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Geologic map of the Livengood quadrangle, Alaska

by

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DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

Qa **Alluvium (Holocene)**—Silt, sand, and granule- to boulder-sized material having minor amounts of organic debris, gray, yellowish-gray to brown, well -sorted and -stratified. Alluvium shows fining-upward cycles. Underlies active stream beds or floodplain, locally frozen in silty channels; includes placer-mine tailings on sections of Quail, Troublesome, Ophir, and Nome Creeks, streams in Livengood village area, and southeast of Chatanika River in Fairbanks mining district; 0.3 m to approximately 15 m thick.

Qg **Reworked creek gravels in placer mining areas (Holocene)**—Placer-mine tailings derived from buried stream gravels worked for gold by methods of pick and shovel, mechanized surface, underground drifting, or dredging methods; shown, as map scale permits, on Fairbanks and Livengood Creeks, elsewhere included in Qa. Commonly less than 9 m thick.

Qab **Abandoned or inactive flood plain deposits (Holocene)**—Silt, sand, granule- to pebble-size gray gravel, and organic material. Abandoned stream channels 0.6 to 4.5 m topographically higher than active channels of Qa, elsewhere flat to hummocky and many bogs. Includes small alluvial fans, deposited by minor side streams, and intermixed alluvial sediments and very silty natural stream levees from cyclical flooding of Minto Flats. Commonly frozen. As thick as 30 m.

Qd **Sand dune deposits (Holocene)**—Sand, moderate yellowish-brown, well-sorted, eolian. Grains 65 to 85 percent quartz, yellowish-white, clear to opaque, angular to round; dark gray to black rock fragments, chert, mica, traces of feldspar and light-colored rock fragments. Isolated dunes mostly covered by eolian silt and stabilized by vegetation. As thick as 9 m.

Qs **Swamp deposits (Holocene)**—Humus, peat, and silt in poorly-drained areas having abundant stagnant water; generally frozen below a depth of about a meter; some small swampy areas included in units Qa, Qab, and Qsu. As thick as tens of meters.

Qaf **Alluvial fan deposits (Holocene)**—Sand, gravel, and boulders, gray to brown, poorly- to well-sorted and stratified, coarse-grained, rounded to angular; clasts locally-derived and deposited under high-energy conditions below major decrease in slope. Locally covered by reworked silt and small amount of vegetation. Thickness varies greatly; only largest alluvial fans shown on map.

Qsu **Silt, undifferentiated, contains reworked loess, swamp and organic-rich deposits (Holocene)**—Silt, pale yellowish brown, largely eolian, and in part, locally retransported to lower slopes and valley bottoms by alluvial and solifluctional processes. Local brown to grayish black organic rich layers, masses, and disseminated debris. Poorly drained and frozen as abundant horizontal and vertical sheets, wedges, and irregular masses of ground ice. Thickness ranges from 1 to 61 m.

Qlc **Loess and colluvium—Including minor upland alluvium (Holocene)**—Unsorted mixture of local bedrock fragments and loess, light-gray to brown, angular or subrounded; partially frozen, fairly well-drained, locally occurs as mixture of reworked loess and colluvium in drainage channels that erode loess downslope forming very irregular contact; at least 0.9 m thick on upper slopes, probably much thicker downslope.

BEDROCK

Schwatka-Rampart area

QTg **Gravel, sand, and silt (Holocene to Pliocene?)**—Alluvial gravel, sand, and silt that vary greatly in composition and size-grade distribution; poorly consolidated deposits; mostly frozen. Some placer gold at Idaho Bar and in other high-level deposits of Hunter Creek area. As thick as 30 m, locally developed and of small extent.

Tvs **Volcanic and sedimentary rocks—Conglomerate, graywacke, siltstone, shale, coal, greenstone, basalt, and tuff (Eocene)**—Rocks at Drew Mine locality, opposite mouth of Hess Creek, and elsewhere on Yukon River, sandy, conglomeratic, light to medium greenish-gray to gray, weather light and medium yellowish-brown and brown, poorly to well consolidated, friable, calcareous, some nodules, lenses, and thin layers of ironstone, non-marine. Conglomerate has locally derived well-rounded pebble- to boulder-sized clasts of greenstone, black chert, rare white quartz and colored chert; siltstone and shale less common. Lignitic shale, bituminous coal, and associated thin clay layers in minor amounts. Coal beds mostly thinner than 0.6 m and probably none thicker than 2 m. Plant fossils and fragments from Drew Mine locality of probable Eocene age represent a temperate climate (T.A. Ager, written commun., 1989). Sedimentary section there about 1,524 m.

Roadcut on west side of Dalton Highway, south of Isom Creek, exposes approximately 457 m of rock overturned to the north. Diabasic greenstone or basalt, light to medium green, bluish-green, and grayish-green, very finely crystalline to aphanitic, in part amygdaloidal, blocky fracturing, has 20-30 percent subhedral clinopyroxene, 8 to 10 percent opaques; 20-30 percent anhedral chlorite and chlorite amygdules; and calcic unaltered plagioclase. Interlayered flows, 2 to 3 m thick, of mafic rocks and greenish-gray tuff. Graywacke and conglomerate, medium to medium dark olive gray, white weathering, locally tuffaceous, iron-rich, non-calcareous, poorly sorted, subangular to rounded, have grains of polycrystalline and monocrystalline quartz, quartz-feldspar aggregates, felsic volcanic fragments, altered tuff, quartz-mica schist, other lithic fragments, and abundant biotite; in channel-fills and lenses that fine-upward to siltstone. Siltstone has grains of angular quartz, cryptocrystalline material, biotite, and chlorite in brown cryptocrystalline matrix of 1 to 3 percent opaques. Shale, dark gray to black, silty and carbonaceous, contains a few unidentifiable broad-leafed plant fossils and *Metasequoia* (J.A. Wolfe, written commun., 1977). On pipeline about 3.2 km SW of Dalton Highway, conglomerate or gravel poorly exposed by construction activities has been mapped as Tvs but may be partially QTg.

Ka **Alaskite (Late Cretaceous)**—Exposed at Raven Creek Hill. Alaskitic rocks that grade to pegmatite and granite; commonly contain as much as 10 percent muscovite and a trace to 1-2 percent biotite; typically contain scattered tiny pink garnets. Schistose in places south of Troublesome Creek. Tourmaline in both igneous and contact rocks. A K-Ar age of 68.1±2 Ma obtained on muscovite (Chapman and others, 1971; and Wilson and others, 1985).

Rampart Group (Triassic to Mississippian)

TRMrv **Intrusive and associated extrusive mafic igneous rocks, a few interlayered sedimentary rocks**—Igneous rocks range from aphanitic greenstone to coarse-grained diorite and gabbro, to very rare occurrences of ultramafic rock, but are mostly fine- and medium-grained originally holocrystalline rocks. Locally showing pillows and amygdules, in places, grade from fine-grained probable extrusives into coarser-grained variants that intrude sedimentary laminae of interbedded sedimentary rocks. Age constrained primarily by Triassic radiolaria found in interlayered chert (C.D. Blome, written commun., 1988) in Livengood quadrangle, additional Triassic to Mississippian radiolaria found in equivalent Circle Volcanics in Circle quadrangle (Foster and others, 1983). A hornblende K-Ar age of 205±6 Ma obtained in gabbro intruding Rampart Group volcanic rocks (Brosgé and others, 1969).

TRMrs **Sedimentary rocks—Argillite, chert, graywacke, shale, limestone, and minor amount of mafic igneous rocks**—Argillite and chert, medium-light gray, greenish-gray and vari-colored, weather white, locally banded, iron-stained, silty, conglomeratic or brecciated; in thin discontinuous blocky fracturing beds. Chert more abundant than clastics in unit. Graywacke, greenish-gray, locally micaceous, feldspathic, quartzose, or calcareous, fine- to medium-grained. Local channel-fills of mutually-erosive small- to medium-scale trough crossbeds. Shale, dark gray to black, graphitic, calcareous, fissile, local iron-stained bands; rhythmically interbedded siltstone and mudstone, light gray to yellowish gray, calcareous, parallel- and ripple-laminated. Interlayered fine-grained clastic rocks and medium dark green mafic welded crystal tuff and pillow basalt. Minor amount of limestone, gray, fine-grained, laminated, silty; contains juvenile pelecypods of indeterminate age (J. Pojeta, Jr., written commun., 1988); probably deposited as shallow-water carbonate platform. May correlate with Permian limestone in Tanana quadrangle, pale yellowish-brown to olive-gray, pelecypod prism grainstone, locally tuffaceous, conglomeratic, thick-bedded, having sparse bryozoan of the genus *Dyscritella* Girty (Helen Duncan, written commun., 1966) (Brosge and others, 1969).

MzPzr **Raven Creek Hill unit (Mesozoic or Paleozoic)**—Medium- to medium-dark gray, garnetiferous quartz biotite-muscovite±chlorite schist, epidote, some carbonate, some mostly quartzitic layers, tourmaline present. Well foliated, and possible weaker secondary alignment, random mica and other late contact effects. Locally gneissic containing incipient albite porphyroblasts near adjoining pluton; as distance from pluton increases, metamorphic grade decreases to phyllite, dark gray slate and shale; possibly originally Rampart Group sedimentary rocks. Contains quartz and pegmatite veins. K-Ar dates of 66.5 and 71.6 Ma obtained on biotite-bearing schist (W. J. Nokleberg, written commun., 1987).

PDms **Metamorphic and sedimentary rocks—Several indeterminate or poorly identified units combined (Permian? to Devonian?)**—Slate, black and greenish-gray, siliceous; chert, shaly chert, and minor breccia, light to dark gray, thinly interbedded; siltstone, light greenish-gray, siliceous, locally sandy, platy to medium-bedded, amalgamated, laterally continuous planar beds have climbing ripples, hummocky crossbedding, horizontal laminae, flaser beds and sole marks. Siltstone fines upward to shale, red and greenish-gray, or dark gray and silty, locally calcareous; phyllite, grayish-green; local sandstone, vari-colored, quartzitic; argillite; greenstone; and lime mud- to packstone, dark gray, fossiliferous. Turbiditic limestone debris flows. Crinoid columnal debris locally abundant. Conodonts in limestone clasts in debris flow of late Famennian (late Late Devonian) age (A.G. Harris, 1987, written commun.).

Schwatka unit (Middle and Early Devonian)

Dsv **Mafic metavolcanic rocks and minor clastic sedimentary rocks**—Massive greenschist-grade basalt flows, agglomerate, tuff, fine-grained volcaniclastic rocks, minor thin lenses of laminated platy impure limestone, and local lenticular bodies of calcite-cemented conglomerate. Basalt contains coarse grains, or aggregates, of albite after calcic plagioclase, augite and coarse porphyroblasts of chlorite have relict amygdaloidal texture. Matrix of basalt is chlorite, white mica, and epidote.

Dsl **Limestone**—Lime mudstone or wackestone, slightly recrystallized, dark gray, sparsely fossiliferous, medium-bedded to massive. Contains two-holed crinoid ossicles. Age is Emsian (late Early Devonian) to Eifelian (early Middle Devonian) (R.B. Blodgett and A.G. Harris, oral and written commun., 1985, 1986). To the north, unit occurs as a thick, discrete carbonate platform sequence; to the south, it is thinner and has interlayers of mafic volcanic rocks of Dsv unit.

Wickersham unit (Earliest Cambrian and Late Proterozoic—unit probably includes Hadrynian and younger rocks)

Ꞓwl **Limestone (Earliest Cambrian?)**—Limestone, medium to very dark gray, weathers medium to dark gray or several shades of brown, yellow, and red, dense to very finely crystalline, non-fossiliferous, micaceous, sandy, or sparsely sandy. Quartz grains monocrystalline, rounded to subrounded, matrix supported. Discontinuous thinly and horizontally bedded or platy to shaly.

ꞒZwa **Maroon and green argillite, grit (bimodal quartzite), quartzite, siltite, graywacke, and phyllite (Early Cambrian to Late Proterozoic)**—Argillite, laminated, maroon and light to medium green and grayish-green, fissile to blocky fracturing, locally phyllitic, slaty, laminated medium-light to dark gray and greenish-gray. Bimodal grit, quartzite, graywacke, and quartz-wacke grit, light to medium olive-gray, commonly conglomeratic or unsorted, feldspars locally abundant, some graded, amalgamated beds; fines-upward to siltite and silty, ripple-laminated phyllite. Contains trace fossil *Oldhamia* in Livengood D-2 quadrangle (Mertie, 1937).

ꞒZwg **Grit, quartzite, graywacke grit, phyllite, slate, limestone, and chert (Early Cambrian to Late Proterozoic)**—Bimodal grit, quartzite, and graywacke, light to medium gray, greenish-gray and olive, fine- to coarse-grained and locally conglomeratic, angular to very well-rounded, poorly sorted to unsorted, weather light to medium gray, and iron stained. Chlorite matrix (recrystallized clay). Quartz grains common, monocrystalline, polycrystalline, glassy, frosted and clear, translucent blue-gray, white, gray or smoky. Potassium or sodium feldspar grains locally abundant. Argillite rip-up clasts rare. Thin- to thick-bedded, internally massive to trough crossbedded, fining-upward graded beds, sole marks, large-scale amalgamated channel-fills, horizontal, inclined and hummocky crossbeds common. Medium- to thinly-bedded and rhythmically interbedded clastics, phyllite, and slate, medium light to dark gray and greenish-gray. Locally contains gray and black chert and thin limestone in units too small to differentiate at this map scale.

Livengood area

QTg **Gravel, sand, and silt (Holocene to Pliocene)**—Gravel or poorly consolidated conglomerate, very light gray. Subangular to rounded cobbles of light gray chert, light-colored tuff(?), scanty black chert. Matrix very light gray, fine-grained,and compositionally similar to the clasts. Clasts are partly stained and iron oxide cemented. Poorly exposed on high-level terraces on sides of Lost Creek and Livengood Creek. May possibly be as thick as 30 m.

Tqm **Quartz monzonite (Paleocene)**—Tolovana Hot Springs Dome pluton. Medium gray, massive, equigranular to sparsely porphyritic, containing thin K-feldspar tablets averaging about 1 cm; contains both hornblende and biotite (average color index 23). Dated at 64.9±2.6 Ma (Chapman and others, 1971; and Wilson and others, 1985).

Tm **Monzonite(?) or monzodiorite(?) (Paleocene?)**—Small bodies, about 4.8 km northeast of Tolovana Hot Springs Dome pluton, and probably satellitic to it. Massive hypabyssal feldspar porphyry containing 2 to 3 mm stubby, clay-altered subhedral plagioclase phenocrysts in micro- to cryptocrystalline matrix, extensively altered. No quartz or K-feldspar recognized.

TKm **Monzonite (Tertiary and (or) Cretaceous)**—Cascaden Ridge pluton. Sub-outcrop rubble of massive, medium-gray hypabyssal monzonite(?) porphyry; composed of 30 percent 1 to 3 mm sub-equant microcline-microperthite phenocrysts; 20 percent altered mafic minerals that consist of limonite and other cryptocrystalline opaque material; 50 percent microcrystalline matrix of feldspar, quartz, and unresolvable semi-opaque material. At local summit "1970", sub-outcrop, rubble of breccia composed of the porphyry was found. Breccia is hard, coherent, containing equant fragments as broad as 7 cm that appear to grade serially into cryptocrystalline matrix of pulverized host rock. The latter was only seen in contact with brecciated rock.

TKg **Felsic granitic rocks (Tertiary and (or) Cretaceous)**—Felsic fine grained hypabyssal porphyritic and non-porphyritic intrusive rocks in dikes, sills and small bodies of irregular shape, scattered throughout central part of quadrangle, mainly in upper Wilber Creek area, very light gray, locally weathering reddish brown.

Kmo **Quartz monzonite, monzonite, and syenite (Late Cretaceous)**—Comprises at least six plutons (including Huron Creek stock) at and near Sawtooth, Elephant, and Wolverine Mountains near the western quadrangle boundary. Massive, medium to coarse grained, medium to dark gray, most commonly porphyritic, the two largest plutons, which are poorest in quartz, typically show striking development of trachytoid texture. Mafic minerals in the latter, besides biotite and hornblende, commonly include pyroxene—locally both ortho- and clinopyroxene—in amounts greater than 20 percent. The quartz-rich plutons typically contain less than 20 percent dark minerals. Sawtooth Mountain is dated at 88.4±1.7 Ma, Elephant Mountain at 89.3±1.0 Ma, and Wolverine Mountain at 89.4±0.9 Ma, and Huron Creek stock at 88.0±0.8 Ma on biotite (N. Shew, written commun., 1989).

Km **Minto unit (Late Cretaceous?)**—Interbedded siltstone, yellowish-gray, iron-stained; light gray to light yellowish gray mudstone that has locally pyritized plant fragments; graywacke, light to medium olive gray, very fine- to medium-grained; sandstone, hard quartzofeldspathic; shale, light yellowish gray to gray weathering; clay shale, medium dark gray, weathering to yellowish-gray and light olive gray common. Grain size fines and bedding thins upsection. Local medium-scale channels truncate beds laterally. Load casts, bioturbation, and burrows occur locally. No precise age determination made, but this unit younger than Wilber Creek unit. Includes deltaic to continental shelf deposits.

Wilber Creek unit (Early Cretaceous; Albian)—Flysch unit

Kwcc **Polymictic conglomerate, conglomeratic graywacke, siltstone, and shale**—Conglomerate, dark olive-gray to medium-dark gray, iron-stained, polymictic, unsorted, subangular to well-rounded granules to cobbles and less abundant boulders. Clasts are locally derived, matrix-supported in sand, silt, and clay, and consist of quartzite, limestone, mafic igneous, greenstone, felsic volcanic, diorite and other intrusive rocks, sandstone, siltstone, phyllite, chert, rare grit, shale rip-ups, and very rare carbonatite. Beds typically internally-massive, large- to medium-scale, graded and amalgamated and have planar bases and tops. Local small-scale trough-crossbeds internally fill large-scale troughs. Fining-upward cycles common. Shale rip-ups as long as 25.4 cm occur. Conglomeratic graywacke occurs in lenses. Base of beds erosional, planar to slightly concave, or locally sole-marked. Minor small-scale scour-fills locally fine-upward into ripple-laminated siltstone, medium-gray to black; and shale, dark-gray to black.

Kwcs **Shale, siltstone, and graywacke**—Shale, dark-gray to black, rarely phyllitic, fissile to blocky fracturing, locally contains pebbles and laminae of siltstone, medium-gray to black, weathering rusty-orange. Rhythmically and thinly interbedded graywacke to quartz-wacke, medium- to medium dark-gray and greenish-gray, iron-stained, moderately sorted, very fine- to medium-grained, subangular to subrounded, some very well-rounded quartz grains, and rarer load casts. Graywacke may occur as discontinuous ripple-laminated or flaser-bedded lenses or small-scale channels that locally grade upward into siltstone and shale. Albian age of Wilber Creek unit based on presence of *Paragastroplites flexicostatus* (J.W. Miller, oral commun., 1989) and other fossils.

KJw **Wolverine quartzite unit (Early Cretaceous and (or) Jurassic)**—Quartzite, light to dark gray, weathers light yellow and yellowish gray, iron-stained, very fine- to medium-grained, well sorted, siliceous, locally feldspathic and has shale rip-ups, thinly to thickly bedded, internally massive, bioturbated, rarely conglomeratic. Interbedded shale, black to dark gray, yellowish gray weathering, graphitic, siliceous and siltstone, medium-light to medium gray. Rare coquinoid beds, grayish-brown, medium bluish-gray, poorly sorted, gritty, locally calcareous, have fragments of *Buchia* and other poorly preserved fossils described in age as Late Jurassic or Early Cretaceous (D.L. Jones, written commun., 1980).

KJv **Vrain unit (Early Cretaceous and (or) Jurassic)**—Slate, dark-gray to black, pyritiferous, shaly; or shale, black, fissile; and minor siltstone, medium to dark gray, olive- or greenish-gray, weathers reddish-yellow-brown or yellowish gray. KJv and ₹s closely resemble two parts of the Glenn Shale in the Nation River area in eastern Charley River quadrangle across the Tintina Fault (Brabb and Churkin, 1969; J.T. Dutro, Jr., oral commun., 1987).

₹s **Calcareous phosphatic shale, limestone and minor calcareous sandstone and granule conglomerate (Triassic)**—Thinly interbedded shale, medium to dark gray, phosphatic, locally calcareous, phyllitic, and graphitic; limestone, medium gray, micritic; and packstone, medium dark gray to dark gray, that has sand- or silt-sized quartz and sparite. These grade into sandstone, medium gray, calcareous; and granule conglomerate, medium light gray, very fine-grained, phosphatic. Conglomerate clasts are chert, clear, rounded quartz, and phyllite in shaly matrix. Small phosphate nodules abundant. Contains Permo-Triassic microfossils (A.G. Harris, oral commun., 1988, 1989), probably Triassic because of resemblance to lower part of Glenn Shale.

₹c **Shale or slate, chert, and tuff (Triassic)**—Interlayered shale, black or slate, chert, light olive-greenish-gray, thinly-bedded to massive and thickly bedded; and tuff, light greenish-gray. This unit intruded by diorite/gabbro in Tanana B-1 quadrangle. Age based on radiolaria (D.L. Jones, oral commun., 1982).

MzPzp **Phyllite, schistose phyllite, quartzite, siltite, amphibolite, diorite, and greenstone (Mesozoic or Paleozoic)**—Phyllite and schistose phyllite, medium to medium dark gray, pyritized; quartzite; and siltite, very finely layered. Intruded by a mafic complex of amphibolite, diorite, and greenstone. Amphibolite composed of pale green actinolitic hornblende, oligoclase-andesine plagioclase and at least 15 percent secondary carbonate which fills fractures. K-Ar date of 163.88±21.1 Ma obtained on amphibolite in this unit (W.J. Nokleberg, written commun., 1987).

Ps **Sedimentary rocks—Argillite, siltstone, sandstone, and minor conglomerate (Permian)**—Thinly and rhythmically interbedded argillite, dark-gray, iron-stained, and siltstone, medium light- to dark-gray, light-gray to yellowish gray weathering, platy, laminated. Sandstone, medium light gray, weathers light olive gray, chert-rich, very fine- to fine-grained, well-sorted, sheared, platy. Quartz and chert granule- to pebble-conglomerate, medium gray, dusky-yellow weathering, iron-stained, locally calcareous, fossiliferous, poorly-sorted, grain-supported, locally stretched grains. Sandstone occurs in rhythmic, medium- to thin-beds having planar tops and bases, and local occurrences of load casts. Conglomerate has clasts, in limonitic clay matrix, of well-rounded chert, very light- to dark-gray and light-green, unfoliated microcrystalline, radiolarian, and locally laminated; chert-rich litharenite; siltstone, light greenish-gray; and argillite rip-ups, dark-gray. Conglomerate occurs in isolated erosional scours at least as wide as 5 m, that internally have small-scale troughs and beds as thick as 5 cm. Conglomerate contains bryozoans and yellowish-white crinoid columnals. Fossils (foraminifera, conodonts, and brachiopods) indicate a Permian age (A. K. Armstrong, written commun., 1974, A. G. Harris, written commun., 1986, J.T. Dutro, Jr., written commun., 1970). Estimated 87 percent interbedded argillite and siltstone, 10 percent sandstone, 1 to 2 percent coarse grit, and less than 1 percent conglomerate.

Pzs **Sedimentary rocks (Late Paleozoic)**—A tectonically disrupted section of slate, greenish-gray, siliceous; chert and cherty argillite, light to medium gray, yellowish gray weathering, brecciated, laminated, iron stained, banded; and greenstone, pale grayish green . Lime wackestone, light to dark gray, recrystallized, has abundant crinoid ossicles and rare unidentifiable brachiopods, occurs as two prominent tors on west side of Troublesome Creek. Trace of conglomerate.

Quail unit (Late Devonian)

Dq **Phyllite, siltstone, quartzose sandstone, graywacke, and conglomerate**—Phyllite, light to medium gray and green, has laminae of locally calcareous gray siltstone to very fine-grained gray quartzose sandstone; graywacke, light greenish-gray to medium gray, fine- to medium-grained, has quartz, chert, and argillite grains in a phyllitic or siliceous matrix. Graywacke thinly bedded as laterally continuous, subplanar and ripple laminated internally filled beds that have planar erosional bases and shaly parting tops. Fine granule conglomeratic graywacke, medium dark gray, in fining-upward internally conformable, laminated, medium-scale scour-fills. Granule- to boulder polymictic conglomerate, dark greenish-gray, stretched, angular to well-rounded, grain-supported. Conglomerate clasts are chert, dark green, yellowish gray, and light gray to black; dolomite, light gray, yellowish gray- to pink-weathering, fine-grained, having silica boxwork; green serpentinite; intermediate and mafic igneous rocks, very fine- to medium-grained; quartzite, light gray to green; dark gray cherty argillite; phyllite; slate, medium gray, siliceous; volcanic rocks; sandstone, lithic, light green to salt and pepper; and minor white quartz. Matrix greenish gray, very well consolidated, sandy to shaly. Bedding in conglomerate medium- to large-scale, mutually-erosive, internally massive trough-fills, locally amalgamated or fining- and thinning-upward into planar- to ripple-laminated tops of graywacke and siltstone. Locally has serpentinite-lined irregular shear surfaces. Lower contact of phyllite and limestone of Dql irregular. Dq may be correlated with Nation River Formation of Charley River quadrangle.

Dql **Limestone (Late Devonian)**—Lime mudstone or wackestone, light- to medium-gray, megafossils (corals and stromatoporoids) locally common, conodonts from several localities suggest a Frasnian age (A.G. Harris, written commun., 1984, 1987, and 1988), as do rugose corals from one locality (J. Sorauf, written commun., 1989). These bodies, as thick as 30 m have a lateral extent of several hundred meters in the basal Quail unit, were deposited as local biogenic buildups upon the Troublesome unit.

Dt **Troublesome unit (Devonian?)**—Rhythmically interbedded dark gray to black cherty argillite to chert, and thin beds of black to gray, siliceous slate. Chert commonly in amalgamated, laterally continuous beds. Extensive mafic intrusive and extrusive rocks are associated with this unit, but they do not penetrate the overlying Dq or Dql. No identifiable fossils found although radiolaria reported. Dt may be correlated with Devonian McCann Hill Chert of Charley River quadrangle (Brabb and Churkin, 1969).

Dc **Cascaden Ridge unit (Middle Devonian)**—Rhythmically interbedded shale, medium to medium dark gray and olive gray; siltstone, light to medium dark gray; and graywacke, medium gray, weathers medium yellow brown to reddish-brown, locally calcareous, mostly very fine to fine-grained. Polymictic conglomerate, light to medium dark gray, poorly sorted, containing mostly dark chert and white quartz granules and pebbles, sandy graywacke matrix, partly calcareous.

Graywacke commonly in thin planar beds internally laminated, ripple bedded, and sole marked. Limestone and minor clastic limestone, light to medium light gray and dark gray, commonly weather light brown and dark yellowish-orange, finely crystalline, locally very fossiliferous having diverse fauna of brachiopods, gastropods (Blodgett, 1992), bivalves, corals, and conodonts.

DSl **Lost Creek unit (Devonian and Silurian)**—Lime mudstone and wackestone, light-gray, massively bedded, have scattered megafossils, primarily brachiopods, rugose corals, and trilobites. Fossils indicate a Wenlockian to Ludlovian (early to middle Late Silurian) age (Blodgett and others, 1988). Limestone occurs mainly as debris flows having a maximum thickness of 12 to 15 m, pinching out laterally in either direction. Both base and uppermost part of limestone include rip-up clasts of shale and chert and varied sedimentary rocks. Basal part of unit locally contains channels of graywacke and chert pebble to cobble conglomerate that cut down into upper part of Livengood Dome Chert. A band of light to medium light gray micritic limestone has possible crinoid ossicles, and is flanked by rubble of light gray to black chert on West Fork of Tolovana River mapped as DSl. Age of latter limestone unknown, possibly Silurian or Devonian.

Old **Livengood Dome Chert (Ordovician)**—Chert, gray, yellowish gray, grayish-green and some black-mottled, recrystallized, in beds at least as thick as 40 cm, sedimentary breccia, stylolitic partings, and less common shaly partings. Chert at least 1 km thick, true thickness unknown. Siliceous slate, rare greenstone, tuff, and limestone occur. Late Ordovician graptolites in shale layers (Chapman and others, 1980). Early to earliest Middle Ordovician conodonts reported from lime mudstone north of VABM Beaver (A.G. Harris and R. Orndorff, written commun., 1988). Rare mafic flows or sills.

SZa **Amy Creek unit (Silurian? to Late Proterozoic?)**—Dolomite, light- to medium-gray, medium-grained, reticulate silica box-work; mud-, wacke-, and packstone, light-gray, yellow-gray or buff, dolomitic, medium- to thick-bedded. Abundant peloids and crossbedding in coarser-grained rocks; laminations common in fine muds; solution breccia and coated algal grains present. Interbedded chert, black carbonaceous argillite, and dolomite, rarely medium gray, iron and manganese stained, locally shaly, thin- to thick-bedded or in small nodules, lenses, and irregular masses. Interbedded and interlayered minor lime mudstone, dark gray at least as thick as 30 m, chert, basaltic greenstone, lenses of tuff, light to dull green, tuffaceous siltstone, shale, and minor volcaniclastic graywacke, very fine-grained. Basaltic flows and flow breccia at least 100 m thick occur locally in shaly rocks on Amy Creek and elsewhere.

Locally unconformably overlain by flyschoid rocks as old as Middle Devonian. Sponge spicules in chert (B.L. Murchey-Setnicker, oral commun., 1992). Lithology and algae strongly resemble Early Paleozoic or Proterozoic dolomites of the western part of the Charley River quadrangle (R.B. Blodgett, oral commun., 1992). Unit at least 1158 m thick.

PzZm **Mafic igneous rocks and minor interlayered sedimentary rocks (Paleozoic and (or) Late Proterozoic)**—Gabbro and diabase, dark-olive green, greenish-gray to dark greenish-black, medium- to coarse-grained, very fine-grained on outer margins of sills; locally gradational into diorite, light-green to medium greenish-gray, medium- to coarse-grained, blocky. Greenstone and basalt, medium to dark grayish-green and greenish-gray, dark olive-green, very fine- to fine-grained, local large calcite amygdules present. Interbedded, interlayered mafics, slate, siliceous shale, medium-dark-gray chert, argillite, gray to black, yellowish gray weathering, slaty to siliceous. Argillite has local laminations of dark-gray to yellowish gray weathering, shaly siliceous claystone, siltite, quartzite, and light- to medium-gray graywacke. Age unknown, but probably pre-Mesozoic.

-CZum **Ultramafic and mafic rocks (Early Cambrian and (or) Late Proterozoic)**—Serpentinite, light to dark yellowish-green, grayish-green, greenish-black and black, weathers to shades of medium to dark brown, reddish-brown and grayish-brown, derived from clinopyroxene peridotite, dunite, and lesser clinopyroxenite; and clinopyroxene-plagioclase metabasalt, medium to dark green, yellowish-green, grayish-green, and greenish-gray; diabase, and minor metatuff, weather to darker shades of yellow, yellowish-brown, reddish-brown, olive gray or greenish-gray. Serpentinite intruded by dikes of clinopyroxene gabbro, microgabbro, and diorite, green or olive gray, yellowish gray to gray weathering (Loney and Himmelberg, 1988). Gabbros and diabase produced several K-Ar dates about 518 to 643 Ma (D.L. Turner, written commun., 1975, 1986, 1987; J. Blume, written commun., 1985; N.B. Shew, written commun., 1990). Serpentinized peridotite and dunite have a high magnetic susceptibility. Mafic rocks occur as layers tens to hundreds of meters thick between layers of ultramafic rock.

Wickersham unit (Earliest Cambrian and Late Proterozoic—
unit age probably includes Hadrynian and younger rocks)

-CZwl **Dark gray limestone**—Sparsely or non-sandy limestone. Lithologies similar to -Cwl in Schwatka-Rampart area.

-CZwa **Maroon and green argillite, phyllite, quartzite, graywacke, siltite, and grit**—Unit characterized by relative lack of grit except in far western part of quadrangle. Lithologies similar to -CZwg in Schwatka-Rampart area, but includes no chert.

Fairbanks—White Mountains area

QTg **Gravel, sand, silt, and minor amounts of sandstone, conglomerate, and coal (Holocene to Eocene)**—Poorly consolidated deposits. Alluvial gravel, sand, and silt that vary greatly in composition and size-grade distribution; locally developed and of small extent. Associated with basalt on and adjacent to Fourth of July Hill in southeastern corner of Livengood quadrangle. Brown micaceous sandstone and conglomerate, composed mostly of schist fragments having vein quartz. Detrital granitic material, partly boulders. Traces of coal float (Prindle, 1913). Probably mostly frozen, and as much as 30 m in thickness.

Tb **Olivine basalt (Tertiary)**—Fourth of July Hill and vicinity. Brownish-black, vesicular in part, shows some columnar jointing and possibly pillows. Basalt has diabasic texture and composite mode includes 17 percent olivine, 42 percent plagioclase, 11 percent pyroxene, 26 percent glass, and 3 percent magnetite. By comparison to similar basalt in Fairbanks quadrangle (Furst, 1968), an early Tertiary age most likely. Thickness unknown, but probably relatively thin.

Tgp **Peraluminous granite (Paleocene)**—Cache Mountain pluton. Massive, light-gray, porphyritic, composed of white K-feldspar and medium-dark-gray quartz phenocrysts together totalling about 50 percent of rock, in medium-grained, light-gray matrix speckled with tiny biotite flakes; a K-Ar date of 59.8±1.8 Ma obtained on biotite (Holm, 1973; Wilson, and others, 1985).

TKg **Leucocratic quartz monzonite (Tertiary and (or) Cretaceous)**—Vault Creek pluton. Medium to coarse-grained, massive to weakly layered, locally porphyritic having elongate K-feldspar phenocrysts as much as 6 cm long, and subequant quartz phenocrysts as much as 1 cm across; Liesegang bands common.

Ks **Syenite (Late Cretaceous)**—Roy Creek stock. Massive, inequigranular, leucocratic to melanocratic, highly varied aegerine-augite syenite occupying about 11.6 sq km at eastern quadrangle boundary. Characterized by trachytoid texture and a large variation in grain size; coarsest rock contains K-feldspar tablets 5 cm in maximum dimension. Several K-Ar age dates of about 86 Ma (Burton, 1981), and a lampophyre dike dated as 90.0±2.0 Ma on biotite (Wilson and others, 1985).

Kg **Granite (Late Cretaceous)**—Pluton mapped at Pedro Dome. Massive, medium to coarse-grained, very light gray, porphyritic containing phenocrysts of K-feldspar, quartz, and plagioclase, which compose 75 percent of the rock; locally associated with pegmatite; granite locally intrudes granodiorite (Kgd).

Kgd **Granodiorite (Late Cretaceous)**—Pluton mapped at Pedro Dome. Massive, medium and light gray, fine- to medium-grained, equigranular, locally clino-, rarely orthopyroxene bearing; average content of dark minerals—hornblende and biotite—about 25 percent. A K-Ar date of 93.0±5.1 Ma obtained on hornblende (Forbes, 1982).

₮m **Mafic igneous rocks (Triassic)**—Gabbro, and diabase or diorite sills and dikes, light- to medium-green, medium- to coarse-grained, equigranular. Augite (25 to 30 percent), diopside, orthopyroxene, hornblende, and biotite (5 to 10 percent, locally), and albitized plagioclase (An 40-60) is common and altered to clay psuedomorphs (Bundtzen, 1983). Intrudes Globe unit. Zircon age of 232.1±4.5 Ma (J.K. Mortensen, written commun., 1991).

Mg **Globe unit (Mississippian)**—Quartzite, light-gray, weathers light-or medium-gray and iron stained, fine- to medium-grained, bimodal to moderately sorted, dense, vitreous, well-rounded to subrounded monocrystalline quartz grains and scanty chert grains. Minor accessory minerals of zircon, augite, and hornblende. Cement mostly silica, but some limonitic clay matrix fills interstices. Massive or thinly interbedded quartzite and medium- to dark-gray slate, phyllite, and minor laminated claystone. Age from date of ₮m intrusive and lithologic and stratigraphic similarities to Keno Hill Quartzite in Yukon, Canada (Mortensen and Thompson, 1990).

Dcg **Beaver Bend unit—Conglomerate, graywacke, siltstone, and slate (Devonian?)**—Polymictic chert pebble conglomerate, light to medium-dark-gray, poorly sorted to unsorted, clast-supported, well-indurated, abundant granules and small pebbles. Conglomerate clasts consist of chert, black to dark-gray and light-green, angular to subrounded; quartz, monocrystalline, very well-rounded; quartzite, well-rounded; mafic and felsic volcanic rock fragments; argillite; slate; siltstone; and sandstone. Argillite rip-up clasts, dark-gray, phyllitic, and siliceous common. Contacts between clasts have pressure-solution and a very minor amount of chlorite matrix. Bedding thick, graded, amalgamated, laterally-continuous has sharp, planar, erosional bases. Grain-size fines upward. Graywacke, fine- to medium-grained, moderately-sorted, has subangular to well-rounded grains of mostly quartz and chert, and lesser amounts of slate, plagioclase, and felsic to mafic volcanic rock fragments. Chlorite matrix probably recrystallized from clay. Interbedded discontinuous, thinly-bedded lenses of fine-grained graywacke and dark-gray to black siltstone and slate, weather gray to olive, laminated, and contain unidentifiable plant fragments. Unit exposed near big bend of Beaver Creek.

Southern boundary overthrust by Wickersham unit, so true thickness unknown, but at least as thick as 90 m.

DSt **Tolovana Limestone (Middle Devonian to Early Silurian)**—Main body of unit as exposed in the White Mountains appears to be more than 1,200 m thick and of Silurian age based on conodonts and brachiopods (Blodgett and others, 1987), as well as corals (Oliver and others, 1975). Its lower part consists of alternating green and maroon lime mudstone, succeeded by yellowish-brown weathering, silty, shaly lime mudstone and wackestone having brachiopods; its upper and greater part consists of light-gray weathering peloid- and ooid-rich lime packstone and grainstone and rare dolomite.

A separate, upper subunit of Middle Devonian age also included in Tolovana Limestone at present. This subunit is at least 457 m thick and is exposed to the southwest of the White Mountains, near the Elliott Highway (north side of Globe Creek, Livengood B-3 quadrangle), at VABM Minto (8 km east of COD Lake, Livengood A-4 quadrangle), and even further southwest in the Dugan Hills area (Fairbanks D-6 and Kantishna River D-1 quadrangles). This subunit is sparsely fossiliferous and consists of dark gray lime mudstone and wackestone, differing from lower Tolovana Limestone in being darker colored and more well bedded. Age of upper subunit is based upon corals (Oliver and others, 1975).

Fossil Creek Volcanics (Late to Early Ordovician)

Ofv **Alkali basalt, agglomerate, volcaniclastic conglomerate, minor limestone and sandstone**—Alkali basalt, olive-green agglomerate, and boulder- to granule-volcaniclastic conglomerate, minor beds of maroon and green colored lime wackestone, and well-sorted calcareous feldspathic sandstone. Agglomerate and conglomerate contain very well-rounded clasts of maroon and olive gray basalt, pink granite, bimodal quartzite, limestone, chert, and phyllite in altered volcanic and tuffaceous matrix. Internally massive, amalgamated, large-scale trough-shaped scour-fills present (Wheeler and others, 1987). Sedimentary rocks from the uppermost part of the unit contain brachiopods, gastropods, trilobites, and conodonts of Late Ordovician age (Blodgett and others, 1987; A.G. Harris, written commun., 1986). Unit deposited as alkali-basalt flows and lahar or debris-flows in a continental margin and (or) nearshore shallow marine (shelf) deposit. Thickness more than 610 m.

Ofs **Slate, phyllite, shale, siltstone, limestone, chert, tuff, and basalt intruded by gabbro**—Slate, dark-gray; phyllite, light-gray; shale, black tuffaceous; siltstone, gray to black, calcareous, siliceous; lime mudstone, medium-gray, thin-bedded; chert, black to gray, banded, silty; aquagene tuff; basalt flows; pillow lavas; and gabbroic dikes and sills. Fossils (trilobites and conodonts) from Fossil Creek Volcanics sedimentary section indicate an Early

Ordovician age for at least part of Ofs. Unit interpreted as a basinal sequence (Wheeler and others, 1987).

Pzc **Chatanika unit (Paleozoic)**—Allochthonous, quartz-biotite-muscovite schist, garnet-bearing; and quartzite. Primarily epidote-amphibolite facies rocks, but also includes eclogitic rocks. Age of rocks in Chatanika allochton is problematical. Oldest K-Ar date obtained from amphibole in eclogitic section is 470±35 Ma; amphibole and mica K-Ar dates ranging from about 103 to 132 Ma also obtained, but age of protolith generally considered to be Paleozoic (Swainbank, 1970). In more recent work M. Lanphere obtained muscovite K-Ar ages of about 141 to 178 Ma, and Rb-Sr internal isochron ages of 137±8 Ma and 157±8 Ma (Lanphere, written commun., 1991). This pattern of ages suggests varied overprinting of older rocks during early Cretaceous metamorphism.

Wickersham unit (Earliest Cambrian and Late Proterozoic—
unit age probably includes Hadrynian and younger rocks)

ꞒZwa **Maroon and green argillite, grit, quartzite, siltite, graywacke, phyllite, and limestone (Early Cambrian and Late Proterozoic)**—Lithologies similar to ꞒZwa in Schwatka-Rampart area, but also includes thin beds of dark gray limestone, probably similar to unit Ꞓwl, as mapped in Schwatka-Rampart area, but limestone is areally restricted and not mapped separately in this area. Intruded by gabbro in and near the White Mountains. *Oldhamia* in this unit in adjoining Circle quadrangle (Foster and others, 1983). A K-Ar date of 1.35±40.6 Gy obtained on white mica (D. Turner, written commun., 1987).

ꞒZwad **Dolomite**—Medium gray, fine-grained, non-siliceous. Contains nondiagnostic stromatolites. Forms a distinct band across quadrangle within ꞒZwa unit.

Zwg **Grit, quartzite, graywacke, conglomerate, limestone, phyllite, slate, and argillite (Late Proterozoic)**—Grit (bimodal quartzite) and quartzite, gradational to hard sandstone and graywacke, light to medium gray, greenish gray and olive, weathers light gray and iron stained. Sparse grit conglomerate has well-rounded chert and quartz pebbles and black rip-up slate fragments in bottom of channel deposits. Feldspar grains potassic or sodic, ubiquitous in grit, but locally abundant in conglomerate. Matrix mostly chlorite, recrystallized from clay. Scanty occurrences of dark gray limestone. Rhythmic bedding, fining upward, graded bedding, sole marks, large-scale amalgamated channel fills have erosional bases, and horizontal, inclined and hummocky crossbedding common.

Zf **Fairbanks schist unit (Late Proterozoic)**—Greenschist facies approximately 60 percent micaceous quartzite and quartz-mica schist, medium light gray, weathers light brown, fine-grained, thin- to massive-bedded, has quartz-muscovite-chlorite-albite, sparse biotite, and garnet. Unit approximately 40 percent pelitic schist, light brown to gray, fine- to medium-grained, has muscovite-chlorite, as much as 10 percent biotite, and pinhead garnets. Quartzite and schist rarely grade into feldspathic quartz-mica schist having trace of K-feldspar and sodic plagioclase. Minor layers of bimodal quartz grains (grit). Locally subdivided into:

Zfc **Cleary subunit**—White felsic schist, micaceous quartzite, chloritic or actinolitic greenschist, greenstone, and marble. Lithologically, the protolith of combined Fairbanks schist and Wickersham units is continental shelf or slope facies which strongly resemble Windermere Supergroup in Canada. Alaska units offset right laterally along the Tintina fault system from Canada and are of same borderline Cambrian-Precambrian age, probably Hadrynian to Early Cambrian. Six U/Pb detrital zircon dates from Cleary subunit in Livengood quadrangle are about 1.2 by or older (J.K. Mortensen, oral commun., 1989; J.N. Aleinikoff, written commun., 1988).

Acknowledgments and References Cited

The work of many geologists, too many to cite, in the last 100 years has contributed to the preparation of this map. Please consult Wheeler and Weber, 1988 for a comprehensive listing of references pertaining to the Livengood quadrangle prior to 1988. The best early summary of the geology of the Yukon-Tanana Upland is in Mertie, 1937. The first geologic map of the Livengood quadrangle alone is in Chapman and others, 1971. The following selected list of references represents valuable field mapping additions to the geology of part of, or all of, the Livengood quadrangle in recent years, including references specifically cited in the text of this report and large-scale mapping in the Livengood area and in the southeast corner of the Livengood quadrangle by the Alaska Division of Geological and Geophysical Surveys. This geologic map was prepared as part of the Alaska Mineral Resources Assessment Program (AMRAP). Data and interpretation of the mineral resources of the quadrangle will be found in the USGS Miscellaneous Field Studies Map (MF) series.

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