small biotite feldspar porphyry body (09MBW269A), possibly a sill, in the metamorphic rocks east of Nuziamundcho Lake in the Tanacross A-3

Quadrangle yields an $^{40}Ar/^{39}Ar$ plateau age of 97.0 ± 0.7 Ma (map location A2; table 1; Solie and others, 2013). The correlative unit in Foster's Tanacross geologic map, Tp, was assigned probable Tertiary age (Foster, 1970). Felsic porphyry rocks may be related at least in part to Cretaceous volcanic rocks of the Sixtymile Butte caldera about 15 miles (24 km) north of Tok. The age of the Sixtymile Butte caldera is based on an unpublished U-Pb zircon weighted-average age of approximately 108 Ma (Mortensen, 2008, as cited in Bacon and others, 2014) and a K-Ar age of 92 Ma for hornblende (Bacon and others, 1990). A nearby Tertiary vitrophyre has an Eocene age based on K-Ar analysis of sanidine (Bacon and others, 1990). Other Early Cretaceous and Tertiary felsic porphyries are found in nearby areas of Alaska and western Yukon (Dusel-Bacon and others, 2009; Tempelman-Kluit, 1974; Ryan and others, 2003). Tertiary porphyries in the Yukon form an extensive dike swarm of north-trending porphyritic rhyolite dikes that cut approximately 72 to 69 Ma Carmacks Group volcanic rocks (Tempelman-Kluit, 1974; Ryan and others, 2003; Grond and others, 1984; Lowey and others, 1986; Hart, 1995).

Silver Creek Granodiorite

Khgd PORPHYRYTIC HORNBLENDE GRANODIORITE (Cretaceous)—Distinctive hornblende–biotite granodiorite with large euhedral hornblende phenocrysts crops out on the south side of Cheneathda Hill and Damundtali Lake in the Nabesna D-1 and D-2 and Tanacross A-1 and A-2 quadrangles. Total mafic mineral content is generally about 10–25 percent, with relative proportions of hornblende and biotite varying widely. Hornblende phenocrysts are generally about 1 cm in length, up to 3 cm; it is also present in the groundmass. Rarely, biotite also forms phenocrysts. Groundmass is generally medium grained, ranging from 1 to 5 mm in diameter; alkali feldspar is interstitial. Unit includes local tonalite with similar texture. Round to subround mafic enclaves up to 22 cm in diameter are not uncommon. Magnetic susceptibility ranges from 0.4×10^{-3} to 11×10^{-3} SI, averaging 3.7×10^{-3} SI. Zircons from unit Khgd yield late Cretaceous U-Pb ages of 97.3 ± 2.6 Ma (09TDH75A), 99.7 ± 2.6 Ma (09TDH74A), 101.0 ± 2.8 Ma (09LF419A), and 103.1 ± 2.9 Ma (09LF433A) (map locations U13, U12, U11, and U14 respectively; table 2; Solie and others, 2014).

Airs Hill Quartz Monzonite

Khqm PORPHYRITIC HORNBLENDE QUARTZ MONZONITE (Cretaceous)—Biotite hornblende quartz monzonite with megacrystic alkali feldspar and hornblende phenocrysts crops out in the southeast map area. Feldspar phenocrysts up to 3 cm long and hornblende phenocrysts up to 1.5 cm long are characteristic, but unit also includes fine- to medium-grained, equigranular textures, and compositionally ranges from granodiorite to monzonite to diorite. Biotite and hornblende are common in groundmass, with minor local chloritization. Trace minerals include local allanite, zircon, tourmaline, and garnet. Magnetic susceptibility is generally low, averaging 0.14×10^{-3} SI, with an observed high of 0.44×10^{-3} SI. Zircon from porphyritic alkali feldspar hornblende quartz monzonite (09Z213A) yields a U-Pb age of 97.5 ± 2.6 Ma (map location U19; table 2; Solie and others, 2014).

Other Igneous Rocks

Kg GRANITE (Cretaceous)—This unit includes undifferentiated granitic plutonic rocks including equigranular monzogranite, porphyritic monzogranite, and leucogranite, as well as minor syenogranite, granodiorite, quartz monzonite, monzonite, and quartz syenite. Intrusive and magmatic relationships between the different phases are uncertain. The granitic rocks are fine to coarse grained, equigranular to subequigranular, locally porphyritic, and commonly tan, gray, or pink colored. Modal mineralogy includes quartz, alkali feldspar, plagioclase, ubiquitous biotite, and local hornblende. Where hornblende is present, it is almost always less abundant than biotite. Chloritization of mafic minerals is common, though not pervasive. Subrounded to rounded mafic enclaves are locally abundant, as are aplite dikes. Due to map scale and thick cover that hindered direct field observations, unit also includes minor felsic porphyry, gabbro, and unmapped zones of metamorphic rocks.

Equigranular monzogranite is typically fine to medium grained, locally coarse grained, with subhedral quartz, alkali feldspar, and plagioclase. Biotite, up to 20 percent, averages about 7 volume percent; lesser amounts of hornblende are present locally. Porphyritic monzogranite is medium to coarse grained with phenocrysts of quartz, commonly as glomerocrysts, and/or alkali feldspar, locally up to 3 cm long. Hornblende phenocrysts up to 1 cm long are rarely present. The groundmass is dominated by interstitial alkali feldspar, quartz, and plagioclase, with biotite comprising an average of about 11 volume percent. Commonly weathers to grus. Leucocratic monzogranite is very light colored, white to pale pink, fine grained, equigranular, with abundant fine- to medium-grained quartz phenocrysts. Both plagioclase and alkali feldspar are white, with alkali feldspar much more abundant than plagioclase. Fine-grained biotite is the sole mafic silicate in leucogranites, generally forming less than 2 percent of the rock.

The magnetic susceptibility of Kg is variable, ranging from essentially zero to 40×10^{-3} SI; overall the unit has moderate magnetic susceptibility with an average value of about 2×10^{-3} SI. Within a granitic phase, lower values are commonly more altered, weathered, or sheared samples; higher values are fresher, less deformed, or may be in close proximity to the pluton margins.

Age data from nine Kg samples yields two groups of Cretaceous ages, from about 95 Ma to 98 Ma, and about 102 Ma to 106 Ma (map locations A6, U3-U5, U7-U8, U15-U17; tables 1 and 2; Solie and others, 2014; Foster and others, 1976). No mineralogical or textural characteristics appear to distinguish the two age groups. Three of the older samples (U3, U4, U5) are from the large Kg pluton at the west end of the map in the Tanacross B-3 Quadrangle.

Kgd GRANODIORITE (Cretaceous)—Biotite granodiorite crops out in small bodies throughout the map area, and may comprise phases related to surrounding or nearby plutons, though intrusive and magmatic relationships are unknown. Unit includes granodiorite and minor quartz monzonite, tonalite, syenite, and granite porphyry. Granodiorite is fine to coarse grained, equigranular to porphyritic, with biotite up to 20 percent, ± hornblende up to 6 percent of rock. Mafic enclaves are not uncommon. Magnetic susceptibility is generally moderately high, averaging 3.5×10^{-3} SI, ranging from 0.05×10^{-3} to 14.1×10^{-3} SI. Zircons from hornblende–

biotite quartz monzonite and granodiorite (09MBW338A, 09MBW103A) yield Cretaceous U-Pb ages of 106.2 ± 2.8 Ma and 100.3±2.7 Ma respectively (map locations U1 and U9; table 2; Solie and others, 2014). Biotite from a hornblende–biotite granodiorite (09LF374A) yields an $^{40}Ar/^{39}Ar$ plateau age of 73.3 ± 0.4 Ma (map location A4; table 1; Solie and others, 2013).

Kgb GABBRO (Cretaceous)—Gabbroic rocks crop out as small bodies that are generally similar, and may be equivalent, to some of the mafic sills and dikes described above. Biotite gabbro and microgabbro is exposed in the extreme western edge of the map area in the Tanacross A-3 and B-3 quadrangles (unit lKb of Werdon and others, 2019a). The biotite gabbro is medium to fine grained, porphyritic to slightly porphyritic, with biotite and plagioclase up to 2 mm in diameter. Primary minerals consist of plagioclase, clinopyroxene, some remnant olivine, and ± biotite.

Other small, unfoliated mafic bodies crop out in the hills between the west edge of the map area and Gardiner Creek fault, including porphyritic hornblende gabbro, pyroxene(?) olivine biotite gabbro, fine-grained biotite amphibole monzonite, and fine-grained diorite. Magnetic susceptibility of gabbro bodies is high, ranging from 0.16×10^{-3} to 38.5×10^{-3} SI, averaging 11.8×10^{-3} SI.

Gabbroic rocks in the map area were emplaced during both the Early and Late Cretaceous. Just west of the map area, biotite from biotite gabbro (08RN785A) yields an $^{40}Ar/^{39}Ar$ plateau age of 70.0 ± 0.3 Ma (Werdon and others, 2019a; Solie and others, 2013). A whole-rock separate from a dike-like gabbro body (09LF493A) in unit Khgd yields an $^{40}Ar/^{39}Ar$ plateau age of 70.5 ± 0.5 Ma (map location A3; table 1; Solie and others, 2013). Biotite from a biotite clinopyroxene gabbro/microgabbro from a small autobrecciated body on Gardiner Creek in unit Kg (09MBW215A) yields an $^{40}Ar/^{39}Ar$ plateau age of 100.4 ± 0.8 Ma (map location A5; table 1; Solie and others, 2013). The mafic body may have the same orientation as a northwest-oriented fault at this site. Zircon from a porphyritic hornblende gabbro (09LF647A) yields a U-Pb age of 103.8 ± 2.7 Ma (map location U2; table 2; Solie and others, 2014).

METAMORPHIC MAP UNITS

Lower Greenschist-Facies Metasedimentary Rocks

Cretaceous metasedimentary units, though interpreted to be in fault contact where observed in the map area, may unconformably overlie Mirror Creek formation (units PTRp and PTRs described below). They probably correlate with the Macauley Ridge formation in Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013). These units are mapped as Tertiary or Cretaceous conglomerate and sandstone (TKc) by Richter (1976).

Kcg METACONGLOMERATE (Cretaceous)—Stretched-pebble metaconglomerate with quartz-rich phyllitic matrix. Andesitic and other pebbles have 10–20 times elongation; forms blocky outcrops. Conglomerate sampled just south of the map boundary is significantly less deformed and metamorphosed. Magnetic susceptibility is moderately low, averaging 0.28×10^{-3} SI, ranging from 0.08×10^{-3} to 0.54×10^{-3} SI. Detrital zircons from two stretched-pebble metaconglomerate samples yield U-Pb ages mostly younger than 350 Ma (map locations U21 and U22; table 2; Solie and others, 2014). Sample 09LF234A yields two ages around 1,800 Ma, another age around 225 Ma, and the other 17 ages are Carboniferous, between around 300 Ma and 345 Ma. Sample 09LF233A yields two zircon ages of approximately 100 Ma and 321 Ma. Based on the analysis of one 100 Ma zircon, we interpret the unit as no older than Cretaceous. If true it best correlates with the Jurassic to Cretaceous Macauley Ridge formation in adjacent Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013), and Cretaceous to Tertiary conglomerate and sandstone (TKc) of Richter (1976) in the Nabesna Quadrangle, Alaska. However, the degree of pebble deformation could suggest an older age for part of the unit, more consistent with the Permo-Triassic Mirror Creek complex (Ryan and others, 2013).

Ks METASANDSTONE, METACONGLOMERATE AND PHYLLITE (Cretaceous)—Very fine- to fine-grained, gray to greenish-gray, phyllite ± graphite, and metasandstone; may include local layers of metaconglomerate. Magnetic susceptibility is generally low, averaging 0.16 × 10^{-3} SI, ranging from 0.10 × 10^{-3} to 0.34 × 10^{-3} SI. Age is assigned based on similar metamorphic grade and spatial association with metaconglomerate, Kcg, but may be part of unit P₸s.

Greenschist-Facies Metaigneous Rocks

Metamafic rocks (₸gs and ₸g) are tentatively correlated with the Triassic gabbro suite of Murphy and others (2009) and Snag Creek suite of Ryan and others (2013) in Canada, and possibly the gabbroic intrusives (₸gb of Dashevsky and others, 2003) in the Tok mining district, Alaska.

₸gs GREENSTONE (Triassic?)—Greenstone varies from blocky isotropic greenstone to foliated greenschist. Greenstone is generally brown-weathering, dark green on fresh surfaces, massive, blocky, very fine to fine grained, granular, with local weak foliation. Mineralogy includes chlorite, epidote-group minerals, actinolitic amphibole, plagioclase feldspar, opaque minerals, ± biotite; some pseudomorphs after clinopyroxene(?). Greenschist is strongly foliated, green, with modal mineralogy including chlorite, plagioclase, and quartz. North of Gardiner Creek fault, the greenstone is generally highly magnetic, with a range from 0.09 × 10^{-3} to 127 × 10^{-3} SI, averaging 12.6 × 10^{-3} SI. South of Gardiner Creek fault, greenstone has a consistently low magnetic susceptibility, ranging from 0.01 × 10^{-3} to 0.98 × 10^{-3} SI, averaging 0.44 × 10^{-3} SI. Age is assigned as Triassic based on interpreted association with Triassic metagabbro (₸g).

₸g METAGABBRO (Triassic?)—Gabbro and microgabbro with primary plagioclase ± hornblende ± clinopyroxene variably recrystallized and metamorphosed to assemblages including actinolite, clinozoisite, albite, chlorite, opaque minerals, and titanite. Pale to dark grayish-green, fine to medium grained, with weak to no foliation. Unit overlaps mineralogically and texturally with greenstone (₸gs), but was only identified south of Gardiner Creek fault. Magnetic susceptibility ranges from 0.08 × 10^{-3} to 2.35 × 10^{-3} SI, averaging 0.53 × 10^{-3} SI. A fine-grained, unfoliated, amphibole clinopyroxene(?) metagabbro from the Airs Hill area (09LF206A) yields an uncertain Triassic zircon U-Pb age (map location U18; table 2; Solie and others, 2014).

Lower Greenschist-Facies Metasedimentary Rocks

Permo-Triassic metasedimentary units probably correlate with adjacent Mirror Creek formation in adjacent Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013; Murphy and others, 2009).

P₮p PHYLLITE (Triassic to Permian)—Very-very-fine- to fine-grained, black to green–gray, white mica quartz phyllite, ± calcite, ± graphite. Foliation locally crenulated. Quartz stringers not uncommon. Stratigraphic relationship with P₮s uncertain; appears to be interlayered. Magnetic susceptibility is generally low, averaging 0.13×10^{-3} SI, ranging from 0.02×10^{-3} to 0.50×10^{-3} SI. Age cannot be younger than Triassic gabbroic intrusive rocks within P₮p; is interpreted as younger than Devonian to Proterozoic greenschist-facies to lower amphibolite-facies package (described below), based on lower metamorphic grade. Assigned Permian to Triassic age based on probable correlation with Mirror Creek formation in Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013), but could be Devonian if correlated with phyllite of Richter (1976, unit Dp) in the Nabesna Quadrangle, Alaska.

P₮s METASANDSTONE, ARGILLITE AND PHYLLITE (Triassic to Permian)—Very fine- to medium-grained, black to tan, generally calcareous metasedimentary rocks. Includes calcareous metasandstone/quartzite, metachert, sandy metalimestone/marble, argillite, and phyllite. Stratigraphic relationship with P₮p uncertain; appears to be interlayered. Magnetic susceptibility is generally low, averaging 0.12×10^{-3} SI, ranging from 0.01×10^{-3} to 0.47×10^{-3} SI. Age cannot be younger than Devonian to Proterozoic greenschist-facies to lower amphibolite-facies package (described below), based on lower metamorphic grade. Assigned Permian to Triassic age based on correlation with Mirror Creek formation in Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013).

Greenschist-Facies Metaigneous and Metasedimentary Rocks North of Gardiner Creek fault

Includes lower metamorphic grade rocks than the amphibolite facies rocks described below, and is characterized by absence of augen gneiss (MDlo) and amphibolite (MDla), predominance of fine- to very fine-grained textures, and presence of greenstone with generally high magnetic susceptibility (₮gs). Correlation of the greenschist-facies package north of Gardiner Creek fault is uncertain; it is likely a greenschist facies part of the Lake George assemblage (Dusel-Bacon and others, 2006), and may correlate with the White River complex (Ryan and others, 2013).

Ms FELSIC SCHIST AND QUARTZITE (Mississippian)—Primarily tan to brown to green, fine- to very-fine-grained, biotite and/or chlorite, feldspar, quartz schist with minor white mica/sericite; interpreted locally as felsic metavolcanic. Original quartz ± feldspar phenocrysts are recrystallized and partially deformed into foliation planes. All other igneous textures are obscured by metamorphic fine-grained minerals, including metamorphic quartz, albite, sericite, epidote-group minerals, chlorite, and opaque minerals. Unit also includes undifferentiated, very-fine-grained, laminated quartzite, chlorite–quartz schist, and greenstone. Magnetic susceptibility is generally moderately low, averaging 1.0×10^{-3} SI, ranging from 0.02×10^{-3} to

21.6 × 10^{-3} SI. Higher magnetic susceptibilities appear to be due to hornfels overprint and/or secondary magnetite on fractures. Zircon from a metarhyolite (09MBW400A) yields a lower Mississippian U-Pb weighted-mean age of 351.7 ± 9.3 Ma based on 49 tightly grouped zircon ages (map location U10; table 2; Solie and others, 2014).

Mcs CHLORITE SCHIST (Mississippian or older)—Very-fine- to fine-grained, green to gray, chlorite sericite quartz schist and phyllite, and fine-grained actinolite(?) albite clinozoisite chlorite schist (greenschist). Magnetic susceptibility is generally moderately low, averaging 0.75 × 10^{-3} SI, ranging from 0.01 × 10^{-3} to 10.8 × 10^{-3} SI. Schist with higher mafic mineral content tends to have higher magnetic susceptibilities. Mississippian or older age assignment is based on similar metamorphic facies and apparent stratigraphic association with and/or beneath unit Ms.

Mcq CHLORITIC QUARTZITE (Mississippian or older)—Very-fine- to fine-grained, massive to laminated quartzite, in shades of pale to dark greens, grays, and browns, with variable chlorite, biotite, and/or white mica content. Locally contains a few percent of slightly coarser-grained, rounded quartz grains (referred to as grit). Magnetic susceptibility is generally moderately low, averaging 0.72 × 10^{-3} SI, ranging from 0.01 × 10^{-3} to 13.1 × 10^{-3} SI. Quartzite with highest values contains magnetite. Mississippian or older age assignment is based on similar metamorphic facies and apparent stratigraphic association with and/or beneath unit Ms.

Amphibolite-Facies Metaigneous and Metasedimentary Rocks — Lake George assemblage of Parautochthonous North America

Amphibolite-facies metamorphosed rocks in the map area exhibit similarities in protolith age, major- and trace-element composition, and metamorphic facies to metamorphic rocks of the southern Big Delta and Tanacross quadrangles (Dusel-Bacon and Cooper, 1999) and to the Fairbanks area (Newberry and others, 1996), suggesting that this unit of amphibolite-facies metamorphic rocks is widespread in eastern Interior Alaska. We divide the amphibolite-facies metamorphic rocks in the map area into four major units (undifferentiated orthogneiss, paragneiss and schist, quartzite, and amphibolite) on the basis of protoliths. Amphibolite-facies rocks are correlated to the Lake George assemblage of the parautochthonous North American assemblage as defined by Dusel-Bacon and others (2006).

MDlo UNDIFFERENTIATED ORTHOGNEISS (Mississippian to Devonian)—Unit MDlo includes granite orthogneiss, granite augen orthogneiss, and granodiorite orthogneiss. Orthogneiss crops out throughout the map area north of Beaver Creek in the Tanacross A-2, A-3, and B-3 quadrangles. Where orthogneiss is mapped in a Cretaceous pluton it could be a pendant of host rock enclosed by the pluton.

Granite orthogneiss is light gray, medium to fine grained, with faint to obvious gneissic banding. Modal mineralogy includes quartz, alkali feldspar, plagioclase, biotite, and less common hornblende or white mica. Accessory minerals include chlorite (after biotite and amphibole), muscovite, apatite, allanite, opaque minerals (magnetite), and zircon. Granite augen orthogneiss has similar mineralogy, texture, and outcrop relationships as the granitic orthogneiss, but with coarse alkali feldspar augen (up to 2 cm long) and often coarser groundmass grain sizes. Some samples have undergone progressive deformation under brittle–ductile conditions where feldspars are fractured and rotated. The interstitial matrix comprises finer-grained, often elongate, quartz and biotite. Granodiorite orthogneiss is medium grained, equigranular, with 20–25 percent biotite. Plagioclase is the dominant felsic mineral with minor quartz and alkali feldspar. The magnetic susceptibility of the orthogneiss unit is generally moderately low, averaging 0.34×10^{-3} SI overall. Higher magnetic susceptibilities above 1×10^{-3} SI (up to 4.95×10^{-3} SI) are present in only a few localities.

The age of the orthogneiss unit is probably Early Mississippian to Late Devonian. Zircon from a monzogranite orthogneiss yields an Early Mississippian U-Pb age of 354.6 ± 9.3 Ma (09MBW243A; map location U6; table 2; Solie and others, 2014). Similar orthogneisses and augen orthogneisses occur throughout the Yukon–Tanana terrane of interior Alaska and the Yukon Territory of Canada. Crystallization ages of zircon by U-Pb zircon geochronology of orthogneisses in the region show three age groups: (1) Late Devonian, 360–375 Ma, (2) Early Mississippian, 341–357 Ma, and (3) Middle and Late Permian [(Mortensen, 1986, 1990 and 1992; Dusel-Bacon and Aleinikoff, 1996; Dusel-Bacon and others, 2004; Ruks and others, 2006; Murphy and others, 2006; for a discussion and summary of the age and outcrop data for regional orthogneisses see Ruks and others (2006)].

pMlp PARAGNEISS AND SCHIST (pre-Mississippian)—Metasedimentary paragneiss and schist are interlayered throughout the Lake George assemblage north of Gardiner Creek fault. Paragneiss is distinguished from schist by having lower modal mica content, from quartzite by having less modal quartz, and from gneiss or orthogneiss by having less modal feldspar. Unit pMlp includes complexly deformed paragneiss, with lesser schist, orthogneiss, quartzite, amphibolite, and minor calc-silicate schist. Where the latter three lithologies crop out in exposures extensive enough to map they are shown as units MDlo, pMlq, and MDla, respectively. Contacts between the lithologies can be sharp or gradational; individual lithologic layers range in thickness from centimeters to many meters. Pervasive metamorphic deformation is evidenced by open and isoclinal folds, crenulated foliation planes, quartz boudinage, locally intense quartz veining, and lateral discontinuity of layers. A dense, very-fine-grained hornfels overprint is locally present due to extensive Cretaceous plutonism.

Paragneiss is interpreted as having a pelitic protolith. Paragneiss is generally fine grained, equigranular to slightly porphyroblastic, and banded with gray, brown, or green layers depending on mineral content. Major mineralogy consists of quartz, feldspar, white mica, and biotite (locally chloritized), ± garnet. Paragneiss locally grades into micaceous quartzite. Another composition included in this map unit is banded green and white gneiss, which is rich in amphibole and albite, with variable amounts of biotite and chlorite. Up to 5 percent quartz may be present. Epidote-group minerals are common, as are trace amounts of titanite, calcite, and opaque minerals. This composition locally grades into amphibolite (MDla), and is included in that map unit description as well.

Schist is typically interlayered with the less micaceous paragneiss. Most schist is muscovite- and quartz-bearing with variable biotite. Some schist is biotite- and chlorite-rich with small amounts of amphibole, quartz, and plagioclase feldspar. Schist commonly has silver–gray foliation planes with broken surfaces of light tan, brown, or gray. One locality of magnetite-bearing schist was noted on the ridge near fault contact with greenschist-facies terrane in the Tanacross A-2 Quadrangle.

Magnetic susceptibility of paragneisses in unit pMlp is variable from zero to 5.6 × 10^{-3} SI. Magnetic susceptibility of schist in pMlp generally is quite low, averaging 0.2 × 10^{-3} SI, ranging from 0.02 × 10^{-3} to 2.3 × 10^{-3} SI. Magnetite-bearing schist layers range from 2.8 × 10^{-3} to 40 × 10^{-3} SI.

The age of this unit is poorly constrained. The roughly correlative Macomb subterrane defined in the Mount Hayes Quadrangle to the west (Nokleberg and others, 1992) is Middle Devonian or older, based on a 372 ± 8 Ma U-Pb zircon age from metaigneous rocks in the metasedimentary unit (Aleinikoff and Nokleberg, 1985). The unit (pMlp) is intruded by, and therefore older than, metaigneous orthogneiss unit (MDlo) which is assigned Early Mississippian to Late Devonian age. Unit could include rocks as old as Precambrian (Foster, 1970).

pMlq QUARTZITE (pre-Mississippian)—Quartzite is fine to medium grained, massive, light gray with faint banding, and locally interlayered with lenses of paragneiss, schist, and amphibolite. Most quartzite layers are thin or have indistinct gradations into paragneiss and schist layers. Graphite and magnetite are notable minerals present in darker-gray quartzite. Quartzite may have minor muscovite and biotite (up to 20 percent), and many of the micaceous quartzites show strong isoclinal folding. Magnetic susceptibility of quartzite is generally low, averaging about 0.10 × 10^{-3} SI. Measured values range from essentially zero to 0.71 × 10^{-3} SI. Age is assigned based on interpreted depositional relationship with Devonian or older metasedimentary unit pMlp.

MDla AMPHIBOLITE (Mississippian to Devonian)—Amphibolite is fine to medium grained, with lesser amphibole–plagioclase gneiss in thin lenses, layers, and localized outcrops in the metamorphic package. Amphibolite modal mineralogy consists of hornblende (60–95 percent) and plagioclase (5–40 percent). Amphibole–plagioclase gneiss is finely banded with modal mineralogy consisting of hornblende (60–90 percent), plagioclase (10–40 percent), and quartz (≤5 percent), with minor biotite, epidote-group minerals, chlorite, titanite, and opaque minerals. Most samples preserve a strong foliation fabric of aligned amphiboles or chlorite, locally lineated. Near Cretaceous to Tertiary intrusions, fabric has been overprinted by hornfels recrystallization. The magnetic susceptibilities for amphibolite are quite low, averaging 0.3 × 10^{-3} SI with a range from 0.2 × 10^{-3} to 0.5 × 10^{-3} SI. Dussel-Bacon and others (2004) suggest a bimodal magmatic association of amphibolite with orthogneiss (MDlo) in the Yukon—Tanana Upland. We therefore assign a Devonian to Mississippian age.

Greenschist-Facies to Lower Amphibolite-Facies Metaigneous and Metasedimentary Rocks South of Gardiner Creek fault

Includes lower metamorphic-grade rocks than amphibolite-facies Lake George assemblage rocks described above. Greenschist- to lower amphibolite-facies metavolcanic and metasedimentary packages south of Gardiner Creek fault are characterized by absence of augen gneiss (MDlo) and amphibolite (MDla), presence of generally low magnetic susceptibility greenstone (ŦRgs), and presence of metagabbro (ŦRg). They probably correlate with rocks of the White River assemblage in adjacent Stevenson Ridge map sheet, Yukon (Ryan and others, 2013). In the Tok mining district roughly 175 km west in the Mount Hayes Quadrangle, rocks of Devonian or older Jarvis belt and Hayes Glacier belt (Nokleberg and others, 1992; Dashevsky and others, 2003) may also be correlative, though this is more tentative.

Dms MAFIC SCHIST (Devonian?)—Very-fine- to medium-grained, green to gray, chloritic schist; interpreted in part as metatuff and metabasite. Unit includes chlorite white mica quartz schist, chlorite quartz schist, and chlorite plagioclase schist ± actinolite. Magnetic susceptibility is moderately low, averaging 0.31×10^{-3} SI, ranging from 0.01×10^{-3} to 0.87×10^{-3} SI. Age assigned as Devonian(?) based on interpreted correlation with Late Devonian White River complex metavolcanic rocks in adjacent Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013).

Dfs FELSIC SCHIST (Devonian?)—Very-fine- to fine-grained, white to pale-gray to green, white mica quartz schist, locally slightly calcareous. Magnetic susceptibility is generally low, averaging 0.19×10^{-3} SI, ranging from 0.03×10^{-3} to 0.39×10^{-3} SI. Age assigned as Devonian(?) based on interpreted correlation with Late Devonian White River complex metavolcanic rocks in adjacent Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013).

DPzmq MICACEOUS QUARZITE (Devonian or older)—Tan to gray to green, fine-grained, weakly foliated, white mica quartzite ± biotite ± chlorite, rarely graphitic. Gritty quartz grains are rare, distinguishing this unit from DPzgq. Magnetic susceptibility is generally low, averaging 0.23×10^{-3} SI, ranging from 0.01×10^{-3} to 0.98×10^{-3} SI. Interpreted as part of the White River complex (Ryan and others, 2013) based on continuity of map pattern across the border with Yukon, though micaceous quartzite is not described as part of the complex. Age is uncertain; Devonian if correlative with White River complex in adjacent Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013) but could be older.

DPzqms QUARTZ MICA SCHIST (Devonian or older)—Tan to gray to green, very-fine- to fine-grained, quartz–white mica schist ± chlorite. Unit is interlayered with DPzmq. Unit also includes micaceous quartzite as well as minor calcareous schist, graphitic schist, and rare fuchsite(?) schist. Magnetic susceptibility is generally low, averaging 0.17×10^{-3} SI, ranging from 0.01×10^{-3} to 0.85×10^{-3} SI. Age is uncertain; Devonian if correlative with White River complex in adjacent Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013) but could be older.

DPzcs CALCAREOUS SCHIST, CALCAREOUS QUARTZITE, MARBLE (Devonian or older)—Very-fine- to fine-grained, gray to green, calcareous schist, phyllite, and quartzite. Mineralogy includes quartz, white mica, chlorite, and calcite in varying abundances. Impure marble comprises thin layers locally; commonly weakly foliated with white mica. Quartzite commonly laminated, weakly foliated. Magnetic susceptibility is generally low, averaging 0.16 × 10^{-3} SI, ranging from 0.02 × 10^{-3} to 0.58 × 10^{-3} SI. Age is uncertain; Devonian if correlative with White River complex in adjacent Stevenson Ridge Quadrangle, Yukon (Ryan and others, 2013) but could be older.

DPgq GRITTY QUARTZITE (Devonian or older)—Very-fine- to fine-grained, light- to medium-gray quartzite, characteristically with larger rounded conglomeratic quartz "grit" grains in the finer-grained matrix. White mica ± biotite content varies; rarely slightly calcareous. Unit also includes minor interlayered white mica biotite quartz schist ± chlorite. Based on fine grain size, common biotite, rare garnet, and relative paucity of chlorite and epidote, unit is interpreted as lower amphibolite facies. Magnetic susceptibility is generally low, averaging 0.11 × 10^{-3} SI, ranging from 0.01 × 10^{-3} to 0.60 × 10^{-3} SI. Detrital zircons from gritty quartzite yield U-Pb ages ranging from about 1,030 Ma to 3,000 Ma (sample 09RN242A; map location U20; table 2; Solie and others, 2014). The largest peak in the distribution is at approximately 1,807 Ma, with two smaller but prominent peaks at approximately 1,946 Ma and 2,648 Ma. Based on lithologic similarity, this unit could potentially correlate with the Scotty Creek formation mapped in adjacent Yukon (Murphy and others, 2009; Ryan and others, 2013). This correlation is uncertain because detrital zircon plots for Scottie Creek (Murphy and others, 2009) contain more zircons between 1.0 and 1.5 Ga than does sample 09RN242A.

DPag AMPHIBOLE GNEISS (Devonian or older)—Green, fine-grained, laminated, amphibole feldspar gneiss ± biotite, locally calcareous; secondary minerals include chlorite, albite, epidote, and opaque minerals. Broken out as separate unit in two localities in the Nabesna D-1 Quadrangle; interlayered with DPgq. Magnetic susceptibility is moderately low, averaging 0.28 × 10^{-3} SI. Age is assigned based on interlayered relationship and apparent equivalent metamorphic grade with DPgq.

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