Report of Investigations 2004-1b

BEDROCK GEOLOGIC MAP OF THE SALCHA RIVER–POGO AREA, BIG DELTA QUADRANGLE, ALASKA

by

M.B. Werdon, R.J. Newberry, J.E. Athey, and D.J. Szumigala

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[in envelope]

BEDROCK GEOLOGIC MAP OF THE SALCHA RIVER–POGO AREA, BIG DELTA QUADRANGLE, ALASKA

by

Melanie B. Werdon,[1] Rainer J. Newberry,[2] Jennifer E. Athey,[1] and David J. Szumigala[1]

INTRODUCTION

Report of Investigations 2004-1b, "Bedrock geologic map of the Salcha River–Pogo area, Big Delta Quadrangle, Alaska," covers an approximately 435-square-mile area in the central Big Delta Quadrangle, Alaska. The bedrock geologic map was produced from field work conducted during the months of June through August, 2000-2002, by mineral-resource personnel from the Alaska Division of Geological & Geophysical Surveys (DGGS) and the University of Alaska Fairbanks. The purpose of the project is to provide 1:63,360-scale geologic mapping of the Salcha River-Pogo airborne geophysical survey (helicopter-based aeromagnetic, radiometric, and electromagnetic data) released by DGGS in 2000 (Burns and others, 2000). The geophysical data sets were useful for identifying locations of geophysically inferred faults and unit boundaries, unusual anomalies for follow-up investigation, and for extending mapped contacts through regions covered by vegetation or surficial deposits.

Currently the southern portion of the geophysical survey is of intense interest to the mineral exploration industry since it includes the Pogo property (a high-grade, plutonic-related(?), 3.6 million ounce gold deposit hosted by a stacked set of shallowly dipping quartz veins; Smith and others, 1999; Teck Cominco Limited 2002 company report; Rhys and others, 2003). Molybdenum from main stage quartz veins in the Liese zone at the Pogo property yields a Re-Os age of ≈104 Ma (Selby and others, 2002). Other ≈90–95 Ma hydrothermal gold systems are present southeast of Pogo (Selby and others, 2002), in the Caribou Creek area in the Big Delta C-4 Quadrangle, and approximately 45 km southwest of the map area in the Richardson district. Several promising gold targets occur throughout the study area, and there is the potential for ultramafic-hosted, platinum-group-element and base-metal-sulfide lode occurrences.

Bedrock field investigations for the Salcha River–Pogo project were conducted for approximately 540 person-days. Field notes and rock samples were collected at approximately 4,830 stations throughout the map area and adjacent portions of the Big Delta Quadrangle. Map unit descriptions are based on field observations and on further analytical work including petrographic study and modal analysis of more than 800 thin sections, and modal analysis of approximately 1,815 rocks stained for plagioclase and potassium feldspar. Also, approximately 560 rocks were analyzed for major- and minor-oxides and trace elements (Werdon and others, 2001a; Athey and others, 2002; Werdon and others, 2003). These data were used to determine permissible protoliths for metamorphic rocks, and to assign root names and trace-element-indicated tectonic settings to igneous and metamorphosed igneous rocks according to established petrologic nomenclature. Supplemental studies included XRF analyses to classify fine-grained greenschist-facies rocks, microprobe analyses of garnet-biotite pairs to define metamorphic temperature-pressure conditions, and 44 $^{40}Ar/^{39}Ar$ laser step-heating analyses and one conventional U-Pb analysis to provide constraints on the timing of metamorphism and igneous activity, as well as hydrothermal alteration associated with gold-bearing quartz veins at the Hook prospect in the northeastern Big Delta B-3 Quadrangle. DGGS's preliminary geologic observations in the vicinity of the Pogo gold deposit, made during reconnaissance work in the Big Delta Quadrangle in 2000 (Werdon and others, 2001c), have been refined and incorporated into this map. To help evaluate the area's mineral resource potential, 306 rocks that were either visibly mineralized, or had features that suggested the potential to be mineralized, were analyzed for geochemical trace elements (Werdon and others, 2001a; Athey and others, 2002; Werdon and others, 2003).

DESCRIPTION OF MAP UNITS

SEDIMENTARY ROCKS

TKc

CONGLOMERATE (Tertiary? to Cretaceous?) — Well-cemented conglomerate with well-rounded clasts up to 3 cm in diameter, located on south side of Shaw Creek fault. Thickness and extent of this unit is unknown due to vegetation and loess cover. Distribution as shown on map is based on geophysical signature of unit and several pieces of loose rock recovered from a single soil pit within this area.

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IGNEOUS AND META-IGNEOUS ROCKS

Tr

FELSIC DIKES (Tertiary) — Fine-grained, aphanitic to quartz- and K-feldspar-porphyritic rhyolite dikes, found south of Shaw Creek fault. Extensional, within-plate, trace-element geochemistry. Magnetic susceptibility is uniformly low (average 0.01 x 10^{-3} SI [Système International]). Zircon U-Pb age of 54.5 ± 0.5 Ma (map location U1; Dilworth, 2003).

Tg

MAFIC DIKES (Tertiary?) — Fine-grained, aphanitic to porphyritic to equigranular mafic dikes, found south of Shaw Creek fault. Extensional, within-plate, trace-element geochemistry. Magnetic susceptibility is uniformly moderate [0.30–0.70, average 0.50 x 10^{-3} SI]. Age assignment is based on correlation with early Tertiary basalt flows and dikes in the Fairbanks and Eagle Quadrangles with indistinguishable major-oxide and trace-element geochemistry from these dikes (Newberry and others, 1996; Werdon and others, 2001b).

Khg

HYPABYSSAL GRANITE (Late Cretaceous) — Fine-grained, biotite-, K-feldspar-, and quartz-porphyritic, hypabyssal stocks and dikes of granite and granodiorite; occur only within upper greenschist-facies rocks. Most of the rocks are too altered for modal or major oxide analysis, as the matrix consists largely of sericite and quartz. Occurs only as weathered float; orange iron-oxide crusts are typical. Spatially corresponds with a pronounced potassium high in radiometric data (Burns and others, 2000). Magnetic susceptibility is highly variable (0.02–0.90, averaging 0.40 x 10^{-3} SI) perhaps due to variable weathering and hydrothermal destruction of magmatic magnetite. The minimum age is approximately 69 Ma, based on two $^{40}Ar/^{39}Ar$ biotite plateau dates (map location A1; table 1). Zircon from a compositionally dissimilar biotite-muscovite ± garnet granite from the Eielson pluton about 75 km to the west–northwest of this intrusion yields a similar SHRIMP U-Pb age of 73 ± 2 Ma (Dusel-Bacon and Murphy, 2001), and zircons from Late Cretaceous volcanic and plutonic rocks with conventional U-Pb ages of 68–69 Ma occur approximately 300 km to the east of the map area in the Yukon Territory (Mortensen, 1999).

Kbgr

BONANZA CREEK PLUTON, GRANITE CORE (Cretaceous) — Medium- to very coarse-grained, equigranular to porphyritic, monzogranite body in the northwest Big Delta C-3 Quadrangle. Forms massive, bold outcrops and 0.5–2 km^2-scale boulder-talus fields with angular >1 m^3 blocks. Displays little compositional or modal variability, averaging approximately 35 percent quartz, 35 percent K-feldspar, 20 percent plagioclase, 9.5 percent biotite, and <0.5 percent accessory minerals, including zircon, apatite, and trace ilmenite. Locally cut by molybdenite-bearing quartz veins (Werdon and others, 2003). Magnetic susceptibility is low (0.01–0.23, average 0.09 x 10^{-3} SI). Based on low magnetite content and occasional veins, this pluton is favorable for hydrothermal-intrusion related gold deposits; the favorable uppermost portions of the main body have been removed by erosion, but peripheral plugs and dikes are present. Spatially corresponds with a pronounced potassium high in radiometric data and a poorly conductive area in resistivity data (Burns and others, 2000). $^{40}Ar/^{39}Ar$ biotite plateau age of 92.8 ± 0.6 Ma (map location A2; table 1). Intrudes both greenschist-facies and amphibolite-facies rocks, hence it provides a minimum age of ≈93 Ma for juxtaposition of the two metamorphic units.

Kbgd

BONANZA CREEK PLUTON, GRANODIORITE MARGIN (Cretaceous) — Medium- to fine-grained, strongly to weakly porphyritic, 10–500-m-wide, hornblende–biotite granodiorite marginal phase of the Bonanza Creek pluton (unit Kbgr). Present as rubble and talus fields and boulder float along unfaulted, intrusive contacts. Granodiorite displays gradational contacts over tens of meters with the granitic core (unit Kbgr); Kbgd is distinguished from Kbgr by its generally finer grain size, presence of hornblende, and from modal analysis of stained rock slabs. Generally consists of granodiorite, but includes some tonalite and quartz diorite. Average modal composition is 20 percent quartz, 40–60 percent plagioclase, 10 percent K-feldspar, 10 percent biotite, 6 percent hornblende, and <0.5 percent accessory minerals including apatite, zircon, and ilmenite. Magnetic susceptibility is low (0.01–0.22, average 0.10 x 10^{-3} SI).

Ku

UNDIFFERENTIATED GRANITIC PLUTONS (Cretaceous?) — Numerous unfoliated granitic bodies of overall granodioritic to granitic composition of presumed mid-Cretaceous age in the northeast Big Delta B-3 and northwest B-2 quadrangles. Medium-grained; typically contain 25–35 percent quartz, 20–30 percent K-feldspar, 30–40 percent plagioclase, and 5–15 percent biotite. Magnetic susceptibility averages 0.15 but shows a wide variability (0.01–0.70 x 10^{-3} SI).

Ktn

TONALITE (Cretaceous) — Several bodies of fine- to medium-grained tonalite and quartz diorite with lesser granodiorite and quartz monzodiorite in the northeastern Big Delta B-3 and northwestern B-2 quadrangles. One small body of similar composition and mineralogy occurs in the northeastern Big Delta C-3 Quadrangle. Dominantly sub-equigranular, with biotite > hornblende > clinopyroxene, although mafic abundances vary within the bodies. Typically contains 20 percent mafic minerals, 10–20 percent quartz, 1–10 percent interstitial K-feldspar, and 50–70 percent plagioclase. Displays variable degrees of hydrothermal alteration, but mostly is little altered. Magnetic susceptibility is very low for a mafic-rich igneous rock (0.02–0.38, average 0.22 x 10^{-3} SI) and the contacts of the bodies are, in part, identified from aeromagnetic data. A 0.5 km^2 area within one of these intrusions (centered 0.5 km south–southwest of map location U3 in the Big Delta B-2 Quadrangle) exhibits anomalously high magnetic susceptibility (0.40–1.47, average 0.70 x 10^{-3} SI). Two hornblendes from a tonalite located north of the Salcha River in the Big Delta C-3 Quadrangle yield pseudoplateau and plateau ages of approximately 96 Ma (map location A3; table 1). Biotite and hornblende from a northwest-trending quartz diorite body on the boundary of the Big Delta B-2 and B-3 quadrangles yield $^{40}Ar/^{39}Ar$ plateau ages of 96.5 ± 0.9 and 99.2 ± 1.1 Ma, respectively (map location A4; table 1). A northwest-trending, composite tonalite–quartz diorite–granodiorite body exposed in Liese Creek near the Goodpaster River extends for 9 km to the east along the ridgeline in a series of blocks offset by northeast-trending, high-angle faults. Zircon from ‘diorite’ exposed in drill core at the Pogo property from this multi-phase pluton yields a conventional U-Pb age of 94.5 ± 0.2 Ma (map location U2; Smith and others, 1999; Dilworth, 2003); 3 km to the east, zircon from a ‘granodiorite’ yields an ion microprobe (SHRIMP) zircon U-Pb age of 103.4 ± 2.2 Ma (map location U3; Dilworth, 2003).

Ka

QUARTZ-ALKALIC PLUTON (Cretaceous) — A poorly exposed, composite body of varied, but typically quartz-poor, igneous rocks in the northeast Big Delta B-3 Quadrangle. Most exposures are from drill core and hillside trenches; rocks near the surface are strongly weathered. Texture is medium- to fine-grained, sub-equigranular. Modal analysis of stained slabs indicates that rock compositions include monzonite, quartz monzonite, quartz monzodiorite, diorite, granodiorite, and granite. Hornblende is common in the quartz-poor and mafic rocks; tourmaline is present in the granite. Variably altered, especially near quartz-sericite veins. Industry drilling and trenching in the body indicate that it is gold bearing. Magnetic susceptibility is extremely variable (0.04–1.0, average 0.24 x 10^{-3} SI), in line with the extreme compositional variability of rocks present. $^{40}Ar/^{39}Ar$ plateau ages for biotite from granite (95.1 ± 0.6 Ma; map location A5; sample 02Z421A; table 1) and for mineralization-associated sericite alteration in an alkalic phase (98.0 ± 0.5 and 101.1 ± 0.8 Ma; map location A5; sample 02Z639A; table 1) indicate that this is a composite body, with older mafic-alkalic units and younger granite. The different ages for coarse- and fine-grained alteration sericite fractions and the younger granite body most likely indicate a partial thermal reset for the sericite; the ≈101 Ma date is thus a minimum age for the mineralization and host alkalic unit.

Kgp

GOODPASTER BATHOLITH (Cretaceous) — Approximately 5-km-wide by more than 40-km-long batholith, with a discontinuous, finer-grained marginal phase (unit Kgpm) and a small, low-hornblende phase (unit Kgpb). The vast majority of this body is medium- to coarse-grained, tan, sub-equigranular, hornblende-biotite granodiorite, with prominent, euhedral biotite phenocrysts. Lack of textural and mineralogical variability is typical. Average modal composition is approximately 10 percent biotite, 7 percent hornblende, 25 percent quartz, 10 percent K-feldspar, 45 percent plagioclase, 2 percent myrmekite, and 1 percent accessory minerals, including zircon, apatite, and ilmenite. Generally little altered, with minor conversion of biotite to chlorite and dusting of plagioclase by sericite. Magnetic susceptibility is low (0.06–0.27, averaging 0.15 x 10^{-3} SI). Reported ages for the Goodpaster batholith include an $^{40}Ar/^{39}Ar$ hornblende weighted-average age of 101.0 ± 2.5 Ma (map location A6; table 1), a 93.7 ± 0.2 Ma zircon U-Pb age, and a 105.7 ± 0.3 Ma monazite U-Pb age (map locations U4 and U5; Smith and others, 1999; Dilworth, 2003). These dates suggest that either the batholith is a composite body, or that it has experienced multiple thermal events.

Kgpb

LOW-HORNBLENDE PHASE OF GOODPASTER BATHOLITH (Cretaceous) — Medium- to coarse-grained, sub-equigranular, biotite granodiorite spatially associated with the Goodpaster batholith in the southeast Big Delta C-3 Quadrangle. This unit texturally resembles the primary unit of the Goodpaster batholith (Kgp) but lacks obvious hornblende in hand specimen; thin-section petrography indicates that it contains little or no hornblende. Average modal composition is approximately 25 percent quartz, 45 percent plagioclase, 10 percent interstitial K-feldspar, 20 percent biotite, and trace accessory magnetite. The unit is exposed as talus and subcrop on steep slopes and as frost boils and float elsewhere; contacts with unit Kgp have not been observed. Magnetic susceptibility (0.03–0.23, averaging 0.11 x 10^{-3} SI) is slightly lower than that of the hornblende-biotite granodiorite comprising the main body of the Goodpaster batholith (Kgp). The hornblende-absent rocks occur on the southwest side of the Goodpaster batholith, and may be more extensive than shown.

Kgpm

NORTHEAST MARGIN OF GOODPASTER BATHOLITH (Cretaceous) — Fine- to-medium grained, 0.5-to 3-km-wide, composite, granitic unit present along the northeast margin of the Goodpaster batholith (Kgp) in the Big Delta C-2 Quadrangle. Usually granoblastic-equigranular textured with porphyritic K-feldspar crystals that are slightly larger than the groundmass. Generally exposed in rubblecrop, subcrop, and float on brushy hillsides. Modal analyses of the granodiorite indicate that both muscovite-bearing granite and biotite granodiorite are present; the average modal composition is 40 percent quartz, 25 percent plagioclase, 30 percent K-feldspar, and 5 percent biotite. Aplite compositional geobarometry (using the method of Tuttle and Bowen, 1958) from a fine-grained sample of the muscovite granite of this unit yields a pressure of 2.0 ± 0.5 kbars (this study). The presence of both fine-grained granodiorite and lesser muscovite granite indicates that this is most likely a composite unit consisting of older granite similar to unit Kub, which is intruded by a chilled margin of the Goodpaster Batholith (Kgp). Magnetic susceptibility is generally low (0.02–0.16 x 10^{-3} SI, averaging 0.09 x 10^{-3} SI).

Kub

UPPER BOULDER CREEK PLUTON (Cretaceous) — Fine- to medium-grained, tan, equigranular to slightly porphyritic, dominantly granite body in the northeast part of the southwest quadrant of the Big Delta C-2 Quadrangle. This multiphase pluton contains 1–10 percent paragneiss xenoliths up to 7 cm in diameter with abundant biotite, cordierite, and sillimanite. There is an extensive hornfels zone adjacent to this intrusion. The upper contact is concordant to the overlying paragneiss, and numerous sills of this unit occur within hornfelsed roof pendants. The body is apparently composite as there are striking differences between the northern two-thirds and the southern one-third of the body. The northern portion is entirely granite, yields an $^{40}Ar/^{39}Ar$ biotite plateau age of 102.3 ± 0.7 Ma (map location A7; table 1), and an aplite geobarometry pressure of 1.0 kbar (this study; using the method of Tuttle and Bowen, 1958). In contrast, the southern one-third contains appreciable granodiorite and tonalite in addition to granite, and yields an aplite geobarometry pressure of 0.5 kbar. Hornblende from granodiorite of the southern one-third of the body yields an $^{40}Ar/^{39}Ar$ plateau and isochron age of 106.4 ± 0.7 Ma (map location A8; table 1). The pluton is exposed as loose subcrop and hillside rubble; no internal contacts were identified. The predominant rock type present throughout the pluton is granite; average modal composition is 30 percent quartz, 35 percent K-feldspar, 25 percent plagioclase, 5–10 percent biotite + muscovite, and <1 percent accessory minerals, including zircon, apatite, and, rarely, garnet. Magnetic susceptibility is low (0.02–0.25, average 0.10 x 10^{-3} SI).

KPzi

INJECTION MIGMATITE (Cretaceous to Paleozoic) — Migmatite formed by the injection of numerous small (centimeter-scale) granite sills and dikes with diffuse boundaries (presumed Kub) into hornfelsed paragneiss (pMp). Noticeably a mixed rock, even at a hand-specimen scale. Granite sills and dikes possess variable textures, but are most commonly medium-grained, equigranular. Modal abundances average 30–40 percent quartz, 20–30 percent plagioclase, 30–40 percent K-feldspar, and 5–10 percent combined biotite and muscovite. The hornfelsed paragneiss portions invariably contain rounded clots, 3–7 cm in diameter, of coarse-grained, partly retrograded cordierite and fine-grained, randomly oriented biotite. On average, the hornfelsed paragneiss portions contain 10–25 percent cordierite (now largely retrograded to fine-grained pinite), 3–8 percent sillimanite as randomly oriented grains in biotite, 1–3 percent garnet, 40–60 percent quartz, and 10–30 percent feldspar with K-feldspar > plagioclase. Forms massive, bold outcrops and subcrops invariably covered with orange-brown iron-oxide staining. Only freshly broken and especially large sawed slabs are confidently identified as the injection migmatite due to the extensive weathering surfaces and small granite sills and dikes. Magnetic susceptibility ranges from 0.05 to 0.35 x 10^{-3} and averages 0.12 x 10^{-3} SI.

Kgd

GRANODIORITE (Cretaceous?) — Medium-grained, sub-equigranular pluton of largely granodioritic and lesser granitic composition, located across the Shaw Creek fault from the Upper Boulder Creek pluton (Kub). Exposed only as rubble and frost boils on vegetated lower slopes. Average modal composition is 25 percent quartz, 20 percent interstitial K-feldspar, 40 percent plagioclase, and 15 percent biotite, with minor apatite, zircon, and ilmenite. Magnetic susceptibility is low (0.02–0.08, average 0.05 x 10^{-3} SI), even lower than that of the more felsic Upper Boulder Creek pluton (Kub). ^{40}Ar/^{39}Ar biotite plateau age of 105.9 ± 1.0 Ma (map location A9; table 1) from a granodiorite body .

Ks

SALCHA RIVER PLUTON (Cretaceous) — Primarily medium-grained hornblende-biotite granodiorite with minor biotite granite and, rarely, hornblende-biotite quartz diorite. Typically fine- to medium-grained, subequigranular to slightly porphyritic. Exposed as moderately weathered rubble piles and float in tundra. Average modal composition approximately 25–30 percent quartz, 15–20 percent K-feldspar, 40–45 percent plagioclase, 7–15 percent biotite, 0.5–8 percent hornblende, and <0.5 percent accessory minerals, including magnetite, zircon, and apatite. Magnetic susceptibility is generally high, up to 5.6, and averages 0.80 x 10^{-3} SI. The high magnetic susceptibility suggests that this pluton has a poor potential as a plutonic-hydrothermal gold source. Hornblende and biotite yield ^{40}Ar/^{39}Ar plateau ages of 105.2 ± 0.8 Ma and 107.3 ± 0.7 Ma, respectively (map location A10; table 1). Intrudes both greenschist-facies and amphibolite-facies rocks, hence it provides a minimum age of ≈106 Ma for juxtaposition of the two metamorphic units.

Kt

TWO-MICA (±TOURMALINE, ±GARNET) GRANITE (Cretaceous) — Fine- to coarse-grained, leucocratic, equigranular, generally non-foliated, but locally, moderately foliated granite. Occurs as a 10-km-long, northwest-trending, elongate intrusion in the west-central Big Delta C-3 Quadrangle surrounded by hundreds of small tourmaline–muscovite–garnet granite dikes, sills, and small plutons. Unit also occurs as a sill-form body in the east-central Big Delta C-4 Quadrangle, and appears to underlie a large portion of the sillimanite- and cordierite-bearing paragneiss (pMp) located south of the Salcha River and west of the South Fork of the Salcha River. South of the Shaw Creek fault, two small plugs occur on the east and west sides of the Goodpaster River in the northwestern Big Delta B-2 Quadrangle, and peraluminous granite bodies are present underground in the Pogo deposit. Texturally varies from aplite to pegmatite, with consistently peraluminous granite major oxide and modal composition. Average modal composition approximately 40 percent quartz, 30 percent K-feldspar, 15 percent plagioclase, 5–10 percent biotite, 3–12 percent muscovite, 0–2 percent garnet, 0–5 percent tourmaline, and 1 percent accessory minerals, including zircon, apatite, and ilmenite. Proportions of muscovite, biotite, garnet, and tourmaline vary widely. Magnetic susceptibility is very low (0.00–0.17, average 0.05 x 10^{-3} SI). Initial Sr isotope value of 0.741 (Aleinikoff and others, 2000) for the sill-form granite body in the Big Delta C-4 Quadrangle indicates a largely melted crust origin. Trace-element compositions, in particular high Rb and low Y+Nb (Aleinikoff and others, 2000; Werdon and others, 2001a) indicate a syn-collisional tectonic setting. Unit is interpreted to be the source for the numerous foliation-cutting quartz veins that contain varying portions of andalusite, tourmaline, muscovite, and (or), rarely, sillimanite. Aplite compositional geobarometry (this study; using the method of Tuttle and Bowen, 1958) for four samples from this unit yields formation pressures of 2.0–2.5 kbars, indicating intrusion at a depth of approximately 6–8 km. Monazite from the small granite plug on the east side of the Goodpaster River near the Pogo deposit in the Big Delta B-2 Quadrangle yields a conventional U-Pb age of 107.9 ± 1.2 Ma (map location U6; Dilworth, 2003). Muscovite from the small granite plug on the west side of the Goodpaster River near Pogo in the Big Delta B-2 Quadrangle yields an ^{40}Ar/^{39}Ar age of 93.0 ± 0.9 Ma (map location A11; table 1). Zircon from the granite sill just south of the Salcha River in the Big Delta C-4 Quadrangle yields a conventional (thermal ionization mass spectrometry) U-Pb age of 116 ± 3 Ma (Aleinikoff and others, 1984), and an ion-microprobe (SHRIMP) age of 113 ± 2 Ma (Dusel-Bacon and others, in press). Muscovite from this body yields an ^{40}Ar/^{39}Ar age of 104.6 ± 1.2 Ma (sample 00RN630; table 1). The northwest-trending granite dike in the Big Delta C-3 Quadrangle has an ^{40}Ar/^{39}Ar muscovite plateau age of 108.2 ± 0.9 Ma (map location A12; table 1). ^{40}Ar/^{39}Ar ages are interpreted to represent minimum ages for these units, given their considerable depth of emplacement and associated lengthy cooling time. Unit is correlated with peraluminous granites in the Big Delta B-2 Quadrangle including the Swede Peak granite pluton (Day and others, 2003). We interpret the peraluminous granites as representing crustal melts associated with a collisional event that produced the final metamorphic textures in rocks of the area. This interpretation is consistent with metamorphic zircon overgrowths with U-Pb ages of ≈116 Ma reported by Day and others (2003) in the Big Delta B-2 Quadrangle.

KJmp

UNDIFFERENTIATED METAGRANITIC PLUTONS (Cretaceous to Jurassic?) — Small bodies of fine- to medium-grained, felsic intrusive rock displaying weak to moderate foliation, located in the northeastern Big Delta B-3, northwestern B-2, and southwestern and southeastern C-3 quadrangles. Rocks vary in composition from granite to tonalite, but granite is most common. Average modal composition is 25 percent quartz, 40 percent plagioclase, 20 percent K-feldspar, 10–15 percent biotite, 0–3 percent muscovite, and traces of zircon, apatite, and magnetite. Magnetic susceptibility is variable, but generally low (0.05–0.60, average 0.13 x 10^{-3} SI), reflecting variations in mafic content. Distinguished from orthogneiss by virtue of the weak foliation; distinction is not always easy and some unit contacts are uncertain. Two $^{40}Ar/^{39}Ar$ analyses of hornblende from a metatonalite on the margin of an undifferentiated granitic body (Ku) in the northwestern Big Delta B-2 Quadrangle both yield high-temperature-fraction and pseudoplateau ages of 105.3 ± 1.0 Ma; biotite yields a plateau age of 104.4 ± 1.0 Ma (map location A13; table 1). Biotite from a small metagranodiorite body on the western edge of the northeastern quarter of the Big Delta B-3 Quadrangle yields an $^{40}Ar/^{39}Ar$ pseudoplateau age of 130.2 ± 1.2 Ma (map location A14; table 1). Actual age range for unit KJmp unknown, but foliated texture of these bodies suggests they predate other nearby less-foliated intrusions (Ku, Ka, Ktn); most likely Early Cretaceous, but some bodies may be as old as Jurassic? based on textural similarity to unit KJm.

KJm

METAGRANODIORITE (Cretaceous to Jurassic?) — An 11 km^2 body of fine-grained, weakly to moderately foliated, hornblende-biotite granodiorite and lesser granite and tonalite in the northeastern Big Delta B-3 Quadrangle. Rocks are sub-equigranular, with foliation more visible in more mafic-rich varieties. Poorly exposed as subcrop and float, commonly in vegetated areas, so internal and external contacts are not apparent. This unit includes lenses and bodies of orthogneiss, schist, and paragneiss; larger inclusions are shown on the map. Average modal composition approximately 15–35 percent quartz, 5–35 percent K-feldspar, 20–65 percent plagioclase, 5–15 percent biotite, 0–5 percent hornblende and <0.5 percent accessory minerals, including zircon, apatite, allanite, and magnetite. Magnetic susceptibility is variable, but generally low (0.02–0.70, average 0.14 x 10^{-3} SI), reflecting variations in mafic content. U-Pb zircon analyses using conventional ID-TIMS methods for a single sample of granodiorite from this unit (map location U7; table 2) yield U-Pb and Pb-Pb ratios indicating variable amounts of inheritance. Zircons from one of the fractions (A) yield a concordant $^{206}Pb/^{238}U$ age of 119.8 ± 0.5 Ma (J.K. Mortensen, written commun., 2003). Mortensen concludes that because fraction A (table 2) is free of inheritance, its concordant age gives the igneous crystallization age of the sample. An alternative interpretation to that proposed by Mortensen is that the concordant Cretaceous age indicates the time of metamorphism, consistent with Cretaceous SHRIMP dates of ≈116 Ma for metamorphic rims on detrital zircons described by Day and others (2003) from the Big Delta B-2 Quadrangle. If this later interpretation is correct, the actual age for this sample could range from Early Cretaceous to potentially as old as Jurassic(?). Analysis of this sample by the ion-microprobe (SHRIMP) method is needed in order to evaluate this last possibility. Foliated texture of this body suggests it predates other nearby less-foliated intrusions (Ku, Ka, Ktn).

METAMORPHIC ROCKS

MAFIC, ULTRAMAFIC, AND SEDIMENTARY ROCKS METAMORPHOSED TO PREHNITE-PUMPELLYITE TO LOWERMOST GREENSCHIST FACIES: NAIL RIDGE SUITE, SEVENTYMILE TERRANE

There are numerous serpentinized ultramafic bodies in interior Alaska, especially in the Eagle and Big Delta Quadrangles (Foster and Keith, 1974; Weber and others, 1978), many of which are described as the ‘Seventymile Terrane’ and interpreted to represent dismembered ophiolites (Foster and others, 1994). In the northeastern Big Delta Quadrangle, ultramafic rocks (harzburgite, dunite, serpentinite), metagabbro and metabasalt (with mid-ocean-ridge-basalt (MORB) trace-element-indicated tectonic signatures), and metasedimentary rocks (volcanic breccia/conglomerate, metachert, metasandstone, meta-argillite) crop out along Nail Ridge; their similar metamorphism and spatial proximity to each other suggest a genetic relationship, and are considered part of the Seventymile terrane (Foster and others, 1994). The vertical sequence exhibited by these rocks, although partially repeated by several low-angle faults and offset by late high-angle faults, is typical of that found in ophiolite suites worldwide. We group these rocks together into the informally named Nail Ridge suite, and distinguish them from nearby upper greenschist- and amphibolite-facies rocks. The Nail

Ridge suite has been metamorphosed to prehnite-pumpellyite- to lowermost greenschist-facies grade. Primary textures are usually well preserved and penetrative deformation is rare, except where adjacent to, or within, low-angle fault zones. Age of ultramafic rocks (harzburgite) unknown but may range from Triassic(?) to Mississippian(?). Metasedimentary rocks may range from Permian to Mississippian(?) in age. Radiolarians and conodonts from chert in the Big Delta D-1 Quadrangle are Early Permian to late Pennsylvanian (Foster and others, 1978; Dusel-Bacon and Harris, 2003). Permian to late Pennsylvanian chert is spatially associated with the two largest ultramafic bodies in Interior Alaska (Foster and others, 1978; Keith and others, 1981); Late Triassic limestones are spatially associated with ultramafic rocks in western Yukon Territory (Abbott, 1983) and in the eastern Eagle Quadrangle (Dusel-Bacon and Harris, 2003). These ages most likely set an upper limit to the ages for the mafic and ultramafic rocks; the lower limit is undefined, but is most likely Mississippian, based on $^{40}Ar/^{39}Ar$ saddle or pseudoplateau ages (map locations A15 and A16; table 1) from gabbro (unit Mgb).

Rocks of the Nail Ridge suite are in low-angle fault contact with underlying middle to upper greenschist-facies rocks. Several repetitions of the ultramafic and gabbroic units with stratigraphically higher parts of the ophiolite sequence, particularly near the base of the Nail Ridge suite, suggests that the contact with the underlying middle to upper greenschist-facies rocks is a thrust fault, as proposed by Weber and others (1978). The timing of low-angle fault emplacement is not well constrained, but predates the oldest undeformed plutons in the region (≈115 Ma). The timing of emplacement of the Nail Ridge suite could potentially be as young as the Cretaceous deformation of metagranodiorite in the region (≈120 Ma), or it may be related to Early Jurassic or possibly pre-latest Triassic deformation of the Yukon–Tanana terrane (Dusel-Bacon and others, 2002).

PIPc

METACHERT AND VOLCANICLASTIC CONGLOMERATE/BRECCIA (Early Permian to late Pennsylvanian) — A composite unit consisting of chert and basaltic volcaniclastic rocks in variable proportions. Chert is very fine-grained; locally contains less than 1 percent carbonaceous material and 5 percent white mica, with up to 40 percent radiolarians. Volcaniclastic rocks comprise tuff breccias and conglomerates of basaltic composition (clasts up to 10 cm in diameter) in a sandy basaltic matrix. Amygdaloidal basalt is locally present. Magnetic susceptibility is generally low (0.01–0.30, average 0.16 x 10^{-3} SI), depending on the amount of intermixed basalt. Age of unit based on correlation with radiolarian- and conodont-bearing chert in the northeastern Big Delta Quadrangle (Foster and others, 1978; Dusel-Bacon and Harris, 2003).

PMv

METASANDSTONE, META-ARGILLITE, AND GREENSTONE (Permian to Mississippian) — Mixed unit composed of weakly metamorphosed sand-, clay-, and basaltic-rich protoliths. Volcaniclastic conglomerates and breccias contain basalt clasts in a sandy basaltic matrix. Metasandstone is largely metagraywacke, of proximal volcanic derivation, but grades to fine-grained, reddish-brown, quartz-rich sandstone cemented by earthy hematite. Argillite is light to dark gray or greenish-gray. Magnetic susceptibility varies from 0.00 to 5.0 x 10^{-3} SI, depending on the proportion of greenstone in a given exposure.

PMt

TRONDHJEMITE DIKES (Permian? to Mississippian?) — Unfoliated dikes of fine- to medium-grained trondhjemite with equigranular to sub-porphyritic texture that intrude gabbro (Mgb) and greenstone (Mg) of the Nail Ridge suite. Individual dikes are typically centimeters to meters wide with high-angle dips. Average modal composition approximately 60–70 percent albite-rich plagioclase, 30–35 percent quartz, 5–15 percent partly chloritized hornblende + biotite, and <1 percent ilmenite + magnetite. K-feldspar is conspicuously absent or present in very low abundance. Magnetic susceptibility is low (0.02–0.20, averaging 0.08 x 10^{-3} SI).

Mg

GREENSTONE (Mississippian?) — Mixed unit composed of several varieties of weakly metamorphosed basalt, both extrusive and intrusive. Textures are aphanitic to fine-grained to porphyritic; some basalts are amygdaloidal. Average modal composition approximately 50 percent clinopyroxene and 50 percent plagioclase; both are usually highly altered to fine-grained secondary assemblages. Locally intruded by dikes of diabase and microgabbro (unit Mdg). Magnetic susceptibility is moderate (0.08–0.50, averaging 0.25 x 10^{-3} SI).

Mdg

DIABASE AND MICROGABBRO (Mississippian?) — Dike swarms of fine- to very fine-grained gabbro with equigranular to diabasic texture. Individual dikes are typically 3-m-wide where visible in outcrop; rubble piles consist of texturally variable rocks comprising multiple dikes. Average modal composition approximately 20–40 percent clinopyroxene, 10–60 percent hornblende and 20–70 percent plagioclase. Magnetic susceptibility is variably high (0.05–2, averaging 0.40 x 10^{-3} SI).

Mgb

GABBRO (Mississippian?) — Occurs as two coarse-grained, equigranular, slightly foliated, plutonic bodies in the northeastern Big Delta C-3 Quadrangle. Average modal composition approximately 50 percent hornblende (up to 8 cm long), 20 percent clinopyroxene, 30 percent plagioclase, and accessory minerals including olivine and magnetite. Also occurs as dikes up to 5 m wide within harzburgite and dunite (unit Pzhd). Magnetic susceptibility is high (0.05–43, averaging 2.5 x 10^{-3} SI). $^{40}Ar/^{39}Ar$ hornblende plateau and saddle ages suggest the unit is Mississippian (map locations A15 and A16; table 1).

Mgl

LAYERED GABBRO (Mississippian?) — Layered, medium-grained, clinopyroxene gabbro occurs along the southern edge of the harzburgite and dunite unit (Pzhd). Average modal composition approximately 50 percent clinopyroxene and 50 percent plagioclase, with minor hornblende and apatite. Modal layering interpreted as cumulate crystallization, not deformation. Magnetic susceptibility is low (0.10–0.20, averaging 0.13 x 10^{-3} SI). Age assignment based on correlation to non-layered equigranular gabbro (unit Mgb).

Pzhd

HARZBURGITE AND DUNITE (Paleozoic) — Primarily harzburgite with lesser dunite and, rarely, olivine orthopyroxenite. Forms bright orangish-brown weathering, blocky outcrops on top of Nail Ridge. Harzburgite contains disseminated to pronounced layers of medium- to coarse-grained, elongate ('tectonized') orthopyroxene. Dunite contains up to 10 percent disseminated grains and layered bands (up to 3 cm thick; average less than 1 cm thick) of chromite; harzburgite generally contains less than 1 percent chromite. Orthopyroxene layering, dunite horizons, and occasional chromite bands are subparallel, and may reflect primary magmatic layering and (or) high-temperature, plastic deformation of mantle. Fractures and joints are commonly filled with secondary serpentine and magnetite. Listwaenite zones are locally present near faults. Low-angle faults at the base of the Nail Ridge suite repeat harzburgite lenses and pods within serpentinite (Pzs) with stratigraphically-higher portions of the ophiolite sequence. Most rocks of the Nail Ridge suite lack penetrative deformation except where proximal to low-, or less commonly, high-angle faults. Magnetic susceptibility is very high (0.60–58, averaging 9 x 10^{-3} SI). Variations reflect differential serpentinization. Age of unit unknown, but presumably Triassic(?) to Mississippian(?).

Pzs

SERPENTINITE (Paleozoic) — Fine-grained, massive to schistose, dark green to black serpentine-rich rock. Alteration product of harzburgite and dunite (unit Pzhd); primarily occurs adjacent to low-angle faults. Magnetic susceptibility is extremely high (10–78, averaging 25 x 10^{-3} SI) due to secondary magnetite produced during serpentinization.

SEDIMENTARY AND LESSER VOLCANIC ROCKS METAMORPHOSED TO GREENSCHIST FACIES

Greenschist-facies metamorphosed rocks in the map area exhibit similarities in protolith age, major- and trace-element composition, and metamorphic facies to metamorphic rocks of the northern Big Delta Quadrangle (Weber and others, 1978), the Eagle Quadrangle (Szumigala and others, 2002), and the Yukon Territory (Mortensen, 1988), suggesting that this unit of greenschist-facies metamorphic rocks is widespread in eastern Interior Alaska and western Canada.

This sequence of rocks consists predominantly of metasedimentary and lesser metavolcanic rocks. The local presence of biotite (and more commonly, its compositional equivalent, muscovite + chlorite) suggests that these rocks were metamorphosed to middle greenschist facies. A biotite-in isograd could not be mapped; either there has been too much deformation subsequent to metamorphism or the rocks of the area essentially straddle the isograd. Sedimentary protoliths are generally quartz-rich feldspathic sandstones or graywackes interlayered with mudstones and minor chert. The high quartz content of these rocks indicates a largely continental source. Minor amounts of detrital tourmaline grains from samples throughout the greenschist-facies sedimentary units were observed in thin sections. Metavolcanic rocks are predominantly metabasite with trace-element compositions indicating a within-plate setting; metarhyolite occurs as sparse lenses of meter- to kilometer-scale strike length. Intermediate-composition metaigneous rocks are conspicuously absent. The overall tectonic setting, indicated by the metasedimentary and metavolcanic rocks most likely represents a rifted continental margin. The localized occurrence of Devonian metarhyolite (unit Dr) suggests a dome morphology. Other felsic units (MDft) likely represent tuff horizons. The metabasalts were shallow intrusions and (or) flows.

We recognize three overall parts to the sequence in the map area: A lowest part, consisting of massive metarhyolite (Dr) and carbonaceous phyllite (MDc); a middle part consisting of mixed metasedimentary and metavolcanic rocks (MDs, MDsv, MDm, MDft, and MDl); and an upper part consisting of a grit- and feldspathic sandstone-rich metasedimentary rocks. A few relatively intact depositional sections of calcareous metasiltstone through metagrit, spanning the middle and upper parts of the sequence, were observed in the Big Delta C-3 Quadrangle. Age assignment is based on one Mississippian and several Late Devonian zircon U-Pb ages of metarhyolite bodies in greenschist-facies rocks of broadly similar character, both in the Big Delta Quadrangle and elsewhere in Interior Alaska. Nearby metarhyolite bodies have yielded both Mississippian and Late Devonian ages (Dusel-Bacon and others, in press).

This sequence of rocks as a whole exhibits more deformation and evidence of strain than rocks of other metamorphic grades in the map area. In particular, relict feldspar phenocrysts in Devonian metarhyolite (Dr) are brecciated and granulated. The middle to upper greenschist-facies unit between the Shaw Creek fault and the Salcha River is strongly crenulated and folded, and small isoclinal recumbent fold axes predominantly plunge shallowly southwest.

Greenschist-facies rocks in the northeastern Big Delta C-3 Quadrangle are in high-angle fault contact with amphibolite-facies rocks to the southwest. The two metamorphic rock sequences were juxtaposed prior to intrusion of the Bonanza Creek pluton at ≈93 Ma (table 1). The northeast-trending block of greenschist-facies rocks in the southeastern Big Delta C-3 Quadrangle dips to the southeast along the faulted northwestern margin; the high-angle, northeast-trending Shaw Creek fault occurs along the southeastern margin. The Salcha River pluton (Ks) intrudes both the greenschist- and amphibolite-facies rock sequences along the northwestern margin of the greenschist-facies block, requiring juxtaposition of these two units prior to ≈106 Ma (table 1). The 10-km-long, northwest-trending, two-mica granite dike (Kt) in the western Big Delta C-3 Quadrangle is truncated by the fault between the greenschist- and amphibolite-facies rocks. The granite body, and hundreds of spatially associated granite dikes, are only found within amphibolite-facies units. This suggests the greenschist- and amphibolite-facies rocks were juxtaposed after intrusion of the granite. Muscovite from the northwest-trending granite dike has an $^{40}Ar/^{39}Ar$ age of 108.2 ± 0.9 Ma (table 1), but it is likely a cooling age since the dike was intruded at a depth of ≈6–8 km. This two-mica granite dike may be approximately age-equivalent to the two-mica granite in the Big Delta C-4 Quadrangle containing zircon with a SHRIMP U-Pb magmatic age of ≈113 Ma (Dusel-Bacon and others, in press). Therefore, juxtaposition of the amphibolite facies units and the greenschist facies units is constrained to be younger than ≈108–113 Ma and older than ≈106 Ma. Along the southeastern margin of the northeast-trending block of greenschist facies rocks, the Shaw Creek fault truncates the Goodpaster batholith, which has U-Pb ages ranging from ≈94-106 Ma (Smith and others, 1999; Dilworth, 2003). Hence, the latest motion on the Shaw Creek fault is younger than ≈94 Ma.

MDg

METAGRIT AND METASANDSTONE (Mississippian to Devonian) — Mixed unit of primarily metagrit and metasandstone, with lesser metagraywacke and phyllite. Metagrit contains rounded quartz and albite grains with a bimodal size distribution and commonly contains >80 weight percent SiO_2. Larger grains range from 1 mm to 1 cm in diameter and constitute 5–40 percent of the rock. The matrix is typically composed of grains <0.05 mm in longest dimension with quartz > albite > white mica > chlorite. Metasandstone is distinguished from metagrit by a more uniform grain size and somewhat lower quartz contents; its protolith is a fine-grained feldspathic sandstone. Metagraywacke contains higher mica abundance (typically 15 percent), displays a pale- to medium-green color, and yields higher magnetic susceptibilities. Phyllite is a quartz-rich, chlorite-white mica-quartz rock with sufficient mica to break into thin sheets. Overall average modal abundance for the unit is 80 percent quartz, 10 percent albite, and 10 percent mica. The unit occurs as loose outcrop knobs and rubble-covered slopes; internal contacts between lithologies were not observed. Magnetic susceptibility is generally low (0.00–0.50, average 0.10 x 10^{-3} SI), with some high values in metagraywacke.

MDs

METASANDSTONE, PHYLLITE, AND METAGRIT (Mississippian to Devonian) — Finely interlayered metasandstone, phyllite (metasiltstone), and minor metagrit, with rare chert. Contains occasional greenstone interbeds (mafic flows or intrusions, MDm) and thin beds of metalimestone and dolomite (MDl), shown on map. Sandstones are feldspathic, sucrosic, and fine-grained. Average modal abundance is 85 percent quartz, 10 percent albite, and 5 percent mica, including trace biotite. Magnetic susceptibility is generally low (0.00–0.50, average 0.14 x 10^{-3} SI); elevated values reflect greenstone horizons.

MDl

METALIMESTONE AND DOLOMITE (Mississippian to Devonian) — Very fine-grained, phyllitic to massive rocks containing >80 percent calcite and (or) dolomite, commonly interlayered with calcareous phyllite. Occurs as lenses, meters to a hundred meters thick; only the thicker layers are depicted. Strongly sheared and recrystallized; no obvious sedimentary structures are evident. Magnetic susceptibility is extremely low (0.00–0.13, average 0.05 x 10^{-3} SI).

MDft

FELSIC METATUFF (Mississippian to Devonian) — Fine-grained, banded, pale gray-green phyllitic rocks with major-element compositions corresponding to rhyolite, keratophyre, and rarely, dacite; presumed to represent seawater-altered tuffaceous horizons. Thickness up to 100 m, but more typically a few tens of meters. Magnetic susceptibility is low (0.00–0.30, average 0.14 x 10^{-3} SI).

MDsv

METASANDSTONE, PHYLLITE, METAGRIT, AND GRAYWACKE (Mississippian to Devonian) — Finely interlayered metasandstone, phyllite, and metagrit, with rare to locally abundant beds of metagraywacke, and, rarely, chert and metasiltstone. Contains lenses of felsic tuff? (MDft) and greenstone (MDm), both shown on map. Distinguished from unit MDs by the greater abundance of metavolcanic rocks (especially lenses of felsic metatuff) and higher graywacke component to metasandstones. Average modal composition of the metasedimentary rocks is 65 percent quartz, 10 percent albite, 10 percent K-feldspar, and 15 percent mica, including chlorite and trace biotite. Magnetic susceptibility is generally low, but variable (0.00–1.0, average 0.11 x 10^{-3} SI), reflecting the variety of rock types present.

MDm

GREENSTONE (Mississippian to Devonian) — Fine-grained, medium to dark green, phyllitic to massive quartz-chlorite-albite rocks that represent basalt flows or fine-grained gabbroic intrusions or dikes. Also contains variable amounts of actinolite, epidote, apatite, ilmenite, rutile, magnetite, and calcite. Some remnant diabasic texture is evident in thin section, but original mineralogy and texture is largely obscured by seawater alteration and subsequent metamorphism. Within-plate, extensional trace-element signature and basaltic major-element composition is uniformly characteristic. Greenstone is present as thin (<1 m) to thick (100 m) layers sporadically present throughout the lower and middle parts of the greenschist package. Thicker layers, as mapped, include minor amounts of metasedimentary rocks. Magnetic susceptibility is variable, but generally high (0.10–58, average 2.3 x 10^{-3} SI); lower values are due to interbedded metasedimentary lithologies.

MDc

CARBONACEOUS PHYLLITE AND META-SANDSTONE (Mississippian to Devonian) — Mixed unit of moderately to highly crenulated, commonly fissile, phyllite, lesser metasandstone, and, rarely, felsic tuff (MDft). Stratigraphically interlayered with the Devonian metarhyolite unit (Dr). Phyllite is carbon-rich, dark gray to black. High carbon content may suggest unit was deposited in a restricted basin within an extensional setting. The metasandstones are particularly quartz-rich and feldspar-poor, commonly containing >85 percent SiO_2. Resistivity data show this unit is strongly conductive (Burns and others, 2000). The magnetic susceptibility is very low (0.00–0.25, average 0.05 x 10^{-3} SI), reflecting the absence of mafic components in the unit. Resembles and is correlated with the Nasina quartzite of eastern Interior Alaska and the central Yukon Territory (Weber and others, 1978; Dusel-Bacon and others, 1998).

Dr

METARHYOLITE (Devonian) — Porphyritic metarhyolite, with K-feldspar megacrysts up to 2 cm in length in a matrix with an average grain size of <1 mm. Located along the North Fork of the Salcha River in the north-central Big Delta C-3 Quadrangle. Porphyroclastic, mylonitic textures are characteristic. Average modal composition approximately 45 percent quartz, 35 percent K-feldspar, 15 percent plagioclase, 5 percent muscovite, and <0.5 percent accessory minerals. Exhibits a pronounced potassium high in radiometric data (Burns and others, 2000). Magnetic susceptibility is extremely low (0.00–0.09, average 0.05 x 10^{-3} SI). Devonian age for this unit based on correlation with a texturally, mineralogically, and chemically similar metarhyolite with a zircon U-Pb age of 371 ± 7 Ma, located approximately 10 km to the west in the Big Delta C-4 Quadrangle (Dusel-Bacon and others, in press).

SEDIMENTARY, PLUTONIC, VOLCANIC, AND ULTRAMAFIC ROCKS METAMORPHOSED TO AMPHIBOLITE FACIES

Amphibolite-facies metamorphosed rocks in the map area exhibit similarities in protolith age, major- and trace-element composition, and metamorphic facies to metamorphic rocks of the southern Big Delta and Tanacross quadrangles (Dusel-Bacon and Cooper, 1999) and to the Fairbanks area (Newberry and others, 1996), suggesting that this unit of amphibolite-facies metamorphic rocks is widespread in eastern Interior Alaska.

We divide the bulk of the amphibolite-facies metamorphic rocks in the map area into three major units on the basis of protoliths and stratigraphic/structural position:

(1) an upper unit characterized by abundant metavolcanic and metaplutonic rocks (metabasites display arc and MORB trace-element signatures); (2) a middle unit dominated by variable sedimentary protoliths including shale and

sandstone and by metabasites displaying within-plate trace-element signatures; and (3) a lower unit of predominantly homogeneous, peraluminous paragneiss.

Our new, detailed geologic mapping and definition of stratigraphy, recognition of bulk-compositional differences between units, petrographic work, microprobe analyses, and recalculated temperatures from previous microprobe analyses from garnet-biotite pairs in the Big Delta C-3 and C-4 Quadrangles (Dusel-Bacon and Foster, 1983) using the methods of Perchuk and Lavrent'eva (1981), Berman (1990), and Kleemann and Reinhardt (1994), indicate: 1) relatively uniform mid-amphibolite-facies temperatures of approximately 550–640ºC, 2) a possible broad regional increase in metamorphic temperatures towards the south, 3) no sharp discontinuities in temperature or metamorphic grade documented between the paragneiss unit (pMp) and stratigraphically-higher units (pMsq, pMaw, pMsp. pMq), and 4) major changes in protolith and bulk composition between schist- and gneiss-rich units. Metamorphic minerals, for example, staurolite and cordierite, appear to be highly stratabound in occurrence, reflecting particular bulk compositional requirements. Amphibolite-facies rocks in the map area appear to have experienced two, and locally three separate metamorphic episodes: (1) regional metamorphism under (kyanite-stable) mid-amphibolite-facies conditions (≈550–600°C?, ≈8 kbars), similar to that experienced in the Eagle and Fairbanks Quadrangles; (2) a high-temperature, relatively low-pressure regional event (≈570–640°C, ≈3–4 kbars) associated with sillimanite indirectly replacing kyanite, centered in the southwestern Big Delta C-3 and central C-4 Quadrangles and spatially associated with peraluminous granite sills and dikes of collisional tectonic affinity (unit Kt); and (3) locally widespread contact metamorphism, best developed in the roof zone of the Upper Boulder Creek pluton (unit Kub) in the southwestern Big Delta C-2 Quadrangle.

Orthogneiss bodies in the Big Delta B-1 and B-2 quadrangles, which intrude the amphibolite-facies package, have zircon U–Pb (magmatic) ages that range from Late Devonian to the Devonian-Mississippian boundary (Day and others, 2003; Dusel-Bacon and others, in press). Within the map area, orthogneiss bodies (MDog, MDogd, MDot, MDo) occur as isolated pluton-shaped bodies several square kilometers in size, as apparent sill-shaped bodies up to several hundred meters thick, and as small, isolated sill-shaped bodies. They range in composition from granite to tonalite. Usually medium- to coarse-grained, the coherent bodies, especially those displaying compositional zonation, are metamorphosed and deformed plutons. Some smaller, sill-shaped bodies might be metamorphosed volcanic rocks or dikes that have been rotated parallel to regional foliation. Since the amphibolite-facies metamorphic rocks are intruded by orthogneiss, they are interpreted to be of Devonian age or older.

Hornblendes from amphibolites in the Big Delta C-3, C-2, B-3, B-2, and C-4 quadrangles yield $^{40}Ar/^{39}Ar$ highest-temperature fraction, stepped pseudoplateau, plateau, and saddle ages that range from approximately 96 to 219 Ma (map locations A17–A22, and sample 02JEA625A in the Big Delta C-4 Quadrangle; table 1). The age spectra for several of these amphibolites record Jurassic metamorphic ages. Amphibolites with younger ages are interpreted to have been partly to completely reset by a Cretaceous thermal event, arguably that related to intrusion of the many Cretaceous plutons in the map area. U-Pb and $^{40}Ar/^{39}Ar$ data indicate that one amphibolite body (unit Ma) at the intersection of the Big Delta C-3, C-4, B-3, and B-4 quadrangles is Mississippian in age (map location A23; table 1); it was not overprinted by Jurassic or Cretaceous metamorphic thermal events.

Ma

GARNET AMPHIBOLITE (Mississippian) — Fine- to medium-grained, green, garnet-bearing plagioclase-hornblende amphibolite. Previously mapped as Paleozoic diorite by Weber and others (1978), but bulk composition is that of basalt, and foliation is clearly of metamorphic origin. Trace-element composition indicates a within-plate, oceanic-island basalt origin (Dusel-Bacon and others, in press). Magnetic susceptibility is moderate (0.20–0.50, average 0.37 x 10^{-3} SI), similar to that of other amphibolites. U-Pb analyses of six fractions of strongly abraded zircons are all concordant between 335 and 357 Ma (J.K. Mortensen, written commun., 2003). Hornblende from this unit yields $^{40}Ar/^{39}Ar$ plateau and pseudoplateau ages of approximately 290–390 (average, 350 $\pm$ 10) Ma (map location A23; table 1). This amphibolite has not been overprinted by Jurassic or Cretaceous metamorphism, unlike all other amphibolites with radiometric dates in the Big Delta Quadrangle. This unit is plausibly part of the Nail Ridge suite; it may represent an amphibolite-facies assemblage that formed during the Mississippian as part of a deeply buried portion of the oceanic package, which cooled to below 500ºC in the Paleozoic. This unit must be in low-angle fault contact with underlying amphibolite-facies units that possess Mesozoic $^{40}Ar/^{39}Ar$ ages. The final emplacement of the garnet amphibolite presumably followed Early Cretaceous deformation and metamorphism indicated by the abundance of $^{40}Ar/^{39}Ar$ cooling ages from metamorphic rocks in the Yukon–Tanana Uplands (e.g., table 1, this study; Dusel-Bacon and others, 2002; Dusel-Bacon and others, 2003).

MDog

GRANITE ORTHOGNEISS (Mississippian to Devonian) — Dominantly moderately to strongly foliated rocks with granite major-oxide and modal composition. Typical rocks are medium- to very coarse-grained with a mylonitic to blastoporphyritic-mylonitic texture composed of large K-feldspar and quartz grains (augen) surrounded by finer-grained, foliated, quartz + feldspar + mica (biotite + muscovite). Commonly is an augen gneiss. Average modal abundance is 35 percent quartz, 30 percent K-feldspar, 25 percent plagioclase, and 10 percent mica (muscovite + biotite), with < 0.5 percent accessory minerals, including zircon, apatite, allanite, and ilmenite. Includes some orthogneiss of granodiorite composition and minor paragneiss and schist. Magnetic susceptibility is generally low, but includes occasional very high values (0.00–3.4, average 0.12 x 10^{-3} SI).

MDogd

GRANODIORITE ORTHOGNEISS (Mississippian to Devonian) — Dominantly moderately- to strongly-foliated rocks with granodiorite major-oxide and modal composition. Texture is fine- to coarse-grained, with occasional K-feldspar augen to 1 cm; more texturally uniform than MDog. Average modal abundance is 25 percent quartz, 20 percent K-feldspar, 40 percent plagioclase, and 15 percent mafic minerals, with biotite > hornblende > muscovite. Includes some orthogneiss of granite and tonalite modal composition. Resembles granodioritic orthogneiss of the Fairbanks mining district (Newberry and others, 1996). Magnetic susceptibility is generally low with occasional high values (0.00–2.7, average 0.13 x 10^{-3} SI).

MDot

TONALITE ORTHOGNEISS (Mississippian to Devonian) — Dominantly moderately to strongly foliated rocks with tonalite to trondhjemite major-oxide and modal composition. Slightly porphyritic, with medium- to coarse-grained quartz phenocrysts in a fine-grained plagioclase–quartz–biotite matrix. Average modal abundance is 30 percent quartz, 1 percent K-feldspar, 59 percent plagioclase, and 10 percent biotite. Includes some granodiorite orthogneiss, minor schist, and paragneiss. Resembles tonalitic orthogneiss of the southeastern Eagle Quadrangle in texture and mineralogy (Werdon and others, 2001b; Szumigala and others, 2002). Magnetic susceptibility is generally low (0.02–0.80, average 0.12 x 10^{-3} SI).

MDo

UNDIFFERENTIATED ORTHOGNEISS (Mississippian to Devonian) — Mixed unit consisting dominantly of foliated granitic orthogneiss with lesser schist and paragneiss. Modal abundances show that granite > granodiorite > tonalite. May represent original granitic dikes or small plutons structurally intermixed with country rocks during deformational events. Magnetic susceptibility is generally low, with occasional high values (0.00–0.60, average 0.12 x 10^{-3} SI).

MzPzum

META-ULTRAMAFIC AND MAFIC ROCKS (Mesozoic to Paleozoic) — Includes serpentinite, clinopyroxenite, hornblendite, dunite, hornblende metagabbro, clinopyroxene metagabbro, and, rarely, anorthosite. Occurs as folded, foliation-parallel bodies exhibiting either a metamorphic-stratigraphic position above or within unit MzPza. Ultramafic rocks locally contain anthophyllite, a high-temperature amphibole, which indicates these ultramafic rocks were metamorphosed to amphibolite facies along with their surrounding host rocks. Spatially corresponds with magnetic highs in aeromagnetic data, and potassium lows in radiometric data (Burns and others, 2000). Magnetic susceptibility is highly variable, reaching extremely high values (0.10–78, average 10 x 10^{-3} SI), reflecting the variety of rocks types present in the unit. Locally, select samples are anomalous in platinum-group elements (up to 25.2 ppb platinum and 45 ppb palladium; Athey and others, 2002; Werdon and others, 2003). It is unclear what, if any, association this unit has with the Seventymile terrane; the metamorphic grade for this unit is higher, and hornblende from the spatially, and probably genetically related unit MzPza, has been overprinted by Jurassic and Cretaceous metamorphic events.

MzPza

AMPHIBOLITE, HORNBLENDE GNEISS, TONALITIC ORTHOGNEISS (Mesozoic to Paleozoic) — Hornblende-bearing metamorphic rocks with variable plagioclase and quartz contents, and mafic to intermediate igneous bulk compositions. Unit is foliation-parallel and has been folded along with underlying amphibolite-facies units. Trace-element analyses of amphibolites indicate this unit contains both calc-alkaline island arc and mid-ocean ridge basalt affinities. Magnetic susceptibility is highly variable, reaching extremely high values (0.00–64, average 2.0 x 10^{-3} SI), reflecting the varieties of rocks present. Unit variably overlies pMq, pMsp, pMaw, MDog, and MDo in the Big Delta C-3 Quadrangle, and hence the lower contact could either be a pre-Jurassic thrust emplaced prior to deformation (as shown on the map), or an unconformable contact, that is, an arc formed on top of an older, more continental package. Unit MzPza is locally cut by orthogneiss (southeastern part of the northeast quadrant of the Big Delta B-3 Quadrangle), indicating a pre-Mississippian age.

pMq

QUARTZITE (pre-Mississippian) — Primarily quartzite, with lesser schist and gneiss, and minor marble and calc-silicate marble. Predominant lithology is fine- to medium-grained, sucrosic, massive, white to color-banded, nearly pure quartzite. Magnetic susceptibility is generally low, but contains occasional highly magnetic interlayers (0.00–10, average 0.25 x 10^{-3} SI).

pMsp

SCHIST AND PARAGNEISS (pre-Mississippian) — Primarily fine- to coarse-grained schist and paragneiss, with lesser amphibolite and quartzite. Laterally grades into unit pMaw. Trace-element analyses indicate amphibolite has within-plate, extensional chemistry. Modal composition of schist is highly variable; primary minerals include biotite, white mica, quartz, plagioclase, and widely varying proportions of metamorphic indicator minerals, including garnet, staurolite, kyanite, sillimanite, andalusite, cordierite, and K-feldspar. Accessory minerals include tourmaline, apatite, zircon, and ilmenite. Paragneiss is less variable, consisting of 50 percent or more quartz and 20 percent or more plagioclase, with less than 20 percent biotite + muscovite. Magnetic susceptibility is variable (0.00–12, average 0.22 x 10^{-3} SI), reflecting the variety of rock types present.

pMaw

AMPHIBOLITE (pre-Mississippian) — Primarily fine- to medium-grained amphibolite, with lesser schist, paragneiss, and quartzite; laterally grades into unit pMsp. Trace-element analyses indicate amphibolite has within-plate, extensional chemistry. Magnetic susceptibility is moderate to high (0.10–11, average 0.40 x 10^{-3} SI).

pMsq

SCHIST AND QUARTZITE (pre-Mississippian) — Primarily schist, with lesser quartzite and, rarely, paragneiss. Schist is fine- to medium-grained, contains quartz + muscovite ± biotite and variable amounts of staurolite, cordierite, kyanite, sillimanite, andalusite, garnet, and (or) tourmaline, and accounts for approximately one-half of the unit. Quartzite is fine-grained, variably micaceous, and accounts for approximately one-third of the unit. Paragneiss is quartz-rich with significant feldspar and little mica and accounts for the remainder of the unit. Magnetic susceptibility is variably low (0.03–0.60, average 0.17 x 10^{-3} SI).

pMp

SILLIMANITE-BEARING PARAGNEISS (pre-Mississippian) — Medium- to coarse-grained, homogeneous, granoblastic, quartz-rich gneissic unit characterized by uniform hand specimen appearance and very few occurrences of interbedded (pMql) or interlayered (orthogneiss) lithologies. Average modal abundance is 53 percent quartz, 12 percent K-feldspar, 17 percent plagioclase, 16 percent biotite, and 2 percent peraluminous accessory minerals [sillimanite and (or) cordierite]. Muscovite is common in trace amounts; the presence of K-feldspar + sillimanite in many samples indicates metamorphism at approximately the upper stability of muscovite + quartz. The bulk composition is consistent with an arkosic sandstone protolith, rather than shale, as evidenced by the high quartz content of the rock. Sillimanite, usually only visible on cut slabs or in thin sections, can exceed 10 percent and is virtually ubiquitous; cordierite can be greater than 15 percent of the rock. Garnet is present locally in trace amounts. Extensively hornfelsed by Kub in the Big Delta C-2 Quadrangle to produce a cordierite-rich gneiss. Exhibits a pronounced potassium/thorium high in radiometric data (Burns and others, 2000), attributed to the high potassium content of the rock. Interpreted to represent a homogeneous sandstone-rich protolith, distinguished from rocks of the middle and upper units by the virtual absence of igneous protoliths and uniformity of composition. On the outcrop scale, this unit characteristically contains a few peraluminous, commonly tourmaline-bearing, granite sills and dikes, with sharply defined intrusive contacts. No evidence for partial or incipient melting is observed, consistent with metamorphic conditions straddling muscovite + quartz stability. Magnetic susceptibility is uniformly low (0.00–0.30, averaging 0.10 x 10^{-3} SI).

pMql

LOWER QUARTZITE (pre-Mississippian) — Primarily quartzite, with rare marble and calc-silicate gneiss. Occurs as thin lenses within pMp. Quartzite compositionally approaches paragneiss, but contains significantly more quartz and less biotite than typical of pMp. Magnetic susceptibility is low (0.00–0.30, averaging 0.08 x 10^{-3} SI).

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Table 1. *Interpreted $^{40}Ar/^{39}Ar$ ages for selected samples from the Big Delta Quadrangle, Alaska*

Map No.	Sample	Quadrangle Location	UTM Easting[a]	UTM Northing[a]	Rock Type	Unit Label	Mineral Analyzed	Integrated Age (Ma)[b]	Best Interpreted Age (Ma)[b, c]	Plateau, pseudoplateau, or saddle-plateau information
PLUTONIC AND METAPLUTONIC ROCKS										
A1	01JEA447A	C-3	585868	7158354	Hypabyssal granite intruding MDs	Khg	Biotite #1	69.6 ± 0.7	69.6 ± 0.7	7 fractions, 67% ^{39}Ar release MSWD = 0.7
A1	01JEA447A	C-3	585868	7158354	Hypabyssal granite intruding MDs	Khg	Biotite #2	67.7 ± 0.7	68.1 ± 0.6	7 fractions, 90% ^{39}Ar release MSWD = 1.6
A2	77AWr370	C-3 Bonanza Creek pluton	581936	7177053	Biotite granite	Kbgr	Biotite	92.5 ± 0.6	92.8 ± 0.6	8 fractions, 98% ^{39}Ar release MSWD = 1.8
A3	02RN496A	C-3	593433	7172907	Hornblende-biotite tonalite	Ktn	Hornblende #1	92.5 ± 0.8	95.9 ± 0.9 pseudoplateau	3 fractions, 58% ^{39}Ar release MSWD = 15.9
A3	02RN496A	C-3	593433	7172907	Hornblende-biotite tonalite	Ktn	Hornblende #2	94.4 ± 1.1	96.5 ± 1.1	8 fractions, 96% ^{39}Ar release MSWD = 0.7
A4	01RN516A	B-2	596711	7148864	Hornblende tonalite	Ktn	Biotite	95.8 ± 0.9	96.5 ± 0.9	11 fractions, 95% ^{39}Ar release MSWD = 0.9
A4	01RN516A	B-2	596711	7148864	Hornblende tonalite	Ktn	Hornblende	100.4 ± 1.1	99.2 ± 1.1	7 fractions, 86% ^{39}Ar release MSWD = 2.1
A5	02Z421A	B-3 Hook Property	595593	7146550	Alkalic multiphase pluton; dated biotite from monzonite	Ka	Biotite, fine fraction	94.1 ± 0.6	95.1 ± 0.6	9 fractions, 89% ^{39}Ar release MSWD = 1.4
A5	02Z639A	B-3 Hook Property	595593	7146550	Sericite alteration associated with gold-bearing quartz vein in pluton	Ka	Sericite fine fraction	97.5 ± 0.5	98.0 ± 0.5	10 fractions, 90% ^{39}Ar release MSWD = 2.2
A5	02Z639A	B-3 Hook Property	595593	7146550	Sericite alteration associated with gold-bearing quartz vein in pluton	Ka	Sericite coarse fraction	99.2 ± 0.7	101.1 ± 0.8	7 fractions, 77% ^{39}Ar release MSWD = 1.8
A6	75AWr263	C-2 Goodpaster batholith	598468	7155522	Hornblende-biotite granodiorite	Kgp	Hornblende	99.1 ± 0.7	101.0 ± 2.5 pseudoplateau	7 fractions, 72% ^{39}Ar release MSWD = 13.0
A7	75AWr267B	C-2 Upper Boulder pluton	606073	7163417	Granite	Kub	Biotite	102.4 ± 0.7	102.3 ± 0.7	5 fractions, 47% ^{39}Ar release MSWD = 0.8
A8	75AFr236A	C-2 Upper Boulder pluton	607133	7160554	Granodiorite	Kub	Biotite	104.8 ± 0.7	106.4 ± 0.7	8 fractions, 75% ^{39}Ar release MSWD = 2.5
A9	02JEA614A	C-2	600385	7168480	Granodiorite	Kgd	Biotite	105.3 ± 1.0	105.9 ± 1.0	6 fractions, 77% ^{39}Ar release MSWD = 0.5
A10	77AWr340	C-3 Salcha River pluton	589094	7168001	Granodiorite	Ks	Hornblende	103.3 ± 0.7	105.2 ± 0.8	6 fractions, high Ca/K 41% ^{39}Ar release; MSWD = 1.1
A10	77AWr340	C-3 Salcha River pluton	589094	7168001	Granodiorite	Ks	Biotite	104.9 ± 0.7	107.3 ± 0.7	8 fractions, 83% ^{39}Ar release MSWD = 1.6
A11	01RN460B	B-2	598297	7148930	Two-mica + tourmaline + garnet granite	Kt	Muscovite	92.9 ± 0.9	93.0 ± 0.9	9 fractions, 85% ^{39}Ar release MSWD = 1.4
[d]	00RN630	C-4	564830	7168872	Two-mica + tourmaline granite	Kt	Muscovite	103.7 ± 1.6	104.6 ± 1.2	5 fractions, 96% ^{39}Ar release MSWD = 0.5
A12	02Z223B	C-3	575209	7164420	Two-mica + tourmaline granite	Kt	Muscovite	107.8 ± 0.9	108.2 ± 0.9	8 fractions, 99% ^{39}Ar release MSWD = 1.9
A13	01Z342A	B-2	598010	7152381	Metatonalite	KJmp	Biotite	104.1 ± 1.0	104.4 ± 1.0	8 fractions, 77% ^{39}Ar release MSWD = 0.98
A13	01Z342A	B-2	598010	7152381	Metatonalite	KJmp	Hornblende #1	103.7 ± 0.9	105.3 ± 1.0 high-temperature fraction	1 fraction, 51% ^{39}Ar release MSWD = 0
A13	01Z342A	B-2	598010	7152381	Metatonalite	KJmp	Hornblende #2	102.3 ± 1.0	105.3 ± 1.0 pseudoplateau	6 fractions, 65% ^{39}Ar release MSWD = 5.1
A14	02JEA529A	B-3	585366	7145512	Metagranodiorite	KJmp	Biotite	129.1 ± 1.2	130.2 ± 1.2 pseudoplateau	8 fractions, 68% ^{39}Ar release MSWD = 3.7

Analysts: Paul W. Layer and Jeff Drake, University of Alaska Fairbanks Geochronology Laboratory.

[a]Coordinates given in Universal Transverse Mercator (UTM) projection, zone 6; based on Clark 1866 spheroid, North American Datum (NAD) 27.

[b]All errors are given at the 1-sigma level.

[c]Ages are plateau ages unless specified otherwise. A plateau is defined as ≥3 consecutive fractions, with a Mean Standard Weighted Deviation (MSWD) < ≈2.5, and more than 50% ^{39}Ar release. If a sample is close, it is termed a 'pseudoplateau'. A saddle refers to the relatively flat central portion of a spectrum that is selected to calculate a weighted average age.

[d]Sample located outside of map area.

Table 1. *Interpreted $^{40}Ar/^{39}Ar$ ages for selected samples from the Big Delta Quadrangle, Alaska–continued*

Map No.	Sample	Quadrangle Location	UTM Easting[a]	UTM Northing[a]	Rock Type	Unit Label	Mineral Analyzed	Integrated Age (Ma)[b]	Best Interpreted Age (Ma)[b, c]	Plateau, pseudoplateau, or saddle-plateau information
PREHNITE-PUMPELLYITE TO LOWER GREENSCHIST-FACIES IGNEOUS ROCKS										
A15	02RN412A	NE C-3 Nail Ridge	593770	7176482	Coarse-grained gabbro	Mgb	Hornblende #1	916.2 ± 12.3	None. Complex spectrum	
A15	02RN412A	NE C-3 Nail Ridge	593770	7176482	Coarse-grained gabbro	Mgb	Hornblende #2	740.5 ± 7.6	Saddle at 380.0 ± 4.5	1 fraction, 43% ^{39}Ar release MSWD = N/A
A15	02RN412A	NE C-3 Nail Ridge	593770	7176482	Coarse-grained gabbro	Mgb	Hornblende #3	718.8 ± 12.1	Saddle at 346.0 ± 14.1	4 fractions, 43% ^{39}Ar release MSWD = 1.0
A15	02RN412A	NE C-3 Nail Ridge	593770	7176482	Coarse-grained gabbro	Mgb	Hornblende #4	906.2 ± 7.9	Saddle at 386.0 ± 6.8	2 fractions, 37% ^{39}Ar release MSWD = 0.4
A16	02Z135A	NE C-3 Nail Ridge	591156	7175094	Coarse-grained gabbro	Mgb	Hornblende #1	394.7 ± 6.7	330.9 ± 11.6 pseudoplateau	4 fractions, 35% ^{39}Ar release MSWD = 21.35
A16	02Z135A	NE C-3 Nail Ridge	591156	7175094	Coarse-grained gabbro	Mgb	Hornblende #2	459.9 ± 7.8	341.5 ± 11.6 pseudoplateau	4 fractions, 70% ^{39}Ar release MSWD = 3.6
A16	02Z135A	NE C-3 Nail Ridge	591156	7175094	Coarse-grained gabbro	Mgb	Hornblende #3	458.1 ± 23.2	357.7 ± 14.3	3 fractions, 74% ^{39}Ar release MSWD = 0.6
A16	02Z135A	NE C-3 Nail Ridge	591156	7175094	Coarse-grained gabbro	Mgb	Hornblende #4	320.0 ± 10.2	311.6 ± 10.5	10 fractions, 87% ^{39}Ar release MSWD = 0.5
AMPHIBOLITE-FACIES METAMORPHIC ROCKS										
A17	02MBW1A	C-3	574106	7176822	Amphibolite	MzPza	Hornblende #1	95.7 ± 3.1	96.3 ± 3.0	9 fractions, 98% ^{39}Ar release MSWD = 1.5
A17	02MBW1A	C-3	574106	7176822	Amphibolite	MzPza	Hornblende #2	105.5 ± 1.5	105.5 ± 1.3	7 fractions, 94% ^{39}Ar release MSWD = 0.9
A18	02Z301B	C-2	601820	7163302	Amphibolite	MzPza	Hornblende	106.1 ± 1.2	107.2 ± 1.2	6 fractions, 94% ^{39}Ar release MSWD = 0.3
A19	02MBW116A	C-3	584548	7171453	Amphibolite	MzPza	Hornblende	128.7 ± 5.6	116.1 ± 5.8	4 fractions, 66% ^{39}Ar release MSWD = 0.6
A20	02RN345A	B-3	593582	7140660	Amphibolite	pMsp	Hornblende	153.9 ± 2.0	160.5 ± 2.3	4 fractions, 52% ^{39}Ar release MSWD = 1.0
A21	02Z256A	C-3	573895	7155060	Amphibolite	MzPza	Hornblende	169.5 ± 4.4	189.6 ± 5.4	3 fractions, 47% ^{39}Ar release MSWD = 0.4
A22	01MBW732A	C-3	579377	7166315	Amphibolite	pMaw	Hornblende	133.1 ± 2.0	132.3 ± 3.0	5 fractions, 42% ^{39}Ar release MSWD = 1.0
[d]	02JEA625A	C-4	567903	7161114	Amphibolite	pMaw	Hornblende #1	123.4 ± 2.8	161.7 ± 11.8	1 fractions, 9.2% ^{39}Ar release MSWD = 0
[d]	02JEA625A	C-4	567903	7161114	Amphibolite	pMaw	Hornblende #2	217.8 ± 2.3	219.0 ± 4.0	2 fractions, 12% ^{39}Ar release MSWD = 1.3
A23	02JEA225A	SW C-3	572810	7153519	Garnet-bearing amphibolite	Ma	Hornblende #1	353.4 ± 2.5	356.3 ± 9.6 pseudoplateau	2 fractions, 72% ^{39}Ar release MSWD = 10.28
A23	02JEA225A	SW C-3	572810	7153519	Garnet-bearing amphibolite	Ma	Hornblende #2	275.4 ± 5.1	289.6 ± 8.6	4 fractions, 74% ^{39}Ar release MSWD = 2.5
A23	02JEA225A	SW C-3	572810	7153519	Garnet-bearing amphibolite	Ma	Hornblende #3	384.0 ± 5.5	361.9 ± 6.5	3 fractions, 68% ^{39}Ar release MSWD = 1.9
A23	02JEA225A	SW C-3	572810	7153519	Garnet-bearing amphibolite	Ma	Hornblende #4	364.4 ± 10.6	392.1 ± 6.0 pseudoplateau	2 fractions, 73% ^{39}Ar release MSWD = 1.7

[a]Analysts: Paul W. Layer and Jeff Drake, University of Alaska Fairbanks Geochronology Laboratory.
[b]Coordinates given in Universal Transverse Mercator (UTM) projection, zone 6; based on Clark 1866 spheroid, North American Datum (NAD) 27.
[c]All errors are given at the 1-sigma level.
[d]Ages are plateau ages unless specified otherwise. A plateau is defined as ≥3 consecutive fractions, with a Mean Standard Weighted Deviation (MSWD) < ≈2.5, and more than 50% ^{39}Ar release. If a sample is close, it is termed a 'pseudoplateau'. A saddle refers to the relatively flat central portion of a spectrum that is selected to calculate a weighted average age.
[e]Sample located outside of map area.

Table 2. *Conventional ID-TIMS U-Pb analytical data for zircon from metagranodiorite in the Big Delta B-3 Quadrangle, Alaska (map location U7, sample number 02RN533A)*

Sample Description[a]	Weight (mg)	U (ppm)	Pb[b] (ppm)	206Pb/204Pb (measured)[c]	Total common Pb (pg)	Percent 208Pb[b]	206Pb/238U[d] (± % 1σ)	207Pb/235U[d] (± % 1σ)	207Pb/206Pb[d] (± % 1σ)	206Pb/238U age (Ma; ± % 2σ)	207Pb/206Pb age (Ma; ± % 2σ)
A: N2, +134,p	0.024	906	16.0	6254	4	4.1	0.01876(0.20)	0.1243(0.30)	0.04806(0.23)	119.8(0.5)	102.0(10.8)
B: N2, +134,p	0.029	379	34.5	12060	5	8.4	0.08420(0.14)	1.7439(0.18)	0.15021(0.10)	521.2(1.4)	2348.3(3.4)
C: N2, +134,p	0.010	1266	53.4	5768	6	7.3	0.04276(0.16)	0.3801(0.23)	0.06447(0.16)	269.9(0.8)	757.2(6.6)
D: N2, +134,e	0.016	346	64.4	10580	6	7.8	0.18034(0.12)	2.6726(0.17)	0.10748(0.09)	1068.9(1.4)	1757.2(3.4)
E: N2, +134,e	0.033	303	10.3	6503	3	11.7	0.03322(0.12)	0.2358(0.23)	0.05148(0.17)	210.7(0.5)	262.2(8.0)
F: N2, +134,e	0.028	531	29.5	5262	9	13.5	0.05261(0.13)	0.4441(0.19)	0.06122(0.11)	330.5(0.8)	647.1(4.9)

Analyst: James K. Mortensen; Pacific Centre for Isotopic and Geochemical Research, University of British Columbia. Sample location: Easting = 591390, northing = 7149038; coordinates given in Universal Transverse Mercator (UTM) projection, zone 6; based on Clark 1866 spheroid, North American Datum (NAD) 27.

[a] A–F = name of zircon fraction; N2 = non-magnetic at 2 degrees side slope on Frantz magnetic separator; +134 = grain size in microns; p = prismatic grains; e = equant grains.

[b] Radiogenic Pb; corrected for blank, initial common Pb, and spike.

[c] Corrected for spike and fractionation.

[d] Corrected for blank Pb and U, and common Pb.

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