# EXPLANATION OF MAP UNITS: NORTHEASTERN TANACROSS GEOLOGIC MAP, TANACROSS D-1, D-2, C-1, AND C-2 QUADRANGLES, ALASKA

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**Cover.** DGGS Geologist Mandy Willingham on an outcrop of Fortymile River metasediments near the Lake George-Fortymile detachment (photograph taken 07/04/2018 by K. R. Sicard).

# EXPLANATION OF MAP UNITS: NORTHEASTERN TANACROSS GEOLOGIC MAP, TANACROSS D-1, D-2, C-1, AND C-2 QUADRANGLES, ALASKA

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## INTRODUCTION

The Mineral Resources section of the Alaska Division of Geological & Geophysical Surveys (DGGS) conducted 500 mi$^2$ of 1:63,360-scale geologic mapping in the northeastern Tanacross Quadrangle (Tanacross D-1, and parts of the C-1, C-2, and D-2 quadrangles), located 15 miles southeast of Chicken, Alaska. The project took place during two periods: a reconnaissance mapping effort June 12–22, 2017, and a detailed campaign from June 18 to July 16, 2018. This map is located within an area of current industry interest; it includes the Taurus porphyry copper-gold-molybdenum ± rhenium deposit and several other occurrence types, including gold, copper, and molybdenum in porphyritic intrusions, structurally controlled silver-lead-zinc prospects, and placer gold deposits.

Prior to DGGS work in the area, the most-detailed mapping was at 1:250,000 scale (Foster, 1970), and the area was the focus of a detailed structural study (Hansen and Dusel-Bacon, 1998). In the decades following publication of Foster's reconnaissance map, U.S. and Canadian researchers established a regional geologic and tectono-stratigraphic framework for the area (for example, Colpron and others, 2006; Dusel-Bacon and others, 2006), which involves two fundamental components: the pericratonic Yukon-Tanana terrane (YTT) and the parautochthonous North American margin (pNA) from which the YTT initially rifted, and to which it was eventually re-accreted. The boundary between the allochthonous YTT and parautochthonous North America is one of the fundamental suture zones in the northwestern Cordillera, and the northeastern Tanacross Quadrangle is one of the rare areas in which it is exposed. The conceptual framework has been developed in the literature but it is not fully represented in compilation geologic maps of eastern Alaska (for example, Wilson and others, 2015). Recent detailed studies in the area include: geophysical surveys (Emond and others, 2015; Burns and others, 2011, 2015) and ongoing USGS studies (Jones and others, 2017a, 2017b), as well as previous 1:63,360-scale mapping in the Eagle A-1 and A-2 quadrangles immediately to the north (Szumigala and others, 2002; Werdon and others, 2001). This newer data and resurgent mineral industry interest in the area prompted the DGGS to conduct new 1:63,360 scale geologic mapping in this area.

## GEOLOGIC BACKGROUND

The northeastern Tanacross Quadrangle is characterized by a very complex geologic history, which can be distilled to three main periods. In the Late Devonian to Early Mississippian, the YTT rifted away from the North American margin, which resulted in the formation of an ocean basin - the Slide Mountain/Seventymile ocean (Dusel-Bacon and others, 2013). During this time, the YTT underwent multiple episodes of arc magmatism, while parautochthonous North America was magmatically

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quiet. During contraction in the Permian, the Slide Mountain/Seventymile ocean was consumed, and prolonged re-accretion of YTT began (Dusel-Bacon and others, 2013). This resulted in polydeformed metamorphic rocks that underwent regional metamorphism up to amphibolite grade. Finally, post-metamorphic arc magmatism occurred during the Cretaceous-Paleogene.

Previous 1:250,000-scale reconnaissance mapping of the Tanacross Quadrangle does not address the complexity of the Paleozoic metamorphic rocks, however it does delineate general Tertiary mafic volcanic rocks, Mesozoic granitic rocks, and Paleozoic or Precambrian metamorphic units (Foster, 1970). Coney and others (1980), proposed a "suspect Yukon-Tanana composite terrane," due to the existence of fragments of oceanic arcs and an unknown origin of the metamorphic rocks in this region. The composite Yukon-Tanana terrane concept evolved and was eventually defined as both a parautochthonous continental margin of North America, the Lake George assemblage, which is present in the southern half of the northeastern Tanacross map area, and an allochthonous Yukon-Tanana Terrane, represented by the Fortymile River assemblage in the northern half of the map area (Colpron and others 2006, Dusel-Bacon and others, 2006; Dusel-Bacon and Hansen, 1991). Parautochthonous North America, a Paleozoic basinal facies of the passive margin of the North American Craton, was later transported along the north-side-bounding Tintina fault, and disrupted by faults related to the south-side-bounding Denali fault; both are crustal-scale, dextral strike-slip fault systems (Dusel-Bacon and others, 2017), connected by high-angle faults and rotated fault blocks throughout the Yukon Tanana Uplands.

The allochthonous Yukon-Tanana terrane (Fortymile River and Nasina assemblages; Dusel-Bacon and others, 2017; Szumigala and others, 2002; Werdon and others, 2001) present in the northern part of the Tanacross map area is interpreted as arc and basinal deposits rifted off the North American margin during the early Mississippian, and thrust over parautochthonous North America during Permian to Jurassic time (Dusel-Bacon and others, 2006, 2017). Detailed mapping in the Eagle A-1 and A-2 quadrangles revealed the complexity of this terrane immediately north of the field area, and provided a very detailed framework to guide mapping within the Fortymile River assemblage in the northeastern Tanacross Quadrangle (Szumigala and others, 2002; Werdon and others, 2001).

Regionally, metamorphic assemblages of YTT and pNA are intruded by Triassic, Cretaceous to Paleogene, possibly Neogene volcanic and plutonic rocks. The oldest igneous intrusive body in the region, the Taylor Mountain batholith, is described by Werdon and others (2001) as a multi-phase intrusion with structural fabric present only on the margins of the batholith. This pluton has a complex intrusive history, but based on a titanite U-Pb crystallization age, it was emplaced around 214 Ma (Dusel-Bacon and others, 2009). Jurassic intrusive rocks include granodiorite, quartz monzodiorite, granite, quartz monzonite, tourmaline granite, porphyritic granite, and granitic pegmatite, as well as felsic and biotite-clinopyroxenite dikes. All Jurassic intrusive bodies have well-constrained $^{40}Ar/^{39}Ar$ or U-Pb crystallization ages ranging from 186 to 191 Ma (Mortensen, 1999; Szumigala and others, 2002; Werdon and others, 2001). Werdon and others (2001) describe one porphyry, Chicken Pluton porphyry, as a separate small body of uncertain (Jurassic to Tertiary) age. Mid-Cretaceous intrusions include granites, such as the 117 Ma Crag Mountain pluton in the Yukon (Yukon Geological Survey, 2019), as well as gabbro, granodiorite, and quartz monzonite ranging in age from 97 to 101 Ma along the Alaska Highway (Solie and others, in press). Late Cretaceous intrusions include the Mt. Fairplay syenite (Foster, 1967), and other granodiorite, diorite, monzonite, trachyandesitic porphyries, and andesite bodies in the region, which have a narrow age range between 68 Ma and 76 Ma (Benowitz and others, 2017). The youngest igneous rocks in the adjacent Eagle A-2 and A-1 quadrangles are gabbro/diabase at 58 Ma ($^{40}Ar/^{39}Ar$ crystallization age; Werdon and others, 2001) and basalt with a 14 Ma $^{40}Ar/^{39}Ar$ whole rock age (Szumigala and others, 2002), respectively. Locally, small fault-bounded sedimentary basins were mapped in the Eagle A-1 and A-2 quadrangles (Szumigala and others, 2002; Werdon and others, 2001). The sediments consist of conglomerates, sandstone, coal, siltstone, and graywacke, with local felsic tuff, and are thought to be Tertiary.

## DESCRIPTION OF MAP UNITS

### *QUATERNARY UNCONSOLIDATED DEPOSITS*

This map includes unconsolidated surficial deposits in the Tanacross D-1 Quadrangle, the eastern one-third of the Tanacross D-2 Quadrangle, the northern half of the Tanacross B-2 Quadrangle and the northeastern one-third of the Tanacross B-2 Quadrangle. To create this map we incorporated (1) geologic information from previous geologic mapping and published literature, (2) new interpretations using remotely sensed imagery, and (3) information gathered from limited field investigations. Previous geologic mapping in the Tanacross Quadrangle includes work by Foster (1970) at a scale of 1:250,000, which provided a framework for our mapping and was instrumental in understanding the regional distribution and character of deposits. Weber (1986) described the glacial history of the Yukon Tanana Upland and gave detailed descriptions of the extent and character of these deposits. Her work along with glacial limits mapped by Péwé and others (1967) helped us identify and map glacial deposits in the map area. Work by Pinney (2001) and Stevens and Burns (2010) in the Eagle A-1 and A-2 quadrangles enabled us to understand the distribution and character of deposits in adjoining areas to the north and enhanced our understanding of the morphology and distribution of alluvial terraces, many of which are gold bearing and extend southward into this map area. Mapping at a scale of 1:50,000 in the adjoining Borden Creek and Crag Mountain quadrangles by Jackson (2005a, 2005b) allowed comparisons with the distribution and character of deposits in Canada.

#### Remotely Sensed Imagery

Surficial geology was mapped by interpreting 2.5-m-resolution SPOT 5 color-infrared and natural color red-green-blue (RGB) imagery (©2013, Distribution SpotImage S.A., SICORP , USA all rights reserved) collected in 2009 and 2010 and stereoscopic pairs of approximately 1:65,000-scale, false-color, infrared aerial photographs taken in 1978 and 1981. SPOT 5 imagery was interpreted in ArcGIS Pro by overlaying it on hillshade and slopeshade images derived from Interferometric Synthetic Aperture Radar (IFSAR) bare-earth digital-elevation models (DEMs) created using data collected in 2010. By using the pseudo-3-D functionality of ArcGIS Pro and adjusting the transparency of the SPOT 5 imagery and the transparency and color of hillshade and slopeshade images, we were able to visualize subtle differences in features and identify geologic landforms. We used aerial photographs to identify geologic features and check our interpretations. Geospatial polygon features, representing geologic units, were drawn using onscreen digitizing techniques in ArcGIS Pro.

#### Field Work

We conducted helicopter-supported field work June 20–23, 2017 and July 3–4, 2018. During field work we visited exposures and dug soil pits to examine material and gather information for unit descriptions and check geologic mapping. We also measured the thickness of the active layer at several locations.

### ALLUVIAL DEPOSITS

Qa

**ALLUVIUM OF MODERN STREAM CHANNELS (Quaternary)** – Stratified, well-sorted to locally poorly-sorted, rounded to subangular, polymictic pebble-cobble gravel, sand, and silt. Includes sediments deposited in active stream channels, floodplains and associated low terraces that cannot be differentiated at the scale of mapping. Frequency and timing of deposition is uncertain. In areas where inundation is infrequent deposits may be locally overlain by ice-rich organic silt. Vegetation includes alders, willows and scattered spruce which are more dense along but not in active stream channels, where stream inundation is more frequent, and the active layer is thicker.

Qaf

**ALLUVIAL-FAN DEPOSITS (Quaternary)** – Fan-shaped deposits of stratified, well- to poorly-sorted gravel, sand, and silt with scattered pebbles and cobbles. Debris-flow deposits are common in upper (proximal) zones of fans. Clast size decreases and degree of sorting increases distally from the head of the fan. Deposits are found along the margins of larger valleys at the mouths of tributary streams and gullies, where they are often associated with complex colluvial and alluvial valley-fill deposits (Qca), and older terrace alluvium (Qat1 and Qat2).

Qat3

**YOUNG TERRACE ALLUVIUM (Quaternary)** – Elongate deposits of well-sorted to locally poorly-sorted, rounded to subangular, polymictic pebble-cobble gravel and sand, with trace to some silt overlain by ice-rich organic silt, and overbank deposits. Deposits form low terraces approximately 10–15 m above modern streams.

Qat2

**OLD TERRACE ALLUVIUM (Quaternary)** – Elongate deposits of well-sorted to locally poorly-sorted, rounded to subangular, polymictic pebble-cobble gravel, sand, and silt capped by variable thicknesses of ice-rich primary and reworked eolian silt. Vegetation generally consists of tussock tundra with scattered to sparse, often stunted, black spruce.

Most deposits are present as benched surfaces along valley margins that are 30–40 m above modern stream channels. Surfaces are moderate to gently sloping parallel to stream channels and have typically been extensively modified by slope processes, such as gelifluction and solifluction. Based on their mapping in the Eagle A-1 and A-2 quadrangles directly north of the map area, Stevens and Burns (2010) and Pinney (2001) suggested these terrace deposits are not related to modern drainage, and may be Pleistocene in age as current streams do not appear to be capable of depositing such material. Based on our observations, including the degree of surface modification from slope processes, we agree with this assertion, although we were unable to date these surfaces.

Qat1

**OLDEST TERRACE ALLUVIUM (Quaternary)** – Elongate deposits of well-sorted to locally poorly-sorted, rounded to subangular, polymictic, pebble-cobble gravel, sand, and silt. Vegetation generally consists of tussock tundra with scattered to sparse, often stunted, black spruce that are often tilted as a result of complex, frost-action processes.

Deposits on benched surfaces along valley margins that are up to approximately 125 m above the modern stream channels. Surfaces are moderately sloping parallel to stream channels and have been extensively modified by slope processes that include gelifluction and solifluction. Primary morphology has generally been destroyed and deposits are often discontinuous. Oldest terrace surfaces are often adjoined by colluvium (Qc) and mixed colluvial and alluvial valley fill deposits (Qca) that are present on steeper slopes and valley sidewalls. Open-system pingos are often found at these unit boundaries.

Oldest terrace surfaces are most common along valley side slopes in larger stream valleys within the map area. The proximity of the oldest terrace deposits to older cirques with subdued morphology in high-elevation source areas indicates that these deposits are of glaciofluvial origin.

Qfp

**FLOODPLAIN ALLUVIUM (Quaternary)** – Elongate deposits of well-sorted to locally poorly-sorted, rounded to subangular, polymictic, pebble-cobble gravel, sand, and silt in floodplains and associated low terraces. Lower surfaces may be flooded during times of maximum stream discharge.

## COLLUVIAL DEPOSITS

Qc

**UNDIFFERENTIATED COLLUVIUM (Quaternary)**– Blankets, aprons, cones, and fans of heterogeneous, angular to subangular rock fragments, gravel, sand, and silt formed by residual weathering and complex, gravity-driven mass movements involving rolling, sliding, flowing, solifluction (or gelifluction where frozen), and frost action on weathered bedrock and unconsolidated deposits. Deposits are generally unsorted to poorly sorted. Thickness is highly variable, often reflecting the configuration of bedrock where thin, and forming thick deposits at the base of slopes.

Unit includes Quaternary deposits whose origins are uncertain or whose primary depositional morphology was modified or destroyed by weathering and slope processes. May be complexly mixed with terrace deposits (Qat1, Qat2, and Qat3), glacial drift (Qgd), and complex colluvial and alluvial deposits (Qca).

Qcf

**FINE-GRAINED COLLUVIUM AND SILT (Quaternary)** – Deposits of fine-grained colluvium and silt. Silt is largely retransported from original hillside sites to lower slopes by a variety of complex slope processes. Deposits are commonly perennially frozen and ice rich.

Qcl

**COLLUVIAL LANDSLIDE DEPOSITS (Quaternary)** – Elongate to lobate mixtures of bedrock blocks, angular to subangular rock fragments, and polymictic gravel, sand, and silt deposited on steep slopes by sliding of failed bedrock and unconsolidated surface deposits. Surfaces modified by creep and flow.

Qcr

**RUBBLE DEPOSITS (Quaternary)** – Heterogeneous mixtures of frost-rived, angular, blocky rock fragments with trace to some gravel, sand, and silt deposited by free fall, tumbling, rolling, and sliding. Most commonly found on steep bedrock slopes and downslope of bedrock outcrops, and undifferentiated colluvium (Qc).

## COMPLEX DEPOSITS

Qca

**COLLUVIAL AND ALLUVIAL VALLEY-FILL (Quaternary)** – Massive to poorly-stratified sand and silt mixed with subangular to rounded pebble-cobble gravel and locally derived bedrock clasts deposited in upper stream courses and on lower slopes along the margins of stream valleys by complex mass-movement processes (including rolling, sliding, flowing, gelifluction and frost action). Locally may include debris flow deposits. Deposits are locally overlain by variable thickness of ice-rich organic silt that when exposed undergoes active thermokarst degradation. Surface commonly has numerous trees that are leaning as a result of frost action. Complexly mixed with colluvium (Qc), older alluvial deposits (Qat1, Qat2), and glacial drift (Qgd).

These types of deposits are present where (1) streams are not able to remove material faster than it is transported by downslope by colluvial processes, or (2) where material originally deposited by stream processes has been reworked by complex slope processes destroying the original morphology.

## GLACIAL DEPOSITS

Qgd

**UNDIFFERENTIATED GLACIAL DRIFT (Quaternary)** – Heterogeneous mixtures of poorly to moderately sorted, subangular to rounded boulders, gravel, sand, and silt deposited by ancient alpine glaciers and then extensively modified by slope processes. Preserved as irregular patches of thin drift within colluvial deposits (Qc). Structure of underlying bedrock typically visible.

Associated valley headwalls in the highest elevations exhibit subdued, cirque-like morphology. Valley cross-profiles are highly modified by the accumulation of colluvium on valley walls and stream erosion. Streams are markedly underfit for the valleys they occupy.

Based on characteristics, such as subdued morphology, elevation of source areas, and apparent extreme age, the mapped deposits could correlate with early Pleistocene glacial deposits of the Charley River glaciation described by Weber (1986) in the Yukon Tanana Upland, Weber and Wilson (2012) in the Eagle Quadrangle, and cirques of the pre-Reid glaciation mapped by Jackson (2005a, 2005b) in Canada just east of the map area.

## MAN-MADE DEPOSITS

Qh

**PLACER-MINE TAILINGS AND ARTIFICIAL FILLS (Quaternary)** – Pebble-cobble gravel with trace to some sand and silt forming tailings piles. Well to poorly sorted. Surface smooth to irregular.

## *BEDROCK GEOLOGIC UNITS*

## SEDIMENTARY ROCKS

Kc

**CONGLOMERATE AND SANDSTONE (Late Cretaceous)** – Lithified conglomerate, sandstone, claystone, and poorly lithified gravel, sand, silt, and clay. Beds are rarely graded. Sandstones are typically medium grained. Conglomerates are clast-supported to matrix-supported, are poorly- to well-sorted, and include pebbles, cobbles, and rare boulders up to 50 cm in diameter. Subangular to rounded clasts of semischist, augen gneiss, volcanic rocks, vein quartz, chert, paragneiss, greenschist, and graphitic quartzite are hosted in either a pale-green clay-rich matrix or quartz-rich matrix. The field relationship between this conglomerate and the volcanic rocks (unit Kv) in the vicinity of VABM Lode suggests the conglomerate was deposited before the volcanic rocks, requiring this unit to be Late Cretaceous or older. The unit is up to 150 m thick. No direct contact was observed. Foster and Igarashi (1990) found pollen assemblages indicating that both Late Cretaceous and Miocene or younger sedimentary rocks comprise a belt extending westward from the westernmost exposure of unit Kc in the map area. Similar conglomerate in the Eagle A-1 and A-2 quadrangles (Szumigala and others, 2002; Werdon and others, 2001), elsewhere in the northern Tanacross Quadrangle, and to the east in Canada (Yukon Geological Survey, 2019) were likely deposited in Late Cretaceous or Miocene or later time based on pollen ages (Foster and Igarashi, 1990).

## VOLCANIC ROCKS

Qb

**PRINDLE VOLCANO BASANITE (Quaternary)** – Cinder cone deposits, flows, and dikes of basanite, trachy-andesite and alkali-basalt. The cinder cone at Prindle Volcano in the Tanacross C-2 Quadrangle consists of interlayered spatter and flow deposits, and a composite lava flow extends 8 miles (12.9 km) to the southeast from the vent site. Spatially limited flows and dikes of the same composition are locally present throughout the map area. Dark-gray, brown-weathering, vesicular flows contain abundant xenoliths of peridotite, tonalite, and metamorphic rocks. Mafic lavas are composed of aphanitic, weathered volcanic glass with about 7 percent phenocrysts, which include subhedral to anhedral olivine and 3 percent subhedral to euhedral pigeonite. Olivine phenocrysts form two distinct populations: one larger fraction (up to 2 mm in diameter), which is often resorbed on the rims, and one smaller (about 0.3 mm in diameter) anhedral fraction. Pigeonite crystals are up to 0.2 mm in diameter, with rare augite lamellae. Unit is magnetic, with magnetic susceptibility ranging from 1.7 to 18.4 x $10^{-3}$ Système International (SI). Cinder cone basanites yielded whole rock $^{40}Ar/^{39}Ar$ plateau ages of 200,000 ± 60,000 years, and additionally, an age of 176,000 ± 16,000 years using the (U-Th)/He method on zircons (Andronikov and Mukasa, 2010; Blondes and others, 2007).

Kv

**VOLCANIC FLOWS, DYKES, AND PLUGS (Late Cretaceous)** – Basaltic andesite and andesite with rare dacite to rhyolite flows; gray, pale green, to dark maroon or gray, weathers orange, tan, or brown. Flows are porphyritic, with aphanitic groundmass, and are autobrecciated at flow edges. Phenocryst size ranges from 0.01 to 7 mm. Mineralogy includes 10- to 30-percent plagioclase laths, 5 percent hornblende, 1 percent quartz, less than 1 percent biotite, some disseminated magnetite, and rare pyrite. Large crystalline hornblende phenocrysts (up to 8 mm in length) and partially clay-altered plagioclase laths (up to 2 cm in length) occur in a gray groundmass. Plagioclase phenocrysts are subhedral, up to 5 mm long, with polysynthetic twinning, some sericitization, and rounded and altered rims. Euhedral hornblende phenocrysts are smaller, 1 mm long on average, but up to 3 mm, with inclusions of opaques and quartz(?). Quartz phenocrysts are rare, subhedral, 2 mm long, and rounded and resorbed on the edges. Rare, medium-grained, subhedral biotite phenocrysts are elongate and often have resorbed edges. The groundmass is recrystallized to a mixture of fine-grained feldspar ± quartz and opaque minerals, with spheroidal chlorite. Weathering is fracture-controlled. The volcanic flows are generally thin, however in the vicinity of VABM Lode they reach a thickness of around 150 m. Magnetic susceptibility varies with alteration. In altered rocks it is as low as 0.1 x $10^{-3}$ SI, and in unaltered outcrops the magnetic susceptibility reaches 55 x $10^{-3}$ SI and averages 18–20 x $10^{-3}$ SI. A dacite whole rock analysis yielded an $^{40}Ar/^{39}Ar$ plateau age of 65.5 ± 0.4 Ma (Naibert and others, 2018) and zircons from andesite yielded a U-Pb crystallization age of 68.09 ± 0.94 Ma (Todd and others, 2019).

## INTRUSIVE ROCKS

Kpd

**PIKA DIORITE (Late Cretaceous)** – Dikes, plugs, and intrusions of diorite to granodiorite in general vicinity of the Pika and Fishhook prospects in the Tanacross D-1 Quadrangle (ARDF reference). Gray, tan, green-gray, or light brown, and weathers orange-tan. Texture is massive, porphyritic, seriate, or equigranular. Porphyritic phases consist of 5 to 30 percent plagioclase, 1 to 15 percent hornblende, and 2 to 10 percent biotite phenocrysts in a gray aphanitic groundmass. Hornblende phenocrysts are up to 8 mm long, and partially clay-altered plagioclase laths are up to 2 cm in length. Rare euhedral biotite is medium-grained. Equigranular to seriate phases consist of up to 85 percent plagioclase crystals between 0.5 and 5 mm in length, up to 20 percent quartz, up to 15 percent pyroxene, 5 to 14 percent biotite, about 2 percent hornblende, up to 5 percent magnetite, and rare epidote. Some propylitic alteration and chloritization is present. This unit is very magnetic – the average magnetic susceptibility is 20 x $10^{-3}$ SI, but it ranges between 2 and 45 x $10^{-3}$ SI. Biotite from diorite yielded $^{40}Ar/^{39}Ar$ plateau age of 66.3 ± 0.7 Ma (diorite) (Naibert and others, 2018) and two zircon U-Pb ages of 70.28 ± 0.46 (diorite) and 68.09 ± 0.94 Ma (porphyry) (Todd and others, 2019).

Ktgd

**TAURUS GRANODIORITE (Late Cretaceous)** – Dikes and intrusions of granodiorite, with lesser quartz monzonite, and porphyries of andesitic to dacitic composition located in the Taurus prospect area in the Tanacross C-1 Quadrangle. Gray, pinkish gray, pink-green, or pale green; weathers orange or pale brown. Outcrops are massive, jointed. Porphyritic phases have a grain size between 0.01 and 10 mm. Contains up to 75 percent feldspar, 15 percent hornblende phenocrysts, and up to 7 percent clinopyroxene in fine-grained or aphanitic matrix. Minor biotite and quartz are sometimes present, but generally do not exceed 1 percent. Feldspar and quartz look fresh, and are between 2 to 5 mm. Hornblende is chloritized, often has biotite cores, and ranges from 3 to 7 mm in length. Sulfides can be disseminated through the rock. In the porphyry end-member, groundmass forms up to 94 percent of the rock. This porphyry is locally altered to a sericite-tourmaline assemblage carrying elevated silver values (Wypych and others, 2017; 2018). Unaltered samples have high magnetic susceptibility values ranging from 0 to 52 x $10^{-3}$ SI, averaging 8 x $10^{-3}$ SI.

Kqp

**TAURUS QUARTZ-FELDSPAR PORPHYRY (Late Cretaceous)** – Dikes and small intrusive bodies of porphyry with trachy-andesite to monzodiorite composition, located in the Taurus prospect area in the Tanacross C-1 Quadrangle. Tan, pale gray to pale green, pale pink, jointed, porphyritic to equigranular, and have grain sizes between 0.01 and 8 mm. The porphyritic rocks are more common, and are composed of up to 75 percent feldspar, 20 percent quartz, and 8 percent biotite phenocrysts in an aphanitic matrix. Equigranular phases have up to 30 percent quartz, 20 percent biotite, up to 3 percent hornblende, and 75 percent feldspar. Both phases are highly altered with potassic as well as quartz-sericite-pyrite alteration, and cut by molybdenite-pyrite veins. Altered rocks have elevated gold and molybdenum (Wypych and others, 2017; Wypych and others, 2018) and low magnetic susceptibility averaging about 1 x $10^{-3}$ SI. The porphyry phase has been dated using U-Pb method to be 70.6 ± 09 Ma (Todd and others, 2019).

Kfg

**FRED GRANITOID (Cretaceous)** – Medium-grained, biotite-bearing granite to quartz-syenite occurring as small stocks in the vicinity of VABM Fred. Pink to gray, jointed, porphyritic to equigranular, and hypidiomorphic; grain size ranges from 1 to 6 mm. Mineralogy includes up to 45 percent euhedral potassium feldspar, up to 25 percent subhedral quartz, 20 to 25 percent plagioclase, and up to 15 percent biotite. Potassium feldspar phenocrysts are up to 6 mm in length and are hosted in a finer-grained matrix of plagioclase, quartz and biotite. Locally contains inclusions of metamorphic material and has similar trace-element lithogeochemistry as the volcanic rocks in the map area (unit Kv); therefore it is most likely of Late Cretaceous age. The magnetic susceptibility is very low, ranging from 0.05 to 0.21 x $10^{-3}$ SI.

Kg

**GRANITE (Cretaceous)** – Garnet-bearing granite and biotite-bearing granite stocks and intrusions, with aplite and pegmatite dikes of similar composition. Granite is tan, cream, or light gray to pale pink, seriate to equigranular, hypidiomorphic, with grain size between 0.1 and 35 mm. Typically the granite has up to up to 40 percent potassium feldspar, 30 percent plagioclase, 30 percent quartz, 3 percent white mica, 3 percent biotite, and locally 1 percent garnet. Locally altered to clay and chlorite, but is generally fresh with rare veins of pyrite. Weak foliation is locally observed, generally near intrusion edges.

Pegmatite dikes are similar in composition to the granite, with up to 50 mm, euhedral orthoclase and microcline crystals in a matrix of about 10-mm-diameter quartz and plagioclase. Thin books of biotite between 50- and 70-mm-long are found irregularly throughout the rock. Biotite is slightly chloritized on margins, and forms up to 5 percent of the rock.

Aplite dikes are light gray and equigranular, with grain sizes between 0.5 and 2 mm. Mineralogy is similar to larger granitic intrusions, and contain rare metamorphic xenoliths. Locally altered, with up to 1 percent disseminated pyrite, sparse quartz veinlets, sericite, and local tourmaline clots (up to 0.1 percent).

The granites, pegmatites, and aplites are characterized by low magnetic susceptibility, ranging between 0 and 1.5 and averaging 0.3 x $10^{-3}$ SI. Granite and pegmatite $^{40}Ar/^{39}Ar$ ages in the map area range from 105 to 110 Ma (Naibert and others, 2018). On the eastern edge of the Tanacross D-1 Quadrangle, the granite extends into Yukon, Canada, where it is mapped as the 110-109 Ma Crag Mountain pluton, part of the Whitehorse Plutonic Suite (Yukon Geological Survey, 2019). The granite has similar age and composition to other granites in the Yukon, such as the Dawson Range batholith, the Coffee Creek granite, and the Moosehorn Range granitoids (Allan and others, 2013).

Ktp

**TIMBER GRANITOID (Cretaceous)** – Biotite-bearing granite or granitoid intrusion forming the bulk of Timber Mountain in the Tanacross C-1 Quadrangle. Gray to dark gray, and weathers tan, pink or gray. Massive, equigranular to porphyritic, and hypidiomorphic; grain size ranges from 0.2 to 15 mm. Composed of 45 to 70 percent feldspar, 20 to 40 percent quartz, up to 15 percent biotite, and up to 10 percent muscovite. Fine-grained equigranular phases are found on the edges of the intrusion, whereas porphyritic and medium-grained equigranular phases are typically observed towards the center. Porphyritic phases have up to 10 percent, 15-mm-long feldspar phenocrysts in a fine-grained quartz-feldspar-biotite matrix. The fine-grained equigranular phase is composed of near equal amounts of quartz, potassium feldspar, and plagioclase, with 2 percent biotite and 1 percent muscovite. The intrusion is weathered, chloritized, and partially replaced by opaque minerals, biotite, and slightly sericitized plagioclase. The medium-grained equigranular phases generally are unaltered. In both equigranular phases, quartz is anhedral, interstitial, and generally inclusion free. Potassium feldspar is anhedral to euhedral, with no twinning or microcline twinning, faint zonation, and rare perthitic exsolution textures. Plagioclase is subhedral to euhedral, with clear polysynthetic twinning, slight sericitization, and myrmekite exsolution textures. The pluton is non-magnetic, with magnetic susceptibility ranging from 0.006 to 0.564 x $10^{-3}$ SI. Biotite fron this pluton yielded a K-Ar age of 108 Ma (Foster and others, 1976).

TRwp

**WITHERSPOON FELDSPAR PORPHYRY (Late Triassic)** – Syenogranite to diorite dikes, plugs, and intrusions, which are chemically similar to magnetic volcanic rocks (Kv) located southwest of VABM Witherspoon. Green, dark green, dark gray, or pink-gray, and weathers to maroon. Typically porphyritic, with phenocrysts ranging from 0.1 to 15 mm. Composed of up to 72 percent feldspar, about 30 percent amphibole, 20 percent quartz, and 10- to 25-percent biotite, with disseminated iron oxides. Abundant feldspar phenocrysts, up to 15 mm long, occur in a dark green groundmass with extensive secondary chlorite and some epidote replacement of plagioclase. Possible weak magmatic or metamorphic fabric and chloritic alteration was observed locally. The unit is non-magnetic to weakly magnetic, with magnetic susceptibility ranging from 0.089 to 0.528 x $10^{-3}$ SI.

## *METAMORPHIC ROCKS*

TRPzum

**SERPENTINIZED ULTRAMAFIC ROCKS (Paleozoic to Triassic)** – Fine-grained serpentinite with relict olivine locally. Occurs along the thrust-fault between Nasina and Fortymile

River assemblages. As described by Flynn (2003), unit is typically green to dark gray, unfoliated, and weathers orange-brown. Typically consists of a matrix of fine-grained serpentine, up to 20 percent relict olivine, and 5 to 10 percent magnetite, with magnesite veining. Serpentine is antigorite, with scarce chrysotile near contacts. Locally altered to coarse-grained chlorite rock. Ultramafic rocks appear to be serpentinized dunite metamorphosed to greenschist facies. Magnetic susceptibility of the serpentinized ultramafic rocks generally is very high, typically 10 to 60 x $10^{-3}$ SI. Waxy massive serpentinite with relatively low magnetic susceptibility, between 0.1 and 1 x $10^{-3}$ SI, is present near some contacts. This unit is a continuation of the greenschist-facies serpentinite (unit MzPzs) mapped in the southeastern Eagle A-1 Quadrangle (Szumigala and others, 2002) and across the border in Yukon (Yukon Geological Survey, 2019); both maps correlate these rocks to the Seventymile terrane (Slide Mountain terrane of Yukon). At Clinton Creek, Yukon, these mafic and ultramafic rocks are interlayered with sedimentary rocks that yielded a Triassic conodont age (Abbott, 1983), likely the minimum age for this unit. The maximum age may be constrained by the opening of the Seventymile/Slide Mountain ocean in the Devonian to Mississippian (Dusel-Bacon and others, 2006).

## NASINA ASSEMBLAGE

The Nasina assemblage is a greenschist- to amphibolite-facies metasedimentary package thrust over the Fortymile River assemblage. Szumigala and others (2002) report local biotite, kyanite, and pyrophyllite, implying the rocks have been metamorphosed to upper greenschist facies. Felsic lithologies interlayered within this unit have yielded zircon U-Pb ages from 349 to 359 Ma (Dusel-Bacon and others, 2006), and 348.2 Ma (Yukon Geological Survey, 2019). Mapping and unit descriptions for the Nasina assemblage in the northeastern portion of this map are adapted from Flynn (2003).

MDsqc

**CARBONACEOUS SCHIST AND QUARTZITE (Devonian to Mississippian)** – Fine-grained, carbonaceous metasedimentary rocks. Predominantly dark-gray, carbonaceous white mica-quartz schist and quartzite, graphite-quartz schist, and banded gray and massive light gray quartzite. Thin layers of white mica-quartz schist are locally interlayered on a scale of millimeters to centimeters in the carbonaceous schist and quartzite. Carbonaceous quartz schist and quartzite grades into biotite-quartz schist ± carbonaceous material and quartzite ± white mica in numerous areas. Biotite-feldspar-quartz schist ± actinolite ± white mica and white mica-feldspar-quartz metafelsite ± biotite are present in a few locations. The carbonaceous quartz schist is locally calcareous, with rare, small areas of marble rubble. Foliation is locally crenulated and mylonitic textures are present in some areas. Magnetic susceptibility of the unit is low, ranging from 0.01 to 0.15 x $10^{-3}$ SI. Interpreted to be part of the Nasina assemblage and is correlative with carbonaceous units to the north (MDq and MDkq) in the Eagle A-1 and A-2 quadrangles (Szumigala and others, 2002; Werdon and others, 2001) and with carbonaceous metasediments in the Finlayson assemblage (DMf3) in the Yukon (Yukon Geological Survey, 2019).

Pzgs

**GNEISS AND SCHIST (Paleozoic)** – Heterogeneous unit characterized by fine- to medium-grained gneiss and schist. Lithologies include biotite-muscovite-quartz schist ± feldspar, quartz-albite-epidote-hornblende gneiss ± biotite ± feldspar ± chlorite, biotite-quartz-epidote-hornblende schist, biotite-quartz-feldspar gneiss ± muscovite ± garnet, and muscovite-feldspar-quartz gneiss ± biotite ± sparse garnet. Some outcrops of gneiss and schist are intensely deformed, with complex folding. Magnetic susceptibility of felsic lithologies are low, ranging between 0.05 and 0.2 x $10^{-3}$ SI. Magnetic susceptibility of lithologies with a substantial mafic component typically is moderate, ranging between 0.15 and 0.7 x $10^{-3}$ SI, with sporadic higher values.

## FORTYMILE RIVER ASSEMBLAGE

The Fortymile River assemblage comprises a heterogeneous group of amphibolite-grade metamorphic lithologies composed mainly of metasedimentary rocks (quartzite, semischist, schist, and paragneiss), which are interlayered with amphibolite and lesser orthogneiss. Regionally, the age of this assemblage is constrained by datable interlayered lithologies. Orthogneiss, interpreted as having a volcanic protolith, yielded zircon U-Pb ages of 355 to 341 Ma (Dusel-Bacon and others, 2006). Other felsic orthogneiss layers yielded Permian zircon U-Pb ages and apparently represent later intrusions (Jones and others, 2017a). The thick marble layer located west of the map area at the headwaters of Alder Creek in the Tanacross D-2 Quadrangle yielded a mid-Mississippian to early Permian conodont age (Dusel-Bacon and Harris, 2003). This assemblage is a part of the Yukon-Tanana Terrane as defined by Dusel-Bacon and others (2006) and is correlative to Finlayson assemblage of Colpron and others (2006) in Canada. The boundary between the allochthonous Fortymile River assemblage and the parautochthonous Lake George assemblage is a regionally significant low-angle structure accommodating both contractional and subsequent extensional displacements (Dusel-Bacon and others, 2015). The Fortymile River assemblage is characterized by Triassic to Jurassic Ar-Ar cooling ages, whereas all the cooling ages observed in Lake George are late Aptian to Albian (Dusel-Bacon and others, 2002; Jones and others, 2017a; Jones and others, 2017b; Naibert and others, 2018).

MDfa

**FORTYMILE AMPHIBOLITE (Devonian to Mississippian)** – Amphibolite and amphibole gneiss; pale- to dark-green to gray-green amphibolite, commonly with light peach-white bands, weathering brown, with foliated or gneissic texture. Foliation is defined by aligned amphibole, biotite, and/or chlorite. Amphibole and garnet locally form porphyroblasts. Grain size ranges from 0.05 to 40 mm. Amphibolites are interlayered with subordinate amphibole-bearing gneiss, orthogneiss, quartz schist, and dark-gray quartzite on decimeter to multi-meter scales. Layers contain 10 to 98 percent amphibole, 5 to 60 percent feldspar, 0.1 to 25 percent biotite, 0.05 to 5 percent garnet, 1 to 38 percent carbonate, up to 88 percent chlorite, 3 to 85 percent quartz, 3 to 80 percent sericite, up to 5 percent magnetite, up to 2 percent graphite, 0.05 to 2 percent sulfides, and 1 to 5 percent epidote. Amphibole is dominantly euhedral with grains ranging up to 40 mm in length; less commonly acicular. Hornblende is the dominant amphibole, but actinolite is locally present. Disseminated sulfides (pyrite and pyrrhotite) up to 5 mm in diameter were observed in some outcrops. Quartzofeldspathic augen up to 15 mm in diameter and rare quartz phenocrysts or xenocrysts were also observed. Plagioclase is generally interstitial. Magnetic susceptibility varies widely, and depends on how mafic the amphibolite is and its magnetite content. Magnetic susceptibility measurements are generally low, ranging between 0.04 and 36.6 x $10^{-3}$ SI, with an average of 0.52 x $10^{-3}$ SI. Amphibolite bodies are thin, up to 30 m, with one exception of a 70-m-thick body. Amphibolites have predominantly volcanic arc trace-element-indicated signatures, with some within-plate signatures (Dusel-Bacon and others, 2009; Wypych and others, 2016). Similar amphibolites have been divided into three different units by Werdon and others (2001); amphibole-feldspar gneiss (pMaf), amphibolite and gneiss (pMa), and amphibolite (pMam). Similar amphibolites were divided into four units by Szumigala and others (2002); amphibolite and gneiss (pMag), amphibolite, gneiss, and schist (pMa), amphibolite (pMam), and amphibolite, paragneiss, and schist (Pza). Similar rocks have been combined with intermediate and mafic metavolcanic rocks into the Finlayson assemblage unit DMf1 by the Yukon Geological Survey (2019).

MDfo

**FORTYMILE ORTHOGNEISS (Devonian to Mississippian)** – Primarily orthogneiss with subordinate interlayered amphibolite and paragneiss. Outcrops are weakly to moderately foliated, grain size ranges from 0.1 to 15 mm, and feldspar augen are rare. Orthogneiss chemistry suggests protoliths range from intermediate to felsic granitoids. Unit contains 30- to 80-percent plagioclase feldspar, up to 30 percent potassium feldspar, 20 to 55 percent quartz, up to 45 percent hornblende, 3 to 25 percent biotite, 1 to 12 percent muscovite, 5 to 40 percent chlorite, and up to 5 percent garnet; interstitial calcite occurs locally. Accessory minerals include epidote, hematite, magnetite, and pyrite. Petrography shows weak to moderate foliation defined by muscovite and biotite; strong S-C fabric. Magnetic susceptibility measurements were generally low, ranging between 0.04 and 10.5 x $10^{-3}$ SI, with an average of 0.18 x $10^{-3}$ SI. In the Eagle A-1 Quadrangle, this unit is split into tonalitic orthogneiss (Motn), felsic orthogneiss (Mog), and undifferentiated orthogneiss (Mo) (Szumigala and others, 2002). Trondhjemitic orthogneiss (Motr) was also mapped in the Eagle A-1 Quadrangle and was observed in the Tanacross Quadrangle at multiple localities, mainly as dikes, which were not spatially extensive enough to map. Orthogneiss interlayered with metasedimentary units and amphibolites may have originated as sills or depositionally-interlayered volcanic rocks. Undifferentiated orthogneiss in the Eagle A-1 Quadrangle has been dated by the 206Pb/238U method on 13 zircon grains at 343 ± 4 Ma (Day and others, 2002).

MDfmb

**FORTYMILE MARBLE (Devonian to Mississippian)** – White to gray, medium- to very coarse-grained, crystalline calcite marble. Marble is locally dolomitic and epidote-bearing, has quartzose layers, and is sparsely micaceous (Flynn, 2003). Magnetic susceptibility of this unit is very low, generally 0.1 x $10^{-3}$ SI or lower. Forms beds within metasedimentary and orthogneiss packages of Fortymile River assemblage. The unit is correlated with the marble and calcareous rocks unit (pMm) mapped in the Eagle A-1 and A-2 quadrangles (Szumigala and others, 2002; Werdon and others, 2001) and the Finlayson assemblage marble unit (DMf5) on the Yukon bedrock geologic map (Yukon Geological Survey, 2019). The age range of this unit is inferred from regional zircon data (Jones and others, 2017b) and interlayered felsic metavolcanic rocks (orthogneiss) dated by U-Pb zircon methods (Day and others, 2002), although conodont evidence suggests the unit could be as young as early Early Permian (Dusel-Bacon and Harris, 2003).

MDfms

**UNDIVIDED METASEDIMENTARY ROCKS OF FORTYMILE RIVER ASSEMBLAGE (Devonian to Mississippian)** – Heterogeneous unit consisting of interlayered schist, quartz schist, semischist, quartzite, and paragneiss, with subordinate greenschist and carbonate-silicate schist. Marble, impure marble of unit MDfmb, and graphitic quartzite layers are present locally. The marble and impure marble were mapped as Fortymile Marble (MDfmb) where possible. Schist, quartz schist, and semischist contain 3- to 75-percent muscovite, up to 30 percent biotite, up to 85 percent quartz, up to 15 percent feldspar, and up to 35 percent garnet. Garnet porphyroblasts are typically 1- to 3-mm in diameter and rarely up to 5 mm. Schistosity is defined by muscovite and fine-grained quartz, chloritized biotite, and garnet porphyroblasts, which are commonly altered to biotite or chlorite along fractures and along grain edges. Feldspars are commonly altered to sericite. Paragneisses have similar mineralogy, with higher feldspar content (up to 60 percent) and less muscovite. Gneissic foliation is defined by quartz- and feldspar-rich bands separating quartz- and mica-rich bands. Gneissic foliation varies from weakly to strongly foliated. Quartzite contains 85- to 99-percent quartz, with anhedral crystals 0.05 to 1 mm in diameter. Quartzite foliation is defined by elongate quartz grains and 1 to 15 percent micas, dominantly muscovite with minor chloritized biotite. Accessory minerals include epidote/clinozoisite and graphite. Strong S-C fabric, multiple foliation orientations, and small-scale folding indicate the unit has undergone multiple deformation events. The unit contains relatively thin (less than 10-m-thick) interlayered amphibolite, and is cut by thin, up to 0.5-m-thick trondhjemitic orthogneiss dikes and sills as well as unmetamorphosed to weakly metamorphosed diorite, granite, granodiorite and pegmatite dikes. A wide range of magnetic susceptibility measurements were observed between 0.02 and 46.9 x $10^{-3}$ SI, with a average of 0.16 x $10^{-3}$ SI. Metasedimentary unit is estimated to be more than 600 m thick. Szumigala and others (2002) and Werdon and others (2001) divide this unit into quartzite (pMq) and quartzite, paragneiss and schist (pMqgs) units. The Yukon bedrock geologic map describes a similar unit as Finlayson assemblage felsic metavolcanics and quartz-muscovite schist (DMf2) (Yukon Geological Survey, 2019).

MDfp

**FORTYMILE PARAGNEISS (Devonian to Mississippian)** – Paragneiss with subordinate interlayered amphibolite, orthogneiss, and thin marble. Grain size ranges from 0.05 to 15 mm with moderate to strong foliation. Paragneiss contains 30 to 88 percent quartz, 1 to 20 percent biotite, 5 to 15 percent chlorite, 20 to 55 percent feldspar, 2 to 10 percent muscovite, 5 to 20 percent calcite, up to 1 percent garnet, minor hornblende, and trace magnetite. A couple samples in the vicinity of the detachment have been highly altered, with up to 55 percent sericite in one of the samples; up to 1.5 percent pyrrhotite was observed near this sericite-altered sample. Magnetic susceptibility measurements are generally low, ranging between 0.04 and 11.1 x $10^{-3}$ SI, with a average of 0.30 x $10^{-3}$ SI. This unit is relatively uncommon in the map area, and is less than 150 m thick. Similar units have been described in the Eagle A-1 and A-2 quadrangles (Szumigala and others, 2002; Werdon and others, 2001) as schist and paragneiss (pMsg) and gneiss (pMg).

## LAKE GEORGE ASSEMBLAGE

The Lake George assemblage represents the parautochthonous North America (pNA) in the map area and is dominated by augen gneiss (Mdag) and orthogneiss (MDlo, MDlom). Orthogneiss forms tabular bodies intruding or interlayered with homogeneous metasedimentary (predominantly quartzite and semischist) rocks with occasional amphibolite layers and bodies. The metasedimentary and orthogneiss package is further intruded by augen gneiss of plutonic origin (unit Mdag). The assemblage is metamorphosed to amphibolite grade. Lake George metasedimentary units yield Cambrian and older detrital zircon populations (Dusel-Bacon and others, 2017; Murphy and others, 2009), however interlayered metatuff from White River formation (a part of pNA) has yielded a zircon age of 363 Ma (Murphy and others, 2009), and metavolcanic rocks interlayered within the metasedimentary units of Butte assemblage (part of pNA) yielded zircon ages from 372 to 353 Ma (Dusel-Bacon and others, 2017). Here we follow the age definition for pNA defined by Murphy and others (2009) and Dusel-Bacon and others (2017) and ascribe a Devonian to Mississippian age to the Lake George assemblage.

Mdag

**DIVIDE MOUNTAIN AUGEN GNEISS (Mississippian)** – Granite and locally granodiorite orthogneiss with prominent potassium feldspar augens up to 10 cm long. Pale cream, pale gray, and pale pink, and weathers pink-gray. The meta-intrusion is porphyroclastic and coarse-grained (up to 70-mm-long augen) near the center, and finer-grained and sheared toward the edges. The unit consists of up to 70 percent feldspar, with up to 40 percent potassium feldspar augen, 20 to 40 percent quartz, up to 10 percent plagioclase porphyroclasts, about 10 percent mica (biotite, muscovite, or both), and locally trace tourmaline. Locally, in the vicinity of Cretaceous intrusions, the augen gneiss is highly altered, sericitized, and brecciated. Anhedral feldspar crystals are about 0.5 mm long, often recrystallized, with no twinning. Sericitization was observed in some samples. Plagioclase is anhedral, with clear polysynthetic twinning, and some samples preserve myrmekite textures. Anhedral quartz up to 0.5 mm in diameter has slight to strong undulatory extinction and forms about 1-mm-thick quartzose layers. The felsic layers are parted by thin muscovite and biotite layers. Biotite often has inclusions of opaque minerals and in some instances about 10 percent of biotite crystals are chloritized. Augen vary in size, from as small as a few millimeters up to 10 cm in length. The stretching of the augen seems dependent on the location within the body; more stretching and shearing is observed near the edges. This results in preserving original igneous textures in some areas away from contacts. The non-stretched or weakly stretched feldspars are subhedral, twinned, and are often rotated. Recrystallized augen usually have no twinning preserved. Samples have accessory relict garnet, zircon, and opaque minerals. The unit is locally altered to chlorite, tourmaline, and sericite. The rocks are often cut by quartz veins (up to 20-cm thick) and pegmatite dikes. The augen gneisses are the main unit observed for the Lake George assemblage, and are characteristically non-magnetic to weakly magnetic, ranging from 0.03 to 0.2 x $10^{-3}$ SI. One augen gneiss yielded an U-Pb zircon crystallization age of 354.97 ± 4.51 Ma (Todd and others, 2019). The augen gneiss can be correlated with the Lake George orthogneiss along the Alaska Highway (Solie and others, in press).

MDlo

**LAKE GEORGE ORTHOGNEISS (Devonian to Mississippian)** – Orthogneiss with diorite to granite composition occurring as tabular bodies interlayered with minor quartzite, paragneiss, amphibolite, and schist. Black and white in color, weathering gray to orange, foliated, with grain size ranging from 0.5 to 7 mm. Mineral composition varies: includes up to 5 percent quartz in dioritic orthogneiss to 60 percent in granitic varieties, 85 and 15 percent feldspar, respectively, and between 15 and 20 percent biotite, up to 9 percent white mica, and up to 1 percent garnet. Accessory minerals include zircon, fluorite, epidote, and chlorite. Quartz crystals are subhedral to anhedral with undulatory extinction and grain size ranges from 0.1 to 2 mm. Anhedral to subhedral feldspars include plagioclase and microcline, which are largely recrystallized, have no twinning, range in size from 0.5 to 2 mm, and are commonly replaced by sericite (up to 50 percent replacement). Biotite is up to 2-mm long with birds-eye extinction and rare chloritization along edges. Weak foliation is defined by biotite and fine-grained muscovite in irregular sub-mm-thick mica bands. Bodies are non-magnetic with measured susceptibilities between 0.01 and 0.2 x $10^{-3}$ SI. The tabular bodies vary in thickness from 30 cm to about 300 m. This unit differs from augen orthogneiss (Mdag) in: 1) lack of large potassium feldspar augen, 2) greater compositional range, and 3) greater heterogeneity and interlayering with metasedimentary rocks. A granite orthogneiss sample yielded a U-Pb zircon crystallization age of 370.64 ± 9.61 Ma (Todd and others, 2019). This unit is included in undifferentiated orthogneiss (unit MDlo) of Solie and others (in press).

MDlom

**LAKE GEORGE ORTHOGNEISS, MAGNETIC (Devonian to Mississippian)** – Magnetite-bearing felsic orthogneiss. Light pink, foliated, with grain size between 0.1 and 3 mm. Mineralogy includes 20 percent euhedral biotite, 55 percent anhedral feldspar, 25 percent anhedral quartz, and 1 percent magnetite. Foliation planes are defined by biotite. This unit is no more than 30-m thick and it is observed north of Fishhook Bend in the Tanacross D-1 Quadrangle. Magnetic susceptibility ranges between 6 and 15 x $10^{-3}$ SI.

MDla

**LAKE GEORGE AMPHIBOLITE (Devonian to Mississippian)** – Amphibolite to amphibole-bearing gneiss located south of North Ladue River near Alaska-Canada border. Dark green to gray, weathering brown, foliated, gneissic, and have grain sizes of 1 to 3 mm. Mineral composition includes 55 to 85 percent amphibole, between 4 and 50 percent plagioclase, up to 3 percent biotite, and rare quartz is present locally. A sample has 5 percent quartz, one sample is chloritized to about 48 percent, and two samples have 55 and 95 percent clinopyroxene. Minerals are generally fresh with strong lineation defined by amphibole. Veins cutting the unit are 1- to 7-mm thick and contain feldspar and quartz. The magnetic susceptibility has a relatively narrow range of 0.25 to 0.49 x $10^{-3}$ SI. Amphibolite is characterized by a strong within-plate geochemical signature, but volcanic arc trace-element-indicated signatures are present as well. This amphibolite is correlated with Lake George assemblage amphibolite (pMa) from the Alaska Highway Corridor (Solie and others, in press).

MDlau

**AMPHIBOLITE AND SERPENTINITE (Devonian to Mississippian)** – Amphibolite, amphibole orthogneiss, serpentinite, and clinopyroxenite occurring within Lake George assemblage north of McElfish Creek in the Tanacross C-2 Quadrangle. These units occur together and comprise several, approximately 300-m-thick, tabular bodies that trend east-west and dip 60 to 80 degrees to the north. All lithologies are black to dark green and weather orange, brown, or black. The rocks are foliated, with grain size ranging from 0.2 to 40 mm. Amphibolite and amphibole orthogneiss are composed of 40 to 95 percent tabular hornblende, 4 to 50 percent plagioclase, 1 to 10 percent biotite, and rare samples have up to 40 percent quartz and 0.3 percent pyrite clots. The hornblende (up to 30 mm long) often have actinolite on their rims. Rare clinopyroxenite has 55 percent euhedral clinopyroxene, 43 percent feldspar, and 2 percent epidote. Clinopyroxenite is moderately foliated with no appreciable compositional banding. Pyroxene crystals are vitreous, euhedral, and preferentially oriented; interstitial space is filled with granular feldspar. Thin feldspathic veinlets run parallel to foliation and have an epidote alteration rind approximately 3- to 6- mm wide. Serpentinite is porphyroblastic, with weak to no foliation, and is composed of 30 to 75 percent serpentine, up to 60 percent hornblende, up to 40 percent tremolite and anthophyllite, up to 20 percent olivine, and 5 percent vein-filling magnetite. Talc and relict orthopyroxene were observed in thin section. The serpentine and talc creates a groundmass for relict olivine, orthopyroxene, and up to 40-mm-long acicular hornblende. This mineralogy is consistent with amphibolite-facies regional metamorphism. The serpentinites are highly magnetic, with magnetic susceptibilities ranging from 16 to 138 x $10^{-3}$ SI with mean of about 30 x $10^{-3}$ SI, whereas the amphibolites have a mean of about 8 x $10^{-3}$ SI. The amphibolites have a primitive mid ocean ridge basalt trace-element-indicated chemical composition. Occurring together, the amphibolite and serpentinite appear to be the metamorphosed equivalent of differentiated serpentinites. The age of this unit is constrained to pre-Jurassic by its involvement in regional metamorphism. This unit could be correlated to Paleozoic ultramafic rocks of the Seventymile or Slide Mountain terranes (for example, units MzPzs and MzPzmg of Szumigala and others, 2002); however, there is no evidence of thrust fault emplacement that would be required under this correlation.

MDlms

**METASEDIMENTARY ROCKS OF THE LAKE GEORGE ASSEMBLAGE (Devonian to Mississippian)** – Quartzite, semischist, and schist with subordinate paragneiss, marble, amphibole-bearing gneiss, and mafic metavolcanic rocks. Quartzites are gray, pale green, and locally weather brown to orange. Quartzite is weakly foliated with grain size ranging from 0.01 to 3 mm, and is composed of up to 96 percent anhedral quartz parted by single-crystal layers of white mica (up to 14 percent) and/or biotite (up to 10 percent). Some quartzite contains up to 1 percent garnet porphyroblasts, reaching 3-mm in diameter. Schist and semischist are pale gray, silver, silver-pink and white, weathering tan to orange with local iron staining. Schist and semischist are foliated, lineated, and often porphyroblastic, with grain size ranging from 0.05 to 18 mm. Felsic layers in the schist and semischist are composed of 0.5- to 1-mm-diameter quartz (20 and 85 percent), and 0.5- to 1-mm-diameter feldspar (2 to 40 percent), parted by sub-millimeter-thick mica layers (up to 40 percent) with chlorite replacing biotite, and rare graphite. Samples have 0.5 to 4 percent euhedral porphyroblasts of garnet, up to 18-mm in diameter. Subordinate paragneiss is the most common minor lithology; it has a nearly identical mineral composition to the semischist and schist but differs in texture, exhibiting gneissic banding and a generally coarser grain size. Rare amphibole-bearing gneisses and mafic metavolcanic rocks are characterized by up to 40 percent amphibole, 15 percent chlorite, up to 20 percent feldspar, and up to 15 percent quartz. A couple of foliation-parallel beds of marble have been described near the detachment separating the unit from the Fortymile River assemblage to the north in the Tanacross D-1 Quadrangle. Marbles are tan to gray, granoblastic, and have grain size ranging from 1 to 2 mm. Interlayered marbles are 93 percent calcite, 5 percent quartz, 1 percent muscovite, and 1 percent biotite. Metasedimentary lithologies of this unit have low magnetic susceptibility ranging between 0.01 and 1.84 x $10^{-3}$ SI, averaging about 0.4 x $10^{-3}$ SI. The amphibole-rich layers however can reach up to 28.8 x $10^{-3}$ SI. This unit is more than 300 m thick and can be correlated with the Scottie Creek Formation in Canada (Yukon Geologic Survey, year), and paragneiss and schist, quartzite and felsic schist and quartzite of Lake George assemblage in Alaska (Solie and others, in press).

MDlp

**LAKE GEORGE PARAGNEISS (Devonian to Mississippian)** – Paragneiss interlayered with subordinate orthogneiss, quartzite, semischist, schist, and amphibolite. Unit is intruded by augen gneiss (Mdag) as well as Cretaceous granitoids, pegmatite and aplite dikes, and Late Cretaceous porphyry intrusions (Kg, Kfg, Kv and Ktgd). Paragneiss is predominantly black and white or tan to dark gray, weathering orange to gray. Paragneiss is foliated with gneissic textures, and grain sizes ranging from 0.1 to 8 mm. Composed of 30 to 70 percent quartz, 10 to 70 percent feldspar, 2 to 35 percent biotite, 1 to 15 percent white mica, and up to 5 percent garnet as porphyroblasts, with local tourmaline-rich layers. Alternating 0.25 to 7.5 centimeter bands consist of white-tan quartzofeldspathic bands and dark biotite-dominant bands. Garnetiferous bands seem to be concentrated in zones of highest ductile deformation. Interlayered lithologies are of similar composition as those described for Lake George metasedimentary unit (MDlms). This unit is over 300 m thick, and characterized by low magnetic susceptibility between 0.06 and 0.47 x $10^{-3}$ SI with a mean of 0.15 x $10^{-3}$ SI. Correlated with the Scottie Creek Formation in Canada (Yukon Geological Survey, 2019) and with paragneiss and schist, quartzite and felsic schist and quartzite of Lake George assemblage in Alaska (Solie and others, in press).

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