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TEXT AND TABLES TO ACCOMPANY THE RECONNAISSANCE GEOLOGIC MAP OF THE TANANA QUADRANGLE, ALASKA

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INTRODUCTION AND ACKNOWLEDGMENTS

This map supersedes the previous maps of the northeastern part of the Tanana quadrangle (Chapman and Yeend, 1972) and of the Tanana and northeast part of the Kantishna River quadrangles (Chapman and others, 1975). Previously unpublished age data from fossil collections and radiometric and radiocarbon determinations are presented. Some additions and revisions have been made in the geologic map and in the age designations of the rock units.

Mapping is based chiefly on data from ground stations and foot traverses (fig. 1), but is supplemented by low-level aerial observations and interpretations from aerial photographs. The alluvial, colluvial, and eolian deposits particularly have been extended by photointerpretation. Field work was done during parts of several field seasons by Chapman in 1970-74, Yeend in 1970-72, Brosge in 1971-73, and Reiser in 1972-73. Geology in the A-1 and A-2 portion is taken largely from the unpublished detailed mapping of David M. Hopkins and Bond Taber that was accomplished by extensive foot traverses in 1956, 1957, and 1959. Their major contribution is gratefully acknowledged, and the authors assume responsibility for the modifications and generalizations required to reduce their 1:63,360-scale compilation to this map scale. Geologic mapping in the extreme northwest part of the quadrangle is incomplete, and the units are only generally outlined based on mapping by Patton and Miller (1970), a brief visit to this area in 1975 by Patton and Chapman, and extrapolation of units in the adjacent Bettles quadrangle (Patton and Miller, 1973) and Melozitna quadrangle (Patton and others, 1978).

Some supplementary data have been obtained from field notes of R. R. Coats and W. N. Laval in 1942 and R. M. Chapman in 1943 and 1952 on the Grant and Moran Domes area; from R. R. Coats and T. G. Payne in 1942 and R. M. Chapman in 1943 on the Morelock Creek area; and from H. M. Eakin in 1911, J. B. Mertie, Jr. in 1922 and 1931, and R. L. Foster in 1967 on the area between the Yukon and Tanana Rivers. Thin-section studies by Glenn J. Mac Pherson and Michael L. Throckmorton facilitated the work, and the radiolarian chert sample and geological observations kindly provided by Sarah M. Roeske of Middlebury College were significantly helpful.

DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

GLACIAL

Present only in the Ray Mountains. Relative ages of till determined by the geomorphic position within valleys and the eroded character of moraines.

Qt_4 TILL, CIRQUE GLACIATION--Boulder- to clay-size particles, unsorted, coarse clasts subangular. Moraine-forms locally present. Deposits restricted to cirques.

Qt_3 TILL--Boulder- to clay-size particles, unsorted, coarse clasts subangular; includes a long, low lateral moraine along lower part of Halu Creek.

Qt_2 TILL--Boulder- to clay-size particles, unsorted, coarse clasts subangular; includes low lateral moraine on Halu Creek.

Qt_1 TILL--Boulder- to clay-size particles, unsorted, coarse clasts subangular; on lower Halu Creek forms the farthest down-valley recognizable moraine.

Qt TILL, undifferentiated--Boulder- to clay-size fragments, unsorted, coarse clasts subangular. No clear morainic forms.

ALLUVIAL

Qal RECENT ALLUVIUM--Sandy gravel and sandy silt, coarse clasts subrounded to well rounded. Forms flood plain of modern rivers and streams.

Qaf ALLUVIAL FAN DEPOSITS--Gravel, silt, and sand, coarse clasts subangular to subrounded; commonly occur at the mouths of small side canyons; some colluvial deposits are included.

Qbg LOW-LEVEL BENCH GRAVEL OF MINOOK CREEK--Gravel and sand present on benches along lower parts of Minook and Hunter Creeks, generally less than 60 m above stream bed.

Qtr TERRACE DEPOSITS--Gravel, silt, and sand near mouth of Fleshlanana Creek.

Qags OLDER ALLUVIUM--Coarse, silty sand and fine gravel, clasts well rounded, moderately well sorted; generally forms a terrace that slopes up and away from flood plains of streams and rivers. Radiocarbon age of >42,000 years B. P., from site on Tozitna River (R2, tab. 3). Commonly mantled with 0.3 m to 3 m of silt.

QTg HIGH-LEVEL GRAVEL--Gravel is well packed, river deposited, chiefly pebble to small-cobble size with some and sand and silt, clasts subrounded to well rounded; in minor part is semi-consolidated. Caps hills in the vicinity of Rampart. Gravels are apparently of local origin; north of Yukon River, the clasts are predominantly fine- to very fine-grained mafic rocks, with some red chert, argillite, and medium- to dark-gray chert; south of Yukon River, the gravel includes many rock types and is in part auriferous (Mertie, 1937). The deposits in northeast corner of map consist of about 95 percent white quartz pebbles and cobbles. Age interpreted as late Tertiary or early Quaternary. Radiocarbon age of >40,000 years B. P., from site on Squaw Creek (R1, tab. 3). Thicknesses range from 3 to about 30 m.

COLLUVIAL AND ALLUVIAL

Qcal COLLUVIUM AND ALLUVIUM, UNDIFFERENTIATED--Silt and sand mantling the broad, flat valley bounded by the Kanuti Kilolitna River and Torment Creek in north-central part of map, and the valley floors in the headwater areas of the Melozitna River in northwest corner of the map. Ice-wedge polygons present.

COLLUVIAL

Qrs RECENT SLIDE AND SLUMP DEPOSITS--Very fresh, unmodified slumps and earthflows; mapped at only one site, which is within an older landslide deposit on north bank of Yukon River at east edge of map; movement occurred about 1940.

Qls OLDER LANDSLIDE DEPOSITS--Slumps and earth and rock slides that have irregular, hummocky topography and associated slide scar. Generally occur on steep slopes, particularly along Yukon River.

Qc COLLUVIUM, UNDIFFERENTIATED--Predominantly silt, with some sand and gravel, commonly poorly sorted. Occurs along valley sides and valley flats, bordering the recent alluvium (Qal). Derived mainly from valley sides by soil creep.

Qta TALUS--Angular boulder rubble in cirque at head of Kanuti Kilolitna River.

EOLIAN

Ql LOESS--Silt, well-sorted, pale-brown, weathering to dark yellowish brown; mantles much of the topography at lower elevations.

Qess SAND AND SILT--Well sorted sand; commonly in subdued dune forms and generally vegetated. Includes silt similar to that of the loess (Ql). Mapped only south of Tanana River.

EROSIONAL SURFACES

Qb ROCK-DEFENDED TERRACES ON MINOOK CREEK--Erosional benches along east side of Minook Creek, 120 to 150 m above the creek. May have thin mantle of silt.

Qat ALTIPLANATION TERRACE--Flat, even surface, formed on bedrock hilltops that generally are above 600 m; commonly possesses thin mantle of coarse, angular rock rubble. Individual terraces are generally less than 20,000 m^2 (5 acres) in area. Not all of these features are shown.

BEDROCK

SEDIMENTARY, VOLCANIC, AND METAMORPHIC ROCKS

QTa ANDESITIC LAVA--Vesicular lava, light to very light gray, weathered to medium yellowish brown and dark reddish brown. Found only at one locality in northeast corner of map near lower Ray River; forms suboutcrop of angular blocks underlying high-level gravel (QTg). Apparently coextensive with basalt unit several kilometers north along Ray River in the Bettles quadrangle (Patton and Miller, 1973). Age uncertain but late Tertiary or Quaternary suggested by field relations. Thickness unknown; probably is at least 15 m.

Tvs RHYOLITIC VOLCANIC AND SEDIMENTARY ROCKS--Rhyolitic lava and breccia, light to very light yellow and yellowish gray to cream and white, generally deeply weathered to various shades of light yellow, orange, and reddish brown; mostly very fine grained; flow banding, lamination, and spherulitic texture are abundant. Tuff and probable welded tuff are common and similar in color to the rhyolitic lavas; generally devitrified. Cherty rocks minor, very light to medium gray, thin bedded and in nodules as much as 30 cm in diameter. Siltstone and shale, grading to argillite in part, probably largely tuffaceous; very light yellow to tan and light olive to medium gray; generally thin bedded to laminated. Unit mapped only in Minook-Fish Creeks area and typically forms "badland" rubble slopes with prominent pastel weathering colors. Appears to cap hills and overlie the mafic and sedimentary rocks unit (JMms) unconformably, but basal contact zone is poorly exposed; locally near contact thin layers of rhyolitic and mafic rocks are intercalated. Tertiary age inferred from the structural setting and lack of rock alteration; relationship to Tertiary sedimentary rocks unit (Ts) is uncertain. Thickness unknown; probably is at least 90 to 120 m.

Ts SEDIMENTARY ROCKS--Interbedded polymictic pebble-cobble-boulder conglomerate, grit, and sandstone, with siltstone, shale, and lignite; light yellowish gray, medium gray, to medium yellowish brown, weather to various shades of yellowish to reddish brown;

range from poorly to well consolidated, commonly with calcareous cement; non-marine, fluvial; plant fossils locally common (Mertie, 1937; Paige, 1959). Lignite at several sites on Yukon River between Rampart and Schieffelin Creek, and prominent as large, tabular blocks on gravel bars in Tozitna River below mouth of Fleshlanana Creek. Unit includes rocks of early Tertiary and Miocene ages based on pollen collections (tab. 2). Basal contact and large continuous sections are not exposed; extent and thickness beneath lowland areas is unknown. Thickness probably ranges from 200 to at least 900 m; possibly 1,200 to 1,500 m thick in Cheyenne-Jordan Creeks area (Paige, 1959).

TKv VOLCANIC ROCKS--Dacite flows, may include some tuff and andesite; light gray, weather white and very light yellow to tan; groundmass fine to very fine grained; porphyritic with small feldspar, quartz, and biotite phenocrysts. Mapped near Melozitna River in northwest corner of quadrangle; the contacts are approximately interpreted. Coextensive with the felsic volcanic rocks unit in Bettles quadrangle (Patton and Miller, 1973) and the volcanic rocks unit in Melozitna quadrangle (Patton and others, 1978) that are dated as Late Cretaceous and early Tertiary.

KJcs CLASTIC SEDIMENTARY ROCKS--Graywacke sandstone, quartzitic sandstone, quartzite, siltstone, shale, slate, slaty argillite, and polymictic conglomerate; generally light to medium gray, with some dark gray to grayish black slaty rocks; weather to various shades of gray and yellow brown; moderately to very well indurated; dominantly marine but may be in small part non-marine; generally thin to medium bedded. Quartzite and conglomerate beds more common in lower half of unit; graded beds and turbidity current features are more abundant in upper half of unit. Structural deformation is moderate to intense with abundant fractures and some "pencil slate"; in part metamorphosed showing incipient to moderately-developed foliation with recrystallization and reorientation of original clay and micaceous minerals; altered to hornfels in zones peripheral to granitic plutons and dikes. No fossils found in this quadrangle; age is based on rare and fragmentary or poorly preserved fossils from this unit in the adjacent part of the Livengood quadrangle. Late Jurassic and Cretaceous ages are indicated by a few pelecypods (D. L. Jones, written communications 1961, 1971, 1980). Unit is correlative with the Jurassic and(or) Cretaceous conglomerate, graywacke and shale, and shale, graywacke and quartzite units of Livengood quadrangle (Chapman and others, 1971), the Cretaceous of Mertie (1937), and in part with Lower Cretaceous sedimentary units of the Bettles and Melozitna quadrangles (Patton and Miller, 1973; Patton and others, 1978). Thickness is poorly known; probably is not less than 1,000 m, and may be as much as 2,700 m.

JMms MAFIC AND SEDIMENTARY ROCKS--Unit includes a volcanic and sedimentary rock sequence that has been described as the Rampart Group by Mertie (1937) and Brosge and others (1969), and abundant intrusive gabbroic rocks with rare ultramafic differentiates. Tuffs, greenstones, breccias, and basaltic, diabasic, and rarely andesitic lavas are dark green and grayish green to grayish black and weather yellowish and reddish brown; generally fine to very fine grained; commonly fractured and sheared, and in part foliated and slightly metamorphosed; pyroclastic tuffaceous rocks apparently grade into sedimentary tuffs and chert. The protoliths (volcanic or sedimentary, and extrusive or intrusive) of many of the rocks are difficult to determine; pillow structures are present in basaltic rocks at three sites near the heads of Hellbent and Reindeer Creeks, but in general clearly extrusive features are rare, possibly because of obliteration by structural deformation. Intrusive rocks are diabase-gabbro with some diorite chiefly in sills ranging from several meters to at least 90 m in thickness; medium to dark green, grayish green, and greenish black, and weathered to various shades of yellow, brown, and reddish brown; fine to very coarse grained; hard with blocky and irregular fractures; commonly form prominent high ridges, knobs, and bluffs. Altered gabbroic and mylonitic rocks containing glaucophane, prehnite, and pumpellyite, are present in the headwaters area of Ptarmigan, Hellbent, and Wrongtrail Creeks. Serpentinized ultramafic rocks occur within gabbro near Ptarmigan Creek, at the head of Twentymile Creek, and on lower Hoosier Creek; they have been reported also on Crash Creek and the upper Tozitna River (S. M. Roeske, oral communication, 1981). The sedimentary and metasedimentary rocks are chiefly argillite, phyllite, chert, and slate, with some tuff, epiclastic tuffaceous rocks, and arkosic semischist, and rare units of clastic limestone. The argillite and slate are commonly grayish red, maroon, and dark reddish brown, but include various shades of gray and green. The chert is generally light-medium to dark gray and in part greenish gray and red; contains radiolarians of late Paleozoic age, chiefly Late Mississippian (Chesterian) to Early Pennsylvanian (tab. 2). Limestone is medium gray, impure, and in part gritty to conglomeratic with pebbles of volcanic rock. A limestone, near Point No Point, contains pelecypod shell prisms and bryozoan fragments of probable Permian age, and gabbro from this area has yielded a Triassic radiometric age of 210 $\pm$ 6 m.y. (Patton and others, 1977). Unit appears to unconformably overlie several of the older rock units; thrust fault may form the lower contact or be within the lower part of this unit. An age range of Mississippian to Triassic or Jurassic(?) is assigned to this undifferentiated unit; part of unit probably is correlative with the Permian slaty shale, siltstone, graywacke, and conglomerate unit (Ps); similar undifferentiated units in the Melozitna, Bettles, and Beaver quadrangles have been assigned age ranges of Permian to Jurassic (Patton and others, 1978; Patton and Miller, 1973; Brosge and others, 1973). Thickness unknown but probably is at least 900 to 1,200 m.

Ps SLATY SHALE, SILTSTONE, GRAYWACKE AND CONGLOMERATE--Shale, medium to dark gray, moderately to well indurated, commonly weakly foliated to slaty, and in part phyllitic. Siltstone, medium to dark gray, well indurated, in part is argillite. Graywacke, medium to medium-dark gray, commonly very fine to fine grained but includes some granules. Conglomerate, medium to dark gray, largely small pebble to granule size; platy shale clasts are common; in part sheared and weakly foliated. Graded bedding is common with sandstone and siltstone beds 2 to 6 cm thick interbedded with shale or phyllite in units 10 to 20 cm thick. A minor amount of interbedded gray chert, similar in appearance to that of the Ordovician chert unit (Oc), is present. These rocks are unfossiliferous. Thin, discontinuous beds of sparsely-fossiliferous, slightly-metamorphosed clastic limestone (recrystallized arenaceous-brachiopod-packstone) occur rarely; these beds are light gray and weather to moderate to dark reddish or yellowish brown, with a rough surface on which fossil fragments stand in relief. Nodosaria spp., a foraminifera of Permian and younger ages was identified in thin sections of this limestone (tab. 2), and the association of crinoidal and bryozoan debris with Nodosaria spp. is indicative of Permian, rather than a younger age (A. K. Armstrong, written communication, 1974). This unit is coextensive with the upper Paleozoic conglomerate and shale unit in the Livengood quadrangle (Chapman and others, 1971) that includes beds of fossiliferous limy grit and gritty limestone; the assemblage of worn and fragmental bryozoans, brachiopods, and corals in old collections from these beds have been reidentified by J. T. Dutro, Jr., (written communication, 1970) as most likely of Early Permian age. Thickness is unknown, but probably at least 300 m in the Minook-Hoosier Creeks area. Lower contact with chert unit (Oc) is an unconformity or possibly a fault. Contact with the Late Jurassic and Cretaceous rocks, which are lithologically similar, is poorly exposed and only approximately located; it is an unconformity and may be a fault.

Pzar ARGILLACEOUS ROCKS--Thin bedded siltstone, slate, and phyllite, thick-bedded argillite, and minor amount of laminated sandstone; pale green, light greenish gray, medium bluish gray, and some medium-dark gray; weather to light yellowish gray, yellowish green, and medium-dark gray; weakly-developed foliation, in part crinkled, is common. Composed chiefly of angular to round silt-size grains of quartz and chert in a matrix of sericite and chlorite; considerable material of probable volcanic origin. Mapped only near Boulder Ridge. Contact relations, and the thickness and age are uncertain; unit apparently is younger than the Ordovician chert unit and older than the Late Jurassic and Cretaceous sedimentary rocks; most probable ages are Middle to Late Devonian or Permian. Probably about 300 m thick.

Pzc CALCAREOUS CLASTIC ROCKS--Siltstone and very fine-grained sandstone, medium gray, weather to various shades of brown; micaceous, largely calcareous, thin bedded and generally schistose. Composed of quartz, limonitic calcite grains, muscovite that is probably both authigenic and detrital, and minor amounts of chlorite, tourmaline, and shale clasts. Subordinate amount of dark gray to grayish black phyllite is interbedded. Mapped only in Minook Creek area. Unit appears to overlie the quartz wacke (Pzw); upper contact is poorly known. Age uncertain; probably early Paleozoic, and possibly Devonian. Thickness unknown, but probably 300 to 600 m.

Pzw QUARTZ WACKE -- Poorly sorted sandstone, granule conglomerate, siltstone, and semischist; dark gray, greenish gray, and limonitic yellow; medium to thin bedded, grading to schistose; generally of greenschist metamorphic facies. In thin section composed of angular, fine- to medium-grained quartz, 10 to 40 percent muscovite with some chlorite, and minor plagioclase; shows bimodal compositional layers of strained, elongated quartz grains and of muscovite-chlorite. Subordinate amounts of dark gray to grayish black phyllite are interbedded. Commonly 15 to 46 m of gray metachert is included near the contact with the overlying calcareous clastic rocks unit (Pzc). Age uncertain; probably early Paleozoic and possibly Devonian. Thickness unknown, but probably more than 600 m.

Pzsr SCHISTOSE ROCKS--Chiefly quartz-mica-garnet schist, white, light to medium gray, silvery gray, and brownish gray, weathers to various shades of light brown, orange, yellow, and gray; fine to coarse grained; foliation generally well developed; composed of quartz, muscovite, biotite, garnet (1 to 6 mm), with lesser amounts of feldspars, staurolite, sillimanite, tourmaline, chlorite, zircon, and pyrite. Includes some quartzite schist, gneissic schist, calcareous schist, marble, medium-dark gray slate-phyllite, schistose chert, hornfels, and skarn. Pegmatite, quartz, and felsic dikes are common; some mafic dikes are present; a small body of gneissic granite and pegmatite at the head of Garnet Creek is included. Structurally complex with isoclinal and recumbent folds and crinkled foliation. Almandine-amphibolite facies regional metamorphism is indicated; contact metamorphic rocks of hornblende- to pyroxene-hornfels facies occur locally. Age and protoliths of rocks in this unit are uncertain; age probably is middle Paleozoic. Unit apparently is conformable with the limestone, greenstone and schist (Pzl), but contacts are poorly exposed; unrecognized minor amounts of other rock units may be included. Thickness is unknown; may be as much as 600 to 900 m. Mapped only in Russian-Ruby-Garnet Creeks area.

Pzl LIMESTONE, GREENSTONE AND SCHIST--Dominantly limestone, partly dolomitic, and dolomite, generally light to light-medium gray, weather to various shades of gray, light buff, yellowish orange,

and chalky white; finely crystalline but in part is dense or coarsely crystalline; commonly medium bedded, but bedding also obscure, thin, or massive; cherty in part; locally carbonate is partly replaced by silica and the rock resembles quartzite or chert; schistose in part; rocks irregularly fractured and cut by calcite and quartz veins. Basaltic greenstone and partly calcareous chloritic schist are associated sequentially or interbedded with the carbonate rocks; chiefly light green to grayish green; protoliths probably mostly flows and agglomerate. Some argillite, phyllite, quartz-mica schist, quartzite and(or) metachert are included. Unit is complexly folded and unrecognized minor amounts of rocks from other units may be included. Carbonate rocks of more than one age probably are present, but, lacking fossils and continuous sections, the unit is not subdivided; interpreted to include rocks of Ordovician(?), Silurian, and Devonian ages. Apparently overlies chert unit (Oc); several thin chert-pebble conglomerate beds in basal 30 to 60 m; upper contact not seen. Mapped only south of Yukon River. May be correlative in part with the limestone, dolomite, greenstone and chert unit (Pzlc) north of the Yukon River, and in part with the Tolovana Limestone unit and the dolomite, limestone, silicified carbonate rocks and chert unit of the Livengood quadrangle (Chapman and others, 1971). Thickness uncertain; probably at least 150 m, and possibly as much as 460 m.

Pzlc LIMESTONE, DOLOMITE, GREENSTONE AND CHERT--Limestone, dolomitic limestone, dolomite, in part silicified, basaltic greenstone, and chloritic schist, all similar to rocks in the limestone, greenstone and schist unit (Pzl), form major part of this unit which is mapped only along and north of the Yukon River. Minor amounts of phyllite, calcareous schist, quartz-mica schist, quartzite, and chert are included. Rocks are structurally complex and show various degrees of greenschist facies metamorphism. Poorly preserved colonial rugose corals (F 10, tab. 2) from Raven Ridge are identified only as in age range of Silurian to Permian; based on regional interpretation, Silurian or Devonian ages seem most probable. Upper and lower contacts are not well defined; particularly the contact with mafic and sedimentary rocks unit (JMms) and the contacts within hornfelsic zones are uncertain. Unit may be correlative partly with the Tolovana Limestone and the dolomite, limestone, silicified carbonate rocks and chert units of the Livengood quadrangle (Chapman and others, 1971). An early Paleozoic age is provisionally assigned. Thickness unknown, but probably at least 460 m.

Pzvs VOLCANIC AND SEDIMENTARY ROCKS--Volcanic rocks are partly altered mafic lava and tuff, medium to dark grayish green and greenish gray, fine to very fine grained, chloritic, amygdaloidal in part, sheared, weakly foliated to schistose, much fractured; some fine to medium grained diabasic rocks, probably intrusive, are included. Sedimentary rocks include slate, slaty shale, phyllite,

tuffaceous limestone, cherty schist, and chert, all medium to dark gray, generally thin bedded, and locally sheared and foliated. Rocks commonly weather to various shades of brown and reddish brown. Unit apparently lies between and is gradational with the chert unit (Oc) and the limestone, greenstone and schist unit (Pzl), and is assigned an Ordovician or Silurian age; may include some unrecognized chert and carbonate beds of these units. Similar to the Ordovician(?) and Silurian(?) volcanic and sedimentary rocks unit of the Livengood quadrangle (Chapman and others, 1971). Differentiated only in area between Rock and Minook Creeks; elsewhere these rocks, if present, could not be discriminated on this map scale and are included in the chert (Oc), the limestone, greenstone and schist (Pzl), or the limestone, dolomite, greenstone and chert (Pzlc) units. Thickness unknown; probably is at least 70 to 100 m.

Oc CHERT--Predominantly chert, light to medium gray, weathers to medium gray and rarely to shades of red and tan; generally thin to medium bedded; sheared, foliated, and locally ranges to metachert and cherty schist; commonly jointed and irregularly fractured. Minor interbedded thin layers of slate and slaty shale, chert breccia, and a few beds of quartzite or recrystallized chert. Owing to structural complexity and discontinuous exposures, unrecognized minor amounts of rocks from other units, particularly chert of Late Paleozoic age, may be included. Nature of the upper and lower contacts is uncertain; unit probably grades upward into the volcanic and sedimentary rocks (Pzvs). Interpreted to be correlative with the Livengood Dome Chert (Chapman and others, 1980) and therefore is assigned a Late(?) Ordovician age. Thickness is unknown; possibly 300 to 600 m.

Ɛal ARGILLITE, SLATE, QUARTZITE AND GRIT--Argillite and slate are medium to dark red or maroon, light to medium green and grayish green, and medium gray; red-and-green-colored rocks alternate in interbedded units, and in bands or irregular mottling within one unit; fissile to chunky. Quartzite and grit are light yellow brown to light gray and weather to various shades of yellow, brown, and red; medium to coarse grained with clear to pale blue rounded quartz granules; commonly in beds 15 to 30 cm thick; minor interbedded finer-grained units and phyllite; in the Livengood quadrangle this unit includes some impure limestone but none was found in this quadrangle. Mapped only in southeast corner of quadrangle, and not well exposed. Correlative with the argillite, slate, quartzite, siltstone and limestone unit of the Livengood quadrangle (Chapman and others, 1971) and with lower part of the Nilkoka Group of the Fairbanks quadrangle (Pewe and others, 1966). Age uncertain, but older than the Ordovician chert unit (Oc); probably Cambrian but may include rocks as old as Precambrian. Thickness unknown; probably at least 300 m.

Pzp€sq SCHIST, QUARTZITE, PHYLLITE AND SLATE--Quartz-mica schist is commonly light to medium gray and silvery gray; quartzite is mostly light to medium gray, very fine grained, micaceous, schistose or chert-like in parts; white quartz in pods, lenses, and irregular veinlets is common; beds range from thin to thick. Slate and phyllite are light to dark gray, silvery, greenish gray, red, green, and rarely mottled red and green, interbedded in part with quartzite; minor amounts of gray chert, medium- to dark-gray shaly limestone, tuffaceous siltstone, and fine-grained and conglomeratic graywacke sandstone with stretched or sheared pebbles and shale fragments. Unit is mapped only north of the Yukon River; its relationship to the argillite, slate, quartzite and grit unit (€al) is uncertain. Underlies the limestone, dolomite, greenstone and chert unit (Pzlc), but contact is not sharply defined; contacts within zone of hornfels and gneiss are approximate. Unit is structurally complex and some unrecognized younger rocks may be included. An early Paleozoic and Precambrian age is provisionally assigned. Unit is generally correlative with the pelitic schist and the quartzite units of the Melozitna quadrangle (Patton and others, 1980), the pelitic schist unit of the Bettles quadrangle (Patton and Miller, 1973), and the pelitic schist unit of the Beaver quadrangle (Brosge and others, 1973). Thickness unknown; probably at least 600 to 900 m.

PLUTONIC ROCKS

Tg GRANITE--Biotite granite, light gray, fine to coarse grained; includes small areas of tourmaline-rich granite in border zone. Occurs only at Manley Hot Springs Dome; sample from top of dome has an early Tertiary radiometric age of 62 $\pm$ 3 m.y. (A2, tab. 1).

TKq QUARTZ MONZONITE--Chiefly quartz monzonite, may range to granite; light to very light gray, weathers to light grayish orange; largely coarse grained and porphyritic. Mapped only along Yukon River between Stevens and Morelock Creeks. Sample from bluff at Moosehead Rack has Late Cretaceous to early Tertiary radiometric age of 61.8 $\pm$ 2.5 m.y. (Silberman and others, 1979).

Kg GRANITIC ROCKS--Quartz monzonite, granite, monzonite, and possibly some granodiorite; light to very light gray, weather to various shades of gray and light yellow to tan; chiefly coarse to very coarse grained and porphyritic, but some fine-to medium-grained phases; blocky jointed, and in parts sheet jointing that resembles the foliation or bedding in adjacent hornfelsic rocks. Sample from Roughtop Mountain shows Late Cretaceous radiometric ages of 92 $\pm$ 5 and 90 $\pm$ 10 m.y. (A1, tab. 1); sample from Mt. Tozi has Early Cretaceous age of 104 $\pm$ 3 m.y. (Silberman and others, 1979); similar to the granitic rocks at Sawtooth Mountain in Livengood quadrangle (Chapman and others, 1971), and granitic rocks of Sithylemenkat pluton in Bettles quadrangle (Patton and Miller, 1973).

Km MAFIC ROCKS--Gabbro, may include some diorite; various shades of medium green and grayish green; generally fine to coarse grained, marginal areas are aphanitic to glassy. Age uncertain; probably about the same as that of the granitic rocks (Kg). Mapped only in Roughtop and Elephant Mountains area.

Ksp SERPENTINITE AND MAFIC ROCKS--Serpentinite, various shades of light to very dark green, weathers light gray and buff; generally sheared and foliated, blocky in part; includes a few blocks of rodingite. Diabase-gabbro and some metadiorite; medium to fine grained, light to medium gray green to green. Some thin layers of medium to dark gray graphitic slaty to schistose rock, phyllite, and mafic volcaniclastic rock are included. Mapped only on Serpentine Ridge and in Woodchopper-Baker Creeks area. Serpentinite and the mafic rocks apparently intrude the clastic sedimentary rocks unit (KJcs); age probably Late Cretaceous.

JPu ULTRAMAFIC ROCKS -- Serpentinized peridotite and dunite. Mapped only in the northwest part of the quadrangle. Close association of these rocks with mafic rocks of the mafic and sedimentary rocks unit (JMms) suggests that these units have approximately the same age. Coextensive with similar unit of Patton and Miller (1973).

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TABLE 1. Age determinations of granitic rocks

Potassium-argon decay constants $K^{40}\lambda_\beta = 4.72 \times 10^{-10}/yr$, $\lambda_\varepsilon = 0.585 \times -10^{-10}/yr$; abundance $K^{40} = 1.19 \times 10^{-4}$ mol/mol K. Lead-alpha age calculated from t - C Pb/α, assumed U/Th ratio 1.0, C = 2485; Pb determined by Harold Westley and Charles Annell.

Potassium-argon determinations by H. H. Thomas, R. F. Marvin, and P. L. D. Elmore.

Recalculated using 1976 IUGS constants. Sites are shown on map, as x A1.

Site Number	Field number	USGS Lab. number	Location	Geologic unit and mineral	K_2O (percent)	Ar^{40} rad (ppm)	Ar^{40}_{rad}/K^{40}	Ar^{40} (percent)	α/mg-hr	Pb (ppm)	Calculated age (m.y. = millions of years)
A1	60ATb-104	164	65°10.3' N. 150°46.5' W. Roughtop Mountain	Kg Biotite	8.28	0.0453	0.00546	90	---	---	92 ± 5 m.y.
A1	60ATb-104A	-do-	-do-	Zircon	---	---	---	---	368	13.5	90 ± 10 m.y.
A2	60ATb-105	165	65°01.8' N. 150°42' W. Manley Hot Springs Dome	Tg Biotite	9.05	0.0310	0.00342	92	---	---	62 ± 3 m.y.

TABLE 2.--Fossil collections

[Sites are shown on map, as X F1. Previously published descriptions of other fossil collections are given by Mertie (1937), Brosgé and others (1969), and Chapman and others (1971)]

Site Number	Field number	U.S.G.S. locality number	Location	Description	Age	Map Unit
F1	59AHp-227 a,b,c,d,f	D1472-1,2, 3,4,6	65°32' N. 150°-9' W. Yukon R.	Pollen assemblage of 34 recognizable genera including the following genera that are now exotic to Alaska: Carya, Ilex, Pterocarya, Tilia, and Ulmus.1/ The assembage is consistent with a Miocene age.2/	Miocene	Ts
F1	59AHp-227	---	---do---	Plant material: Metasequoia sp., Cercidiphyllum cf. C. crenatum (Ung.) R.W. Br., and Alangium n. sp. The Alangium is a species that is characteristic of the early and middle Miocene ages in Alaska, and the other two genera are consistent with this.2/	Miocene	Ts
F2	71ACh-166f	---	65°15.6' N. 151°10.8' W. Yukon R.	Pollen assemblage including Alnipollenites and Aquilapollenites.3/	Early Tertiary	Ts
F2	71ACh-166F	---	---do---	Leaves similar to other early Tertiary collections from this region.4/	Early Tertiary	Ts
F3	71ACh-186	---	65°14.2' N. 151°24.5' W. Yukon R.	Pollen assemblage including Alnipollenites.3/ Plant material similar to other early Tertiary collections from this region.4/	Early Tertiary	Ts
F4	71ACh-36A	---	65°13.3 N. 151°26' W. Yukon R.	Pollen and spores including Alnipollenites, Aquilapollenites, and Appendicisporites.3/ Plant material similar to other early Tertiary collections from this region.4/		
F4	71ACh-48	---	---do---	Pollen assemblage, non-diagnostic.3/	---	Ts
F5	WY-A3-71	D4782	65°35' N. 151°22' W. Gishna Cr.	Pollen assemblage including Caryapollenites, Ilex, Tiliaepollenites, and Ulmipollenites.3/	Early Tertiary	Ts
F6	71ACh-18	D4780	65°32.7' N. 151°30' W. Tozitna R.	Pollen assemblage including Ilex, Platycarya, and Tiliaepollenites.3/	Early Tertiary	Ts (in Qal)
F7	WY-A5-71	D4783	65°31.5' N. 151°34' W. Tozitna R.	Pollen assemblage including Tiliaepollenites and Ulmipollenites.3/	Early Tertiary	Ts
F8	WY-A2-71	D4781	65°32.5' N. 151°38' W. Tozitna R.	Pollen assemblage, including Ilex.3/	Early Tertiary	Ts
F9	73ACh-59	M1166	65°25' N. 149°56.7 W. Off east edge of map	Foraminifera; Nodosaria spp.5/ Sample site is near head of Little Minook Creek in Livengood quadrangle in rocks that are an eastward extension of unit Ps.	Permian	Ps

TABLE 2.--Fossil collections - Continued

Site Number	Field number	U.S.G.S. locality number	Location	Description	Age	Map Unit
F10	72ACh-86	---	65°24.5' N. 150°55' W. Raven Ridge	Colonial rugose coral.6/	Post-Ordovician, could be Silurian to Permian	Pzlc
F11	74ACH-162	D5930	65°12.5' N. 152°44' W. Near Lancaster Creek.	Pollen abundant and well perserved; Tsuga, Picea, and Alnus are Common, and Pinus, Albies, Lycopodium, Salix, Betula, Pterocarya, and Myrica types are present. Assemblage is consistent with a Miocene age.7/	Miocene	Ts
F11	74APa-98A	D5931	--do--	Pollen sparse and badly corroded; assemblage includes those in D5930 and also Fagus(?) and Nyssa(?). A Miocene age is suggested.7/	Miocene	Ts
F11	74APa-93C	D5932	--do--	Pollen is abundant, but in general poorly preserved; Pinus, Picea, Tsuga, and Alnus are common, and Abies, Myrica type, Ulmus-Zelkova(?), Carya(?), and Pterocarya(?) are present. Assemblage is consistent with a Miocene age.	Miocene	Ts
F11	74APa-98D	D5933	--do--	Pollen is sparse and many grains are badly degraded and broken; Pinus, Tsuga, Picea, Alnus, Myrica type, Betula(?), Pterocarya, Liliaceae, and Bryophyte spores can be recognized. Assemblage is consistent with a Miocene age.7/	Miocene	
F12	79-68A	MR0954	65°30.9' N. 150°39.6' W. VABM Moose	Radiolaria; Spongodiscaceid (tetrahedral), Spongotripus sp., "Parahagiastrid" sp., Paronaella sp. aff. P. ruestae Ormistan and Lane. Age is Late Paleozoic probably Late Mississippian (Chesterian) to Early Pennsylvanian; absence of some groups of radiolaria suggests that sample is not as young as Permian.8/ Sample collected 1979 by Sarah M. Roeske.	Probably Late Mississippian (Chesterian) to Pennsylvanian	JMms
F12	70ACh-115	MR0047	---do---	Radiolaria; very poorly preserved spumellarians.	Indeterminable	JMms
F13	70ACh-79A	---	65°35.6' N. 150°56.4' W. Tozitna R.	Radiolaria; assemblage same as in sample 79-68A from VABM Moose.8/	Probably Late Mississippian (Chesterian) to Pennsylvanian	JMms
F14	71ACH-37	MR0048	65°27.4' N. 151°44.5' W. Ptarmigan Cr.	Radiolaria; poorly preserved spumellarians including possible Spongodiscarceid gen. nov. (tetrahedral) and "Parahagiastrid".8/	Late Paleozoic	JMms
F15	71ACH-39	MR0049	65°30' N. 151°31.8' W. Tozitna R.	Radiolaria; very poorly preserved Spumellarians.8/	Indeterminable	JMms
F16	71ACh-89	MR0050	65°24' N. 151°56.1' W. Reindeer Cr.	Radiolaria; Spongotripus sp.8/	Late Mississippian to Permian	JMms

1/ Identified by Estella B. Leopold, U.S.G.S., 1963.
2/ Identified by Jack A. Wolfe, U.S.G.S., 1975.
3/ Identified by Richard A. Scott and Gene Doher, U.S.G.S., 1972. Age confirmed by Jack A. Wolfe, oral communication, 1975.
4/ Identified by Jack A. Wolfe, oral communication, 1971.
5/ Identified by Augustus K. Armstrong, U.S.G.S., 1974.
6/ Identified by William A. Oliver, Jr., U.S.G.S., 1972.
7/ Identified by J. Platt Bradbury, U.S.G.S., 1979, and age confirmed by Jack A. Wolfe, oral communication, 1981.
8/ Identified by David L. Jones and Bonnie L. Murchey, U.S.G.S., 1981.

TABLE 3.--Radiocarbon age determinations

[Sites are shown on map, as X R1. Measurements made in laboratory of U.S. Geological Survey by Meyer Rubin.)

Site number	Field number	USGS Lab. number	Location	Description	Age (yrs. B.P.)
R1	WY-A14-70	W-2554	65°32.2' N. 150°20' W. Squaw Cr.	Wood from bed of sand and silt, or poorly consolidated sandstone, in a cobble-boulder gravel, or semi-consolidated conglomerate (unit QTg).	>40,000
R2	WY-A8-71	W-3001	65°33.2' N. 151°56.8' W. Tozitna R.	Wood from bed of sand that is overlain by 7.6 m of muck and underlain by 1.8+ m of boulder gravel (unit Qags).	>42,000