Preliminary Interpretive Report 2017-3

EXPLANATION OF MAP UNITS: GEOLOGIC MAP OF THE TOK RIVER AREA, TANACROSS A-5 AND A-6 QUADRANGLES, EASTERN ALASKA RANGE, ALASKA (1:63,360 SCALE)

Karri R. Sicard, Travis J. Naibert, Trent D. Hubbard, Evan Twelker, Alicja Wypych, Melanie B. Werdon, Amanda L. Willingham, Robert J. Gillis, Lauren L. Lande, and Rainer J. Newberry

DGGS Geologists Evan Twelker (left) and Mandy Willingham (right) interpret folding within the metamorphic units of the Tok River map area. Photo by Alicja Wypych.

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State of Alaska
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DESCRIPTION OF SURFICIAL-GEOLOGIC MAP UNITS

Map units are identified by the symbols described below. Symbols shown in parenthesis indicate combined map units consisting of bedrock overlain by thin or discontinuous surficial deposits. For example (Qgd1) indicates Qgd1 thinly or discontinuously covering bedrock.

UNCONSOLIDATED DEPOSITS

ALLUVIAL DEPOSITS

Qa **Undifferentiated Floodplain Alluvium**—Stratified, well-sorted to locally poorly-sorted, rounded to subangular, polymictic gravel, sand, and silt comprising stream channel and overbank deposits. Frequency and timing of deposition is uncertain. Vegetation consists of thick stands of willow and alder. Includes active, inactive, and abandoned floodplain deposits (Qaa, Qai, Qab) that cannot be differentiated at the scale of mapping.

Qaa **Active-Floodplain Alluvium**—Stratified, well-sorted to locally poorly-sorted, rounded to subangular polymictic gravel, sand, and silt comprising active stream channels, stream banks, point-bar deposits, and floodplains that are frequently inundated. Surfaces are unvegetated or have sparse open shrub vegetation that includes willow and low shrubs. Mapped extent is a function of river level (stage) and reflects the transitory extent of exposed river bars and channel locations at the time Spot 5 imagery (GINA, 2014) was collected and may change significantly as the active stream channel evolves.

Qab **Abandoned-Floodplain Alluvium**—Poorly-sorted to well-sorted rounded to subangular polymictic gravel, sand, and silt with cover of sandy silt to silty sand; surfaces are former active floodplains subject to inundation only during rare, high-magnitude floods; may include multiple surfaces at different levels; surfaces typically have numerous abandoned stream channels (Kreig and Reger, 1982) that are often at least partially infilled. Surfaces differentiated from inactive floodplains (Qai) by a slightly higher elevation above the modern floodplain (~1–3 meters), the presence of numerous infilled former stream channels, and a denser vegetative cover that includes willows, alders, and scattered to numerous spruce.

Qaf **Alluvial-Fan Deposits**—Locally-derived, fan-shaped deposits of stratified, well- to poorly-sorted gravel, sand, and silt with scattered cobbles and boulders. Clast size decreases and degree of sorting increases distally from the head of the fan. Deposits are common along the margins of larger valleys at the mouths of smaller streams and gullies, especially where there is a pronounced decrease in gradient as a tributary enters a larger stream. May be mixed with debris-flow deposits, particularly in fan apex zones. Transitional with mixed colluvial-alluvial deposits where fans have developed at the mouths of small streams.

Qai **Inactive-Floodplain Alluvium**—Poorly-sorted to well-sorted, rounded to subangular polymictic gravel, sand, and silt deposited by periodic stream flooding. Unit typically includes numerous interconnected, abandoned stream channels with surfaces at multiple levels. Vegetation, which includes willows and alders, is scattered to sparse on lower floodplain surfaces and denser on less frequently inundated, higher surfaces. Differentiated from abandoned floodplains (Qab) by the presence of fewer infilled abandoned channels, less-dense vegetative cover, and lower elevation above the modern floodplain (generally < 1 meter).

Qat **Alluvial-Terrace Deposits**—Poorly-sorted to well-sorted subangular polymictic gravel, coarse sand, and silt with a cover of organic silt to silty sand. Surfaces are no longer subject to inundation by the streams that deposited the alluvium and may include several levels (Kreig and Reger, 1982). Generally present more than ~5 meters above the modern stream. Differentiated from abandoned floodplain alluvium (Qab) by the presence of small rounded lakes, a general absence of visible abandoned channels, higher elevation above

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modern stream channels, and a denser cover of spruce with heights commonly > 50 meters. Weathered to depths up to 12 cm. May be frozen. Outwash alluvium may be incorporated in the highest terraces.

Qfb **Flood-Bar Deposits**—Clast- and sandy matrix-supported gravel interbedded with minor layers of crudely-bedded pebbly sand. Gravel units contain tabular clasts and are crudely bedded with thicknesses measured from 0.9 to 1.2 meters. Deposits occur beyond the modern floodplain of the Little Tok and Tok rivers and are interpreted to record jökulhlaup events originating from glacial Lake Ahtna in the northwest Copper River basin (Reger and others, *in press*). Gravels include diagnostic vesicular basalt, originating from the Wrangell Mountains (Holmes, 1965), and rare boulders emplaced by extraordinary, large-flood events. Differentiated from glacial outwash of Donnelly age by the presence of massive gravels identified at field localities.

COLLUVIAL DEPOSITS

Qc **Undifferentiated Colluvium**—Blankets, aprons, cones, and fans of heterogeneous, angular to subangular rock fragments, gravel, sand, and silt formed by complex, gravity-driven mass movements involving sliding, flowing, solifluction (or gelifluction where frozen), and frost creep of glaciogenic deposits and weathered bedrock. Deposits are commonly formed near rock glaciers, on bedrock slopes, and along lower valley walls. 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 colluvial and alluvial deposits (Qcf), rock glacier deposits (Qcg), and glacial deposits (Qgd1, Qgd2).

Qcf **Mixed Colluvium and Alluvium**—Massive to poorly-stratified sand and silt mixed with subangular to rounded pebble-cobble gravel and locally derived bedrock clasts, deposited where streams are not able to remove material faster than it is transported downslope by colluvial processes. Deposits are present as fan-shaped features at the mouths of gulleys and small streams and along lower walls and floors of narrow valleys. In stream bottoms vegetation commonly includes thick alders. May be complexly mixed with colluvial deposits (Qc) and older glacial deposits (Qgd1).

Qcg **Rock Glacier Deposits**—Tongue-shaped heterogeneous deposits of angular to subangular blocks of local bedrock, with trace to some gravel, sand, and silt at depth, and likely ice-cored in active rock glaciers. A thin (10- to 20-cm-thick) organic mat may be present on the surface. These deposits accumulate on valley floors and along lower walls of cirques and glaciated valleys by flow of rock debris derived from shrinking of former glaciers (ice cored) or from deposition, cementation, and deformation of precipitation-derived ground ice (ice cemented). Locally may include glacial drift of Holocene age.

Qcl **Landslide Deposits**—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, especially in older deposits. Recently active surfaces are typically irregular, steep, and unvegetated. Ground cracks may be present. May be complexly mixed with talus and undifferentiated colluvium (Qct, Qc).

Qct **Talus and Blockfield Deposits**—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. May be complexly mixed with rock glacier deposits (Qcg) and undifferentiated colluvium (Qc).

GLACIAL DEPOSITS

Qgd2 **Drift of Late Wisconsinan Age (25,000 TO 11,000 y.b.p.)**—Poorly- to well-sorted, subrounded to subangular pebble-cobble gravels in a matrix of sand and minor silt; locally includes moderately well-sorted sand and gravel. Primary glacial morphology is well preserved, except where deposits thinly cover bedrock or along steep valley slopes, where the deposits are modified by colluvial processes and complexly mixed with undifferentiated colluvium (Qc). Weathered to a depth of 12–20 cm. Gravel clasts may have silt caps, and scattered schistose clasts are rotten. Vegetation commonly includes dense spruce with willows and alders in downvalley areas, but in valley headwall areas and where bedrock is near the surface may consist of a thin moss mat.

Qgd1 **Drift of Early Wisconsinan AGE (75,000 to 40,000 y.b.p.)**—Poorly- to well-sorted, subrounded to subangular pebble-cobble gravels with scattered boulders in a matrix of sand and minor silt. Numerous clasts have a “rotten” appearance and silt caps are generally present. Primary glacial morphology is locally well preserved but is generally extensively modified by slope processes. Deposits may be discontinuous, especially on bedrock slopes and areas where deposits are thin, and surfaces are more weathered than on younger glacial deposits (Qgd2). Unit may be complexly mixed with colluvial (Qc) and colluvial-alluvial deposits (Qcf).

GLACIOFLUVIAL DEPOSITS

Qgf2 **Outwash Deposits of Late Wisconsinan Age**—Stratified, generally well-sorted to locally poorly-sorted, rounded to subangular polymictic pebble-cobble gravels with a matrix of silt and coarse sand deposited by glacial streams of latest Wisconsinan age. Deposits form terraces at multiple levels ~10–20 meters above the floodplain of modern streams. Surfaces can be traced upvalley to, and are sometimes inset into, drift deposits of the Late Wisconsinan glacial advance (Qgd2). Vegetation commonly includes tall (up to ~20 m) black spruce. May include flood bar deposits (Qfb) which are not easily differentiated without exposure or subsurface data.

GLACIOLACUSTRINE DEPOSITS

Qgl **Glacially Impounded Lake Deposits of Late Wisconsinan Age**—Well-sorted to locally poorly sorted, silt and sand. Deposits may be locally fine grained, with thermokarst lakes on the surface indicating scattered ice-rich permafrost. Deposits overlie and may be complexly mixed with sandy pebble-cobble gravel outwash deposits (Qgf2). In the map area, deposits were mapped in Dry Tok Creek drainage near its confluence with the Tok River. Although not identified at the scale of mapping, similar deposits may be present near the mouths of other drainages blocked by late Wisconsinan ice.

DESCRIPTION OF BEDROCK-GEOLOGIC MAP UNITS

North of Denali Fault

SEDIMENTARY ROCKS

Tc **Conglomerate (Tertiary?)**—Poorly consolidated, subangular to rounded pebble-cobble gravels. Clasts, up to 20 cm in diameter, include vein quartz, gray quartzite, sandstone, siltstone, tripolitic chert, and possible felsic volcanic rocks. Deposits are unconformably perched on top of metamorphic rocks, 1,200 to 2,000 feet above the Tok River valley in the northeastern Tanacross A-6 Quadrangle. Small isolated outcrops are 10- to 30-feet thick. Correlates with gravel and conglomerate (unit Tc) of Foster (1970).

VOLCANIC ROCKS

lKba **Basaltic Andesite to Andesite Flows (Late Cretaceous)**—Aphanitic to porphyritic, massive to vesicular, basaltic andesite to andesite lava flows with 5–20 percent lath-shaped plagioclase phenocrysts up to 10 mm in diameter, 2–5 percent pyroxene phenocrysts up to 0.5 mm in diameter, and <2 percent olivine, in a dark gray to brown groundmass of needle-shaped feldspar and glass. Locally contains lithic fragments and subrounded inclusions of older volcanic rocks of similar chemistry. Blocky, vesicular breccia and weathered, orange flaggy interbeds suggest multiple stacked flows. True thickness is unknown, although the unit spans 900 feet of elevation where it is exposed. A whole-rock sample yielded a $^{40}Ar/^{39}Ar$ plateau age of 71.7 ± 0.5 Ma (sample 15LF064; Benowitz and others, 2017). Magnetic susceptibility is high (0.67–13.73, averaging 6.40 x 10^{-3} Système International (SI)).

INTRUSIVE ROCKS

Basaltic Andesite to Andesite Dikes (Late Cretaceous? to Tertiary)—Dark-gray to brown, fine-grained, biotite-, orthopyroxene-, and clinopyroxene-porphyritic basaltic andesite to andesite dikes up to 10-m wide. Subophitic and hypidiomorphic, with 35 percent euhedral biotite, 25 percent 1-mm-diameter orthopyroxene, and 10 percent clinopyroxene interlocked with feldspar (30 percent of the rock). Biotite is slightly chloritized; feldspar is slightly sericitized. Contains small accessory opaque minerals (magnetite?). Dikes often have planar margins and crosscut metamorphic foliation, hence, intruded post-peak metamorphism. Dikes possibly correlate with basaltic andesite to andesite flows (lKba) based on geochemical similarities, but the correlation is uncertain due to the geographic distance separating the flows from the dikes. A biotite separate yielded a $^{40}Ar/^{39}Ar$ plateau age of 58.4 ± 0.2 Ma (sample 16KS215; Benowitz and others, 2017). Magnetic susceptibility is moderately high (0.23–1.70, averaging 0.716 x 10^{-3} SI).

lKgd **Granodiorite and Granodiorite Porphyry (Late Cretaceous)**—Fine- to medium-grained, crystalline Hona and Clearwater Creek plutons, with two major textural phases sharing similar geochemistry. Phaneritic granodiorite phase is hypidiomorphic, seriate to porphyritic, and contains ~10 percent 2-mm-diameter orthoclase phenocrysts, ~30 percent 0.5- to 1-mm-long plagioclase, ~30 percent interstitial potassium feldspar, ~15 percent interstitial quartz, ~15 percent biotite, and trace accessory zircon. Interstitial biotite is very fine-grained, often altered to chlorite, with occasional larger (~0.2-mm-diameter), fresh blades. Fine-grained biotite is often accompanied by small opaque minerals (pyrite?). Large, fractured potassium-feldspar phenocrysts remain euhedral with visible zonation and little to no alteration. Smaller potassium-feldspar crystals have sericite- and biotite-altered cores. The porphyritic granodiorite phase contains phenocrysts of ~10 percent rounded quartz, 15 percent euhedral potassium feldspar, ~20 percent euhedral to subhedral plagioclase, ~5 percent subhedral biotite, and ~5 percent euhedral to subhedral hornblende in a very fine-grained matrix of feldspar, quartz, and mafic minerals (45 percent of the rock). Felsic minerals tend to be larger (up to 25 mm in diameter), whereas mafic minerals range from 0.5–1 mm in diameter. Crystals are largely unaltered, and phenocrysts often have rounded edges. Rare hornblende is slightly chloritized; feldspar crystals are often sericitized. Rare magmatic breccias occur at the edges of the intrusion and are associated with different phases of emplacement. Dark colored, very fine-grained matrix comprises about 50 percent of the breccias. Clasts range from 2- to 20-cm in diameter.

Three ^{40}Ar/^{39}Ar ages were measured from this unit. A biotite separate yielded a plateau age of 73.1 ± 0.9 Ma (sample 15AW021) and two hornblende separates yielded a weighted-average age of 71.1 ± 0.5 Ma (sample 15ET031) and a plateau age of 75.8 ± 0.6 Ma (sample 15KS026), respectively, which, along with textural variations, suggests the possibility of multiple intrusions (Benowitz and others, 2017). Magnetic susceptibility ranges widely, but is often quite high (0.0–17.5, averaging 2.64 x 10^{-3} SI).

Trachyandesite Dikes (Late Cretaceous?)—Dikes appear altered at all sample localities in the field area; trachyandesite in composition based on immobile-element classification of Winchester and Floyd (1977). Porphyritic texture with a completely devitrified matrix. Phenocrysts are composed of 3 percent relict, up to 10-mm-long, amphibole phenocrysts, and 2 percent, structurally undeformed feldspar phenocrysts. Magmatic breccia and intermediate-felsic dikes associated with different phases of emplacement occur in the area surrounding lKgd intrusions. Magnetic susceptibility is low (0.04–0.14, averaging 0.09 x 10^{-3} SI).

METASEDIMENTARY AND METAIGNEOUS ROCKS

GREENSCHIST FACIES

Ꞧg **Metagabbro (Triassic?)**—Dark-green to dark-gray, fine- to coarse-grained metagabbro, amphibolite, pyroxenite, and hornblende gabbro sills ranging from less than 1 m to ~450 m thick; generally parallel or subparallel to foliation in host rocks. Thin metagabbro dikes are found proximal to larger sills. Metagabbros are foliated to porphyroblastic, with hornblende typically metamorphosed to actinolite (?) or other fibrous amphibole aligned with foliation; interstitial quartz and leucoxene replacing titanite are also present. Metamorphosed gabbro lacks relict pyroxene, and feldspars are completely replaced by clay minerals. The thickest sills commonly retain primary mineralogies in the center, but have varying degrees of metamorphic-mineral development near host rock contacts. These porphyritic to equigranular gabbro sills contain 40–60 percent primary pigeonite, clinopyroxene, and orthopyroxene, which are often overgrown by hornblende and chlorite; also present are about 40 percent twinned plagioclase, which is often completely replaced by white mica or chlorite, and up to 10 percent titanite. Unit correlates with gabbroic intrusions (unit Ꞧgb) of Dashevsky and others (2003), which were assigned a Middle Triassic age in the Delta mineral belt, and greenstone (unit Dg) of Richter (1976). Magnetic susceptibility is moderate, but can be much higher locally (0.01–70, averaging 0.9 x 10^{-3} SI). Higher magnetic susceptibility correlates with visible magnetite.

Metagabbro Dikes (Triassic?)—Thin, foliated dikes found proximal to geochemically indistinguishable, thick metagabbro sills (^g). Typical composition is about 35 percent medium-grained biotite, 30 percent medium-grained actinolite, 20 percent medium-grained quartz, 10 percent epidote, and 5 percent medium- to coarse-grained, subhedral porphyroblasts of clinozoisite (±epidote), with secondary, coarse-grained (2 to 5 mm), calcite in pods.

MDp **Phyllite, Metaconglomerate and Marble (Devonian to Mississippian?)**—Gray, bluish-purple-gray, and black phyllite with rare interbedded metasandstone and metaconglomerate, and minor interbedded impure marble. Phyllite is very fine-grained, with up to 5 percent rounded to subangular stretched quartz and other porphyroclasts (0.1 mm in diameter) and blades of graphite in a very fine-grained matrix of quartz, feldspar, and clay (?). Fine-grained white mica and graphite occur in separate layers. Up to 8 percent of the rock is fine-grained white mica and less than 30 percent is graphite, locally containing secondary ellipsoids of coarse-grained calcite comprising about 10 percent of the rock. Magnetic susceptibility is low to moderate (0.01–10.8, averaging 0.36 x 10^{-3} SI).

MDgs **Graphite-Bearing Quartz Schist with lesser Metavolcanic Schist (Devonian to Mississippian?)**—Metasedimentary quartzite, quartz schist, and quartz phyllite with significant (up to 10 percent) interbedded metavolcanic schist. Unit also contains graphitic schist and minor impure marble, calcareous schist and phyllite. Coarse-grained quartzite layers have up to 93 percent, ~0.1-mm-diameter quartz crystals interlayered with 1–10 percent white mica and less than 10 percent graphite. Quartzite locally also contains very small, accessory pyrite (?) and rotated, subangular to subrounded quartz porphyroblasts (0.3 mm in diameter; up to 30 percent of the rock). Phyllite contains about 4 percent fine-grained quartz porphyroclasts in very fine-grained quartz and feldspar (?) groundmass, with 10 percent very fine-grained recrystallized carbonate, 10 percent fine-grained white mica, and 2 percent graphite along partings. Fine-grained, schistose metavolcanic layers have dominantly basalt to basaltic andesite protoliths. Magnetic susceptibility is low (0–1.2, averaging 0.19 x 10^{-3} SI). Unit is characterized by high conductivity (Emond and others, 2015).

MDms **Mafic Metavolcanic Schist with Quartz Schist and Minor Felsic Metavolcanics (Devonian to Mississippian?)**—Light- to dark-green to dark-grey, mafic metavolcanic schist, with subordinate intermediate and felsic metavolcanic schist, minor interbedded quartzite, and quartz schist. Layers are continuous for several kilometers and pinch out or thin into less common metavolcanic beds farther west in unit MDgs. Magnetic susceptibilities are low to moderate (0.01–0.94, averaging 0.39 x 10^{-3}SI). Unit is characterized by high conductivity (Emond and others, 2015).

MDcs **Quartzite and Quartz Schist with Calcareous Schist and Marble (Devonian to Mississippian?)**—Quartzite and quartz schist with significant interbedded impure marble and calcareous schist (about 23 percent of unit). Marble and calcareous schist layers range in thickness from 0.1–20 meters and are often intensely folded. Thicker layers are laterally continuous up to several kilometers; thinner beds are discontinuous. Unit also includes impure dolomite, graphitic schist, and minor mafic to felsic metavolcanic rocks, and is characterized by moderate conductivity (Emond and others, 2015). Where quartzite grades into semischist, it is dominantly schistose and rarely porphyroblastic with 70–97 percent, fine-grained, ~0.1- to 0.2-mm-diameter quartz, <25 percent coarse-grained calcite, less than 8 percent white mica, ~3 percent feldspar, and 2 percent stilpnomelane (?). Siliceous layers are parted by ~0.5-mm-thick layers of mica or carbonate. Graphite is often present along partings with mica. Carbonate, along with fine-grained disseminated pyrite, is weathered to iron oxides at some localities. Locally rocks have up to 4 percent 1-mm-diameter recrystallized quartz porphyroclasts with a few small twinned feldspar porphyroclasts that have subgrain formation along the edges. Unit includes a rare garnet-bearing skarn in the southwest corner of the map area. Magnetic susceptibility is generally low, with uncommon high values (0–65, averaging 0.63 x 10^{-3} SI).

MDq **Quartzite and Quartz Schist (Devonian to Mississippian?)**—Quartzite and quartz schist with minor graphitic schist, impure marble, calcareous schist, and mafic to felsic metavolcanic schist. Marble and metavolcanic units are discontinuous. Semischist and quartzite occur on a continuum, with 70–93 percent fine-grained (~0.1- to 0.2-mm-diameter) quartz and less than 10 percent feldspar forming alternating 1-mm-thick layers. Siliceous layers are parted by ~0.2- to 0.5-mm-thick, fine-grained white mica (5–15 percent) and stilpnomelane (<10 percent) layers. White mica is very slightly pleochroic, contains remnants of biotite, and is replaced by up to 10 percent chlorite; metamorphic chlorite composes about 5 percent of the rock. Rare calcite, graphite, and very small opaque minerals are present. Unit includes a rare garnet-bearing skarn in the west of Timber Creek. Magnetic susceptibility is generally low (0–73, averaging 0.63 x 10^{-3} SI), with thin (<0.5-m-thick), high-magnetic-susceptibility, magnetite-bearing schist layers occurring south of the Tok River and east of Dry Tok Creek.

Unit often has a strong dominant foliation or cleavage orientation. Micas often align in two directions, along foliation and in shear bands in S-C fabric. Outcrop-scale recumbent folds and similarly oriented axial-planar cleavage define a secondary folding event (F2) and are well developed in more schistose units and in many marble layers. Unit has been metamorphosed to greenschist facies, and the lower contact is defined by lack of garnet and significantly less gneissic layers compared to the underlying Gneiss and Schist unit (Dg).

No fossils have been found in the map area; Devonian age designation is based on the presence of Middle Devonian corals in similar metamorphic rocks in the adjacent Nabesna quadrangle (Richter, 1976). A white mica separate yielded a $^{40}Ar/^{39}Ar$ plateau age of 121.6 ± 0.5 Ma (sample 16KS042; Benowitz and others, 2017), which is interpreted as a metamorphic cooling age during Early Cretaceous uplift. White mica from quartz schist northwest of Dry Tok Creek yielded a complex $^{40}Ar/^{39}Ar$ age spectrum with no preferred age interpretation. A weighted-average age of 109.3 ± 0.7 Ma (sample 15ET005; Benowitz and others, 2017) could indicate a potential age of fluid alteration, but it is likely that further alteration occurred during the Late Cretaceous or Tertiary.

MDd **Drum Unit Felsic Schist (Devonian to Mississippian?)**—The Drum unit is likely a subunit of the Quartzite and Quartz Schist (MDq) unit and is identified on the geologic map of the Delta mineral belt (Dashevsky and others, 2003), but does not appear as a distinguishable subunit east of Dry Tok Creek, possibly due to lateral variation during protolith deposition. Dashevsky and others (2003) describe the Drum Unit as "a relatively thin, felsic unit composed of white to pale gray-green, rusty weathering, fine-grained quartz-eye-bearing quartz–sericite ±chlorite ±pyrite schist with minor gray to black carbonaceous phyllite and rare chloritic phyllite interbeds. A fine, dark-gray phyllitic parting often is present within Drum sericite schists. Volcanic protolith compositions are dominantly felsic to intermediate in a 2:1 ratio. Quartz-eye content is typically 1–5 percent, though percentages are higher locally. The basal contact is transitional with the underlying Felsic Metavolcanic Schist (unit Dfs) and equivalent Tiger Unit metavolcanics in the Delta Mineral Belt (Dashevsky and others, 2003). The Drum unit has been dated at the Devonian–Mississippian boundary based on results of two SHRIMP U–Pb zircon ages determined at the DD South deposit (359 ± 6 Ma) and the HD South mineralized horizon" (364 ± 7 Ma; Dashevsky and others, 2003). The Drum unit averages 200–500 feet in thickness in the Delta mineral belt, exclusive of gabbroic sills.

Dfs **Felsic Metavolcanic Schist (Devonian?)**—Metarhyolite is schistose and includes quartz-rich layers about 1-mm thick, parted by 0.2- to 0.5-mm-thick layers of elongate white mica and stilpnomelane. The unit is composed of 60 percent 0.1-mm-diameter quartz forming a matrix for 25 percent 1- to 5-mm-diameter feldspar porphyroblasts, with 10 percent stilpnomelane and 5 percent white mica. Feldspar porphyroblasts have sericitized cores; stilpnomelane is often chloritized, contains very fine inclusions of oxides, and is very slightly pleochroic. Accessory epidote is present. Metarhyolite beds are mappable but discontinuous, and are not aerially extensive. A white mica separate yielded a $^{40}Ar/^{39}Ar$ plateau age of 125.2 ± 0.5 Ma (sample 16MBW209; Benowitz and others, 2017), which is interpreted as a metamorphic cooling age during Early Cretaceous uplift. Magnetic susceptibility measurements are low (0.07–0.7, averaging 0.27 x 10^{-3} SI).

Dl **Lagoon Unit Schist (Devonian?)**—The Lagoon unit is likely a subunit of the Quartzite and Quartz Schist (MDq) unit and is identified on the geologic map of the Delta mineral belt (Dashevsky and others, 2003), but does not appear as a mappable subunit east of Dry Tok Creek. Dashevsky and others (2003) describe the Lagoon unit as "a thick metavolcanic–metasedimentary unit that hosts a number of important massive-sulfide deposits and prospects. It consists of a basal section of banded, medium- to coarse-grained, quartz–sericite (±chlorite) schists and carbonaceous schists contrasting with finer grained schists and phyllites in the upper section. Protoliths in the basal section are immature sediments or wackes, mudstone, quartzarenite, and lesser calc-arenite and carbonate beds. Thin gray interbedded metavolcanic rocks of the Lagoon are gray to white and pale green in color. These metavolcanics typically have felsic compositions that cluster in the rhyodacite–dacite field (after Winchester and Floyd, 1977), but a significant proportion have a more intermediate-mafic composition. A prominent graphitic interbed is traceable in float and by electromagnetic surveys as an extensive low-resistivity zone." Dashevsky and others (2003) also note that "gabbroic sills and lenses are common throughout the Lagoon unit, and significantly inflate the sequence. These mafic bodies crosscut massive sulfides of the mineralized upper horizon. A structurally repeated section of the Lagoon unit is mapped southwest of the main Lagoon exposure, and is interpreted as a thrust-faulted slice. The thickness of the Lagoon unit, exclusive of gabbroic sills, is uncertain, but is estimated at a minimum of 1,000 feet locally and may exceed 2,000 feet. The structurally repeated section of the Lagoon unit has been dated at 372 Ma (±6 Ma) based on sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon analyses from a felsic volcanic interbed at the LZ East massive-sulfide prospect" (Dashevsky and others, 2003).

AMPHIBOLITE FACIES

Dag **Granitic Augen Orthogneiss (Devonian?)**—Granular augen orthogneiss body with deformed margins in the northeastern Tanacross A-6 quadrangle. Contains ~10 percent, <4-cm-diameter, euhedral to subhedral, potassium feldspar porphyroclasts in a finer-grained quartz-plagioclase-mica matrix. Recrystallized quartz <1 cm in diameter comprises 20–45 percent of the rock. Euhedral to subhedral plagioclase (~10 mm) comprises 20–50 percent of the rock, and very small biotite crystals form about 10 percent of the rock. Feldspars are replaced by sericite, and fine-grained feldspar (?) and quartz. Fine-grained biotite, chlorite, and feldspar replace larger biotite (?) grains. Unit has a clear metamorphic fabric, particularly along the edges. These textures suggest correlation with Devonian-Mississippian augen orthogneiss seen elsewhere in the Tanacross quadrangle (Foster, 1970). Biotite yielded a $^{40}Ar/^{39}Ar$ metamorphic plateau age of 126.2 ± 0.5 Ma (sample 15ET033; Benowitz and others, 2017). Magnetic susceptibility is very low (0.09–0.21, averaging 0.15 x 10^{-3} SI).

Dg **Gneiss and Schist (Devonian?)**—Undifferentiated quartz-mica schist, quartz-mica-garnet schist, calcareous schist, mafic schist, quartzite, felsic- to intermediate-composition orthogneiss, paragneiss, and minor marble and impure marble layers. Schist and quartzite layers are fine-grained (0.5 mm) and composed of 50–90 percent quartz and less than 15 percent feldspar. Quartz and feldspar form 1- to 2-mm-thick layers, with 3–30 percent white mica and 0.5–15 percent biotite defining foliation planes. Micas are locally slightly chloritized, and biotite crystals contain rare opaque inclusions. Garnet porphyroblasts 0.2- to 5-mm in diameter, often very heavily included and resorbed, are present in about 1–2 percent of the rock; up to 10 percent locally. In some garnet crystals the inclusions align with stress directions, forming S shapes. Mafic schist often contains up to 20 percent fine-grained epidote concentrated in mica layers. Some layers contain secondary, interstitial calcite. Unit was metamorphosed to amphibolite facies, with some areas undergoing retrograde metamorphism to greenschist facies based on chlorite overgrowths. Magnetic susceptibility is generally low (0.01–22.1, averaging 0.44 x 10^{-3} SI).

Unit is equivalent to the Macomb subterrane in the Mount Hayes Quadrangle (Nokleberg and others, 1992b), the Birch Creek Schist in the Tanacross Quadrangle (Foster, 1970), and the Birch Creek Schist terrane of Resource Associates of Alaska (Nauman and others, 1982; cited in Dashevsky and others, 2003). The unit has been described as Devonian or older based on a U-Pb age of 372 ± 8 Ma for a composite sample of several metagranite bodies north of the map area in the correlative Macomb belt (Nokleberg and others, 1992a). A white mica separate yielded a $^{40}Ar/^{39}Ar$ plateau age of 124.7 ± 0.5 Ma (sample 16ET484; Benowitz and others, 2017), which is interpreted as a metamorphic cooling age during Early Cretaceous uplift.

The upper contact of this unit is defined by the presence of garnet, which is absent in the overlying Quartzite and Quartz Schist (MDq) unit. In the vicinity of Clearwater Creek in the Tanacross A-5 Quadrangle, the contact appears to be gradational or interfolded with greenschist facies unit MDq, though a granodiorite pluton (lKgd) south of Clearwater Creek obscures the contact. In the Tanacross A-6 Quadrangle, the southeastern boundary of this unit with unit MDq is mapped as a high-angle fault due to the abrupt change from garnet-bearing gneiss and schist north of the fault (Dg) to Quartzite and Quartz Schist lacking garnet (MDq) southeast of Natahona Creek. Garnet is not present everywhere in the unit, either due to compositional differences or retrograde greenschist metamorphism. This interpretation is consistent with map relationships to the west, where the correlative Macomb unit of Nokleberg and others (1992b) is truncated by the Elting Creek fault, which strikes northwest-southeast and dips 40–60 degrees to the west (Dashevsky and others, 2003).

South of Denali Fault

INTRUSIVE ROCKS

Kqd **Quartz Diorite (Cretaceous?)**—Generally massive but locally foliated, fine- to medium-grained hornblende granodiorite, hornblende diorite, biotite-hornblende monzodiorite, and minor quartz diorite and tonalite (Wilson and others, 2015; Richter and others, 1977). Quartz diorite is seriate, with 40 percent 0.5- to 2-mm-long subhedral feldspar, ~30 percent 0.5-mm-long subhedral plagioclase, ~10 percent primary pyroxene, overgrown by anhedral 2-mm-long hornblende, with 1 percent subhedral 0.1-mm-long biotite, ~5 percent interstitial quartz, and accessory anhedral opaque minerals. Feldspar crystals (orthoclase or albite?) are zoned, with some highly sericitized zones and undulatory extinction. Plagioclase, generally the smaller feldspar, has clear polysynthetic twinning, and is less sericitized as compared with larger feldspars. Pyroxenes, mostly clinopyroxene, are replaced by amphibole on rims. Hornblende shows dissolution textures, is often chloritized, and contains multiple opaque inclusions. The diorite is altered, with some evidence for pressure solution along grain boundaries due to metamorphism. The pluton is only exposed within the map area on a very small hill in the southwest corner of the Tanacross A-5 Quadrangle, where it locally exhibits weak foliation.

Cretaceous (?) age is based on K-Ar dates from similar granodiorite to quartz diorite of the Buck Creek and Slana plutonic rocks in the Nabesna Quadrangle (Richter and others, 1977; Richter and others, 1975). These rocks are described as fresh, medium-grained, subhedral granular, and nonfoliated. The Slana Plutons are chiefly hornblende granodiorite, while the Buck Creek Plutons are principally hornblende quartz diorite and syenodiorite. The plutons occur in roughly linear lenses adjacent to the Denali Fault, and have hornfelsed adjacent clastic rocks, greenstone, or marble country rocks.

METAMORPHIC ROCKS

KJgn **Gravina-Nutzotin Belt (Late Jurassic to Early Cretaceous?)**—Unit is poorly exposed in the southwest corner of the Tanacross A-5 Quadrangle, south of the Denali Fault. The unit was not observed or described in the field, but was described and mapped as Late Jurassic to Early Cretaceous argillite, greywacke, and conglomerate; andesitic volcanic, tuffaceous, and volcaniclastic rocks; and mid-Cretaceous granitic rocks (Jones and others, 1987; McClelland and others, 1991; McClelland, Gehrels, Samson, and Patchett, 1992; McClelland, Gehrels, and Saleeby, 1992). Sedimentary rocks ranging from marine greywacke and mudstone to shallow-water and nonmarine deposits (Jones and others, 1987) were deposited in the age-equivalent

Gravina and Nutzotin basins, and subsequently thrust under the Yukon Tanana terrane between 113 and 97.5 Ma, ending by 90 Ma in Southeast Alaska (McClelland and others, 1992b). In Southeast Alaska this unit is interpreted as being deposited on top of the northern edge of the Wrangellia composite terrane due to derivation of clasts in the conglomerates from the Wrangellia composite terrane and from continental sources (Berg and others, 1972; Richter, 1976; Ridgway and others, 2002). These relationships are not found in the map area due to lack of exposure.

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