UNITED STATES
DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

TO ACCOMPANY OPEN-FILE REPORT 83-170-A

Preliminary Geologic Map of the Circle Quadrangle, Alaska

by

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Menlo Park, California
1983

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INTRODUCTION AND ACKNOWLEDGEMENTS

The preliminary reconnaissance geologic map of the Circle quadrangle is based primarily on fieldwork carried out in the summers of 1978, 1979, 1980, and 1981 as a part of AMRAP (Alaska Mineral Resources Assessment Program) of the U.S. Geological Survey. The fieldwork was carried out by the following geologists, who each worked all or parts of the field seasons indicated:

Helen L. Foster	1978 through 1981,
Florence R. Weber	1978 through 1981,
Jo Laird	1979 through 1981,
Terry E. C. Keith	1978 through 1980,
and W. D. Menzie	1978 through 1981.

Field assistants were:

Diana Nelson	1978 and 1979,
Stephen Luthy	1978,
Christopher Norton	1979,
Anna Burack	1980,
Grant Cushing	1980 and 1981.

Guest workers included:

Michael Churkin, Jr.	1979 and 1980,
James H. Trexler, Jr.	1979 and 1980,
J. T. Dutro, Jr.	1981,
John N. Aleinikoff	1980, and
Frederic H. Wilson	1979

John W. Cady, geophysicist, took part in the mapping in 1979 and briefly in 1981. Warren E. Yeend studied stream and terrace gravels and the Tertiary sedimentary rocks briefly in 1980 and 1981.

Aerial photograph interpretation has been done largely by Florence R. Weber, primarily for the mapping of surficial deposits. J. T. Dutro, Jr., William A. Oliver, Jr., Anita G. Harris, David L. Jones, Benita Murchey, Kirk Denkler, and Charles D. Blome have identified fossils. Frederic H. Wilson obtained many ages, especially on plutonic rocks, by the potassium-argon method. John N. Aleinikoff obtained ages on several samples of metamorphic rocks by the Ur-Pb method.

John B. Mertie's classic compilation, U.S. Geological Survey Bulletin 872 (1937), still provides a foundation and framework for geologic mapping in the quadrangles of the Yukon-Tanana region, including the Circle quadrangle. In 1960, 1961, and 1962, William E. Davies and Daniel B. Krinsley worked in the eastern Circle quadrangle, and they generously furnished us with some of their unpublished data including unpublished geologic maps. A considerable amount of other published and unpublished data were used, including unpublished theses of Norma Biggar amd Bjarne Holm. Unpublished geologic information was also furnished by Ann Byrd, James Barker, and others, including local miners and prospectors, mining company geologists, and U.S. Geological Survey geochemists.

The Circle quadrangle is located near the margin, possibly a fragmented margin, of the North American continent. Faults of the Tintina fault zone trend northwesterly through the northern part of the quadrangle, and in part separate greenschist and amphibolite facies metamorphic rocks on the southwest from only very slightly metamorphosed rocks on the northeast. Other faults, including thrust faults, some of which may also be related to the Tintina system, separate the quadrangle into a number of areas with minor to major differences in structure and stratigraphy. For ease of description, the Circle quadrangle is divided into three major areas; the northwest Circle quadrangle, the area north of the Tintina fault zone, and the area south of the Tintina fault zone (about the southern two-thirds of the quadrangle) (fig. 1).

The northwest Circle quadrangle includes the Beaver, White Mountains, Kandik River, and Livengood terranes of Churkin and others (1982). The rocks in this part of the quadrangle are, for the most part, the northeasterly continuation of the stratigraphy and structure of the northeastern part of the Livengood quadrangle (Chapman and others, 1971, 1980). In the explanation of units in the northwest Circle quadrangle frequent reference is made to the mapping in the Livengood quadrangle and the units used there form the basis of the units in the northwest Circle quadrangle. However, due to a lack of detailed mapping in both the eastern Livengood quadrangle and western Circle quadrangle, some contacts and structures are not in agreement on the two maps.

The area north of the Tintina fault zone consists of the Circle and Crazy Mountains terranes of Churkin and others (1982). The Circle terrane in the northern part of the Crazy Mountains and Little Crazy Mountains is dominantly mafic igneous rocks, primarily diabasic gabbro, some basalt, and intercalated chert. However, chert is the most common rock type along the southern margin of the terrane. The Circle terrane is probably in fault contact with metasedimentary rocks to the south. The Crazy Mountains terrane consists of two separated mountain blocks, the east and west Crazy Mountains, which have both similarities and differences in their stratigraphy. A third block, south of the West Crazy Mountains, here called the Preacher block, has some stratigraphy in common with that of the Crazy Mountains, but also has different stratigraphic units. Some elements of the stratigraphy of the Crazy Mountains area are similar to those of the northwest Circle quadrangle area.

The largest part of the quadrangle is the area south of the Tintina Fault zone most of which is included in the composite Yukon Crystalline terrane (Churkin and others, 1982). It is primarily composed of metamorphic rocks with continental affinities, but some ultramafic and mafic rocks also occur. Regional metamorphism is primarily medium-pressure facies series and ranges from amphibolite facies (sillimanite + potassium feldspar grade in pelitic rocks) to greenschist facies (chlorite grade). Metamorphic grade generally decreases from southeast to northwest. Omphacite + quartz + garnet-bearing mafic assemblages in the southwestern part of the quadrangle (northwestern A-6 quadrangle) and staurolite-andalusite pelitic schist in the southeastern part of the quadrangle (southern A-2 quadrangle) indicate that regional high-pressure and low-pressure intermediate facies series metamorphism, respectively, also occur. Locally, contact metamorphism associated with the intrusion of Late Cretaceous and early Tertiary granites is superimposed on the regional metamorphism. A complex deformational history is recognized and consists of at least four events, including development of penetrative

schistosity, two generations of recumbent folds, and a late open folding (Cushing and Foster, 1982).

Previous mapping (Davies, 1972) indicates that the rocks of the Circle quadrangle are cut by hundreds of small high-angle faults, but these are difficult to establish in the field without detailed mapping; only a few of the more prominent ones are indicated on this map. In the metamorphic terrane, rocks only very slightly metamorphosed are believed to be overthrust by highly deformed greenschist to amphibolite facies rocks, which are in turn overthrust by greenschist (chlorite grade) facies rocks. Thrust fault contacts are also postulated between the dominantly quartzitic metamorphic rocks and the dominantly pelitic group, and distribution of isograds indicate that these rocks were in thrust contact before they underwent major regional metamorphism. Thrusting is believed to account for the exposure of the eclogitic rocks in the west central part of the quadrangle. Northeasterly-trending high-angle faults cut the thrust sheets.

The Tintina fault zone in the Circle quadrangle includes several fault strands. The postulated Hot Springs fault (Weber and Foster, 1982) separates the metamorphic rocks of the Yukon Crystalline terrane from unmetamorphosed to very slightly metamorphosed rocks on the north. A fault north of Medicine Lake, upthrown on the north, cuts Quaternary surficial deposits and may be an active fault (Davies, 1972; Weber and Foster, 1982). A fault crosses Preacher Creek below the mouth of Loper Creek separating Tertiary(?) conglomerate from Paleozoic(?) slate, quartzite and greenstone (Weber and Foster, 1982).

DESCRIPTION OF MAP UNITS
UNCONSOLIDATED DEPOSITS

Qa ALLUVIUM--Gravel, sand, and silt, gray, buff, or brown; unconsolidated, well-sorted, well-stratified; mapped only in valleys of major streams. In some valleys, such as the valley of Birch Creek and Preacher Creek and the flood plain of the Yukon River, contains dark-colored organic silt and peat which generally is perennially frozen, and fills old channels and cutoff meanders. In some mountain areas includes reworked outwash gravel. Includes gravel, sand and silt of low terraces. In the Yukon valley most alluvium is perennially frozen although extensive thaw zones occur beneath the modern river channels, lakes, river bars and abandoned channels. Thickness of permafrost estimated at 3 to 20 m beneath the floodplain and at 0.3 to 50 m beneath the low terraces (Williams, 1962).

Qab ABANDONED FLOOD PLAIN ALLUVIUM--Gravel, gray to brown, granule to boulder size, well-sorted, well-stratified, rounded with minor amounts of sand and silt, and a few layers and lenses of peat and woody material, covered with as much as 8 m of silt and organic material. Perennially frozen except beneath water bodies and well-drained sites. Mapped only along the Yukon River.

Qac ALLUVIUM AND COLLUVIUM--Boulders, gravel, sand, silt, and angular rock fragments. Mostly poorly sorted and poorly stratified. Occurs on valley sides of large stream valleys. In most small stream valleys includes alluvium of valley floor, low terraces,

alluvial fan debris and colluvium on valley sides. In glaciated valleys may include outwash, reworked outwash, and morainal material.

Qaf ALLUVIAL FAN DEPOSITS--Gray, tan and brown, locally stained by iron oxide; sandy pebble-cobble gravel and pebble-cobble-boulder gravel with lenses and layers of sand, silt and organic material; considerable variation in size of clasts depending on proximity to bedrock; some fans in the Yukon Flats are mostly silt; gravel fans are stratified and well-sorted. Generally much dissected with only remnants remaining of older fans. Commonly partly covered by sand, silt, and organic material. Mostly perennially frozen. Mapped primarily along the Yukon River and tributary drainages in the northern part of the quadrangle. A few small fans mapped along the east fork of the Chena River and near Sourdough Creek on the Chatanika River. Other small alluvial fans included in units of alluvium (Qa) or alluvium and colluvium (Qac).

Qs SILT AND PEAT--Organic silt deposited in swamps; black, dark gray, or mottled dark gray and brown; mostly perennially frozen. Only a few large areas of this unit mapped in the Yukon Flats area in the northeastern part of the quadrangle. Small areas of silt and peat included in units of alluvium (Qa) or alluvium and colluvium (Qac).

Qsu SILT, UNDIFFERENTIATED AND ORGANIC MATERIAL--Silt, organic silt, and peat, with local sandy lenses and layers. Gray, dark gray, dark brown or black. Originally largely of eolian origin, but commonly retransported from original site of deposition to lower slopes and valley bottoms by alluvial and solifluctional processes. Locally highly organic; generally perennially frozen with abundant ground ice as horizontal and vertical sheets, wedges, and irregular masses. Thickness ranges from one meter to about 60 m. Mapped only in the Yukon and tributary drainages in the northern part of the quadrangle.

Qg GRAVEL--Light gray to light yellowish brown, pebble to boulder size, with thin layers of sand and silt; subangular to well-rounded and well-stratified. At one time probably formed a large alluvial fan of the Yukon River extending out into the flats; present now in high-level terraces as much as 80 m above the Yukon River and Yukon Flats. Clast size decreases over short distances to granules and coarse sand at the distal edge. Gravel also forms a thin mantle over bedrock in many places (not shown on map) in the Tintina Fault zone; lithologies derived from the metamorphic rocks in the Yukon-Tanana Upland to the south. Clasts in deposits near the Yukon River reflect upstream lithologies. Thickness ranges from a few cm to over 60 m.

Ql LOESS--Silt and sandy silt, eolian; yellowish gray to light gray, locally mottled by iron-oxide staining; well-sorted, homogeneous, unconsolidated; generally perennially frozen, especially in low areas, with abundant ground ice. Forms extensive mantle over much of the northern part of the quadrangle. Where mapped is generally 0.3 m or more thick. Where thinner is included in other units such as alluvium (Qa) or alluvium and colluvium (Qac), or abandoned flood plain alluvium (Qab). Includes colluvium in some areas.

Qm MORAINAL DEPOSITS, UNDIFFERENTIATED--Boulders, gravel, sand, and silty sand in terminal moraine, lateral moraine, moraine in cirques, and minor ground moraine of several different ice advances. Deposits range from comparatively unweathered without evident surface oxidation to considerably weathered with surface oxidation extending to a depth of 2 m. Moraines range from young, steep-sided and sharp-crested with ponds to old with subdued topography and no ponds. Some of the oldest moraines and small deposits are not shown. Some small morainal deposits are included in other units such as alluvium and colluvium (Qac).

SEDIMENTARY ROCKS

Tcs CONGLOMERATE AND SANDSTONE--Conglomerate, mostly gray or tan, but locally pink or orange brown. Coarse to fine; grades into sandstone. Clasts are generally well-rounded and range from 1 to 5 cm in diameter, but boulders up to 45 cm in diameter occur. Conglomerate well to poorly consolidated; breaks around clasts; commonly forms rounded gravel-surfaced hills. Generally poorly stratified. Clasts most commonly gray and black chert, gray quartzite, with lesser amounts of white quartz, but in places may include gray and light-green phyllite, green chert, black shiny "coaly" material, very rare biotite granite, and conglomerate; generally well-polished. However, pebble count on East Albert Creek indicates that the clasts are 44 percent quartzite, 37 percent white quartzite, 10 percent chert, and 10 percent schistose quartzite. Matrix commonly minor and generally consists of medium to coarse sand of the same general composition as clasts; locally argillaceous.

Sandstone, gray, tan, or iron-oxide stained, and commonly has "salt and pepper" appearance; fine to coarse grained; locally slightly argillaceous. In places has poor to moderately-well preserved plant material and impressions, including Metasequoia and broadleaf types. Well to slightly cemented; occurs as minor discontinuous layers and lenses in conglomerate. Locally chunks of lignite and coal are found in float associated with conglomerate and sandstone and may be derived from this unit. Unit gold bearing on East Albert Creek. Bedding generally obscure, but on East Albert Creek dips up to 55°. Minimum thickness known to be as much as 90 m. Distribution of this unit, as presently known, restricted to area near Tintina Fault system. Age uncertain but presumed to be Tertiary (Mertie, 1937, p. 175).

UNMETAMORPHOSED IGNEOUS ROCKS

TKg GRANITE[1/]--Mostly light to medium gray, hypidiomorphic granular to porphyritic; biotite is most common mafic mineral, but hornblende locally present; a small amount is two-mica granite generally with minor amounts of white mica. Occurs in

1/ Use of the term "granite" follows that of the I.U.G.S. Subcommission in the Systematics of Igneous Rocks (Streckeissen, 1973).

batholithic or stock size intrusions; K/Ar ages range from about 56.5 to 65.9 m.y. Typical modes are estimated from thin sections stained for potassium feldspar (table 1).

Victoria Mountain pluton--Light to medium gray, and pinkish-gray hypidiomorphic granular to porphyritic hornblende-biotite granite (table 1).

Lime Peak pluton--Includes 3 textural variations of granite. Most common type is medium-grained hypidiomorphic granular biotite granite; second type is porphyritic with zoned potassium feldspar phenocrysts 2 cm long in a groundmass of quartz, plagioclase and biotite; third is medium fine-grained hypidiomorphic granular biotite granite. All three varieties crop out near Lime Peak (table 1). On the north flank of Lime Peak, tors of coarse grained granite with smoky quartz and green amphibole altering to chlorite, occur along with coarse-grained biotite granite. Coarse-grained inequigranular granite composed mostly of large gray frosted quartz grains and feldspar apparently is a common dike rock. Several other types of granitic and intermediate dikes are also common locally.

Quartz Creek pluton--Light to medium gray, medium to coarse grained, hypidiomorphic-granular to porphyritic biotite granite with minor muscovite, hornblende and tourmaline (table 1).

Mt. Prindle pluton--Light to medium gray, fine to coarse grained porphyritic biotite granite. Local areas with a hypidiomorphic-granular texture (table 1). Numerous aplite, pegmatite and quartz porphyry dikes cut the biotite granite. A small outcrop of fine-grained porphyritic hornblende granite occurs southeast of the biotite granite pluton.

Chena Hot Springs pluton--Three phases differentiated based on grain size and(or) mafic mineral content. Coarse-grained biotite granite is most abundant; fine-grained biotite granite occurs in the valley of Monument Creek and in a few localities at higher elevations; fine-grained hornblende-biotite granite is rare, but found east of the hot springs (Biggar and Forbes, 1980) (table 1). Hydrothermal alteration locally present. Several kinds of felsic and mafic dike rocks cut the granite and nearby country rocks.

Big Windy Creek pluton--Light to medium gray, medium grained biotite-muscovite granite; hypidiomorphic granular (table 1).

Circle Hot Springs pluton--Light to medium gray, medium to coarse grained biotite and minor biotite-hornblende granite. Hypidiomorphic granular to porphyritic (table 1).

Pluton north of Yukon Fork in Circle B-1 quadrangle--Light to medium gray, medium to coarse grained biotite granite; hypidiomorphic granular. Portions of the pluton contain both white mica and biotite. Garnet present in some samples. Tourmaline is a minor accessory mineral (table 1).

Pluton in Circle A-2 quadrangle--Light to medium gray, medium to coarse grained, hypidiomorphic granular to porphyritic biotite granite. Some potassium feldspar poikilitic; plagioclase zoned and partially sericitized (table 1).

TKf FELSIC IGNEOUS ROCK--Light gray weathering gray or tan, fine to coarse-grained quartz porphyry. Quartz is gray, commonly

terminated and frosted; feldspar is white to tan and altered; mafic minerals are sparse or absent. Occurs as small shallow-level intrusive bodies, dikes and sills west and north of Twelvemile Summit in the B-5 and B-4 quadrangles. Age uncertain but most likely similar in age to granites (TKg) which range from Late Cretaceous to Paleocene.

NORTHWEST CIRCLE QUADRANGLE
(Beaver, White Mountains, Livengood, and Kandik terranes of Churkin and others, 1982)

KJqs QUARTZITE, ARGILLITE, CONGLOMERATE, AND HORNFELS--Quartzite, mostly gray, fine- to medium-grained, interlayered with argillite. Argillite mostly gray, greenish gray, reddish-gray, and tan; locally quartzitic; graded bedding observed rarely. Quartzite and argillite are hornfelsed near Victoria Mountain. Hornfels generally light to dark gray with dark green spots locally; in places, banded with maroon and pink layers. Orange-brown stained zones common. Coarse conglomerate with boulders as much as 1.5 m in diameter crops out along Beaver Creek. Boulders and cobbles are well-rounded and composed mostly of quartzite, with some chert, chert-pebble conglomerate, greenstone, diorite(?), and porphyrytic andesite(?). Matrix is greenish-gray or gray of probable graywacke composition. No sorting evident; generally breaks around clasts, but in places breaks across pebbles and cobbles but around large boulders; matrix weathers out around clasts. In places, conglomerate is sheared and stretched. Slickensides locally abundant. Contacts may be structural. Assumed to be an eastward continuation of the conglomerate, graywacke, and shale unit (Kdc) in the Livengood quadrangle (Chapman and others, 1971) and therefore considered of probable Cretaceous or Jurassic age.

MzBat ARGILLITE, TUFF, QUARTZITE, AND CONGLOMERATE--This unit consists of two distinct parts; one, which includes VABM Vrain D-5 quadrangle, composed of mostly argillite with minor quartzite and slaty argillite; and the other, which includes areas shown by tt symbol, characterized by tuffaceous rocks associated with black or dark gray argillite and conglomerate. Argillite, including siltstone, siliceous siltstone, and shale of the eastern area is dominantly gray, olive, or greenish gray and generally weathers reddish-yellow brown or tan; commonly limonite or manganese stained along fractures; locally slaty; cleavage commonly well-developed and folded. Quartzite mostly greenish gray or gray, but some white or light gray. Sulfides and hematite(?) locally abundant. Argillites, especially olive-colored argillites, very similar to those of the argillite grit and quartzite unit (Zpcs). Felsic tuff and pyroclastic rocks are medium light-gray; some crystal tuff with large dark gray, glassy quartz crystals. Pyroclastic rocks interlayered with gray and dark gray argillite. Tuff and argillite appear to be interlayered with conglomerate, especially near the western and northern margins of unit. Conglomerate has pebbles as large as 3 cm in diameter composed mostly of white quartz and gray and black chert. Most pebbles stretched and flattened. Shearing

common in conglomerate and tuff. Rocks of this unit poorly and sparsely exposed except in the eastern part of area near VABM Vrain. Springs, with surrounding sediments and vegetation stained orange-brown, emerge from rocks of this unit in several places. Contact may be structural, at least in part.

Age relations of this unit are uncertain and the two parts of it may be of different ages.

MzPzaq ARGILLITE AND QUARTZITE--Argillaceous rocks include argillite, mudstone, and siltstone mostly dark gray to black, locally quartzitic, and calcareous in a few places; gray and black chert occurs locally. In at least three localities a vitreous quartzite (shown by dots on map), probably an eastward extension of vitreous quartzite unit (Oq) of the Livengood quadrangle (Chapman and others, 1971), crops out. Quartzite is light gray, dense, and has a vitreous luster. Outcrop of quartzite is not as continuous or as prominent as in the Livengood quadrangle. Limestone, gray, very fine grained and thinly bedded crops out at one locality in the C-6 quadrangle and contains bar and simple cone conodont fragments which have an age range of Ordovician through Triassic (map no. 1, table 2).

Mafic lavas, dark greenish gray, including amygdaloidal basalt and basalt breccia appear interlayered with sedimentary rocks; gabbroic rocks occur as dikes and sills.

Some contacts may be structural. Both early Paleozoic and early Mesozoic ages have been postulated by different workers for this unit, but definitive fossils have not been found.

PzuG ULTRAMAFIC AND MAFIC ROCKS AND GREENSTONE--Serpentinized peridotite, mostly greenish-black; bastite visible on weathered surfaces. Associated cumulate clinopyroxene gabbro and clinopyroxenite; also amphibole gabbro and clinopyroxene gabbro with secondary quartz crop out locally as layers. Secondary chlorite and actinolite abundant in gabbros; local clinozoisite and sphene. Brecciated in places. Magnesite marble locally infolded in serpentinized peridotite. Aeromagnetic data suggests that the ultramafic rocks of this unit which crop out on Beaver and Victoria creeks are continuous beneath a loess cover.

Greenstone consists of metamorphosed basalt and tuff. Volcanic textures include aphanitic, intersertal, microporphyritic, and glomeroporphyritic with clots of plagioclase and pyroxene. Secondary chlorite, talc, and actinolite. Outcrops mostly massive, but locally brecciated. Locally vesicular, commonly with a lumpy weathering surface. Probably in thrust fault contact with adjacent metasedimentary rocks.

Dsd DOLOMITE AND ARGILLITE--Dolomite mostly yellow-gray, weathering tan or brown; argillaceous rocks include argillite, shale and siltstone mostly gray and dark gray to black; interlayered with light and dark gray chert, yellow-gray dolomite, gray marble, and gray, fine-grained quartzite. Locally includes amygdaloidal greenstone with calcite veinlets and calcite-filled amygdules, and mafic to intermediate(?) dikes. Poorly exposed. Some contacts are structural. Rocks of unit extend eastward from Livengood quadrangle (dolomite, limestone, silicified carbonate rocks and chert unit (Dod) of Chapman and others (1971)).

Suggested Early Devonian to middle Silurian age and stratigraphic relationships are based on determinations in the Livengood quadrangle (Chapman and others, 1980).

Dsl LIMESTONE, DOLOMITE, AND SHALE--Limestone gray, medium light to dark; weathers tan or yellowish brown; fine to medium grained; partly recrystallized; locally brecciated and cut by calcite veinlets; in a few places contains interlayered minor dolomite and dark gray shale. No fossils found, but coral and echinodermal debris occur to the west in the Livengood quadrangle. Rocks of this unit are on trend with Tolovana Limestone in the Livengood quadrangle and probably correlative. Contacts probably mostly unconformable, but some may be fault contacts.

Sos SILTSTONE, DOLOMITE, CHERT, AND MAFIC IGNEOUS ROCKS--Siltstone, along with argillite and mudstone, gray, black, or olive gray; commonly sheared with locally well-developed cleavage. Dolomite tan, weathers brown; generally layers are a few cm to one m thick. Limestone also occurs and is gray or dark gray, banded, fine-grained; chert gray or dark gray, commonly sheared and brecciated. Rocks slightly metamorphosed, folded, and commonly sheared; axial plane cleavage locally well developed. Dikes, sills, small lense like bodies, and layers of dark greenish black gabbro and basalt. Some basalt contains carbonate amygdules; in places vesicular where carbonate has been removed.

These rocks crop out in two bands, one in the northeastern part of the Circle quadrangle and one south of Beaver Creek. Chert occurs mostly in the northern band and the mafic rocks are present in the southern band. Outcrops are very limited, especially in the southern area. Because of poor exposure, lack of fossils, uncertain stratigraphic sequences, and non-distinctive lithologies, these rocks have not been subdivided. They are tentatively mapped as an extension of the volcanic and sedimentary rocks (SOvs) of the Livengood quadrangle. They may include Mertie's unit, the Fossil Creek Volcanics (Mertie, 1937, p. 81-85). However, they are not typical of type Fossil Creek Volcanics. Provisionally considered Ordovician and(or) Silurian in age.

Old LIVENGOOD DOME(?) CHERT--Unit includes chert, slate, argillite, dolomite, limestone, and altered mafic rocks. Chert dark gray and black, brecciated near contacts. Argillite, with some shale and slate, gray. Dolomite gray, weathering tan, brown, and orange-brown. Minor limestone, greenish-gray, dirty and dark gray; recrystallized. Mafic volcanic rocks, greenish-gray, vesicular and amygdaloidal with calcite-filled amygdules, also are minor in occurrence. The only fossils found are poorly preserved radiolarians (Spumellariina) (map no. 3, table 2) of indeterminable age. A tentative unit designation is based on lithologic similarities to the Livengood Dome Chert in the Livengood quadrangle (Chapman and others, 1980) and apparent continuation of its structural trend into the Circle quadrangle. Type Livengood Dome Chert is Late Ordovician.

Zpεa ARGILLITE, GRIT AND QUARTZITE--Argillite, gray, maroon, and green; slaty. Interlayered gray and greenish gray grit and quartzite; quartzite commonly has a boxwork of calcite veinlets; near southern contact minor interlayered gray, recrystallized

limestone and greenish gray impure limestone; also minor gray chert. Minor basalt and gabbro, dark greenish gray; some amygdaloidal; calcareous; has sulfides in places. Maroon and green argillite not abundant, but unit defined on first occurrence of maroon and green argillite above quartzite and argillite of the quartzite and argillite unit (Zpεgq) as in the Livengood quadrangle (Chapman and others, 1971). Grit and quartzite, probably the most abundant rock types in this unit in this quadrangle, are lithologically similar to that of the grit, quartzite and argillite unit (Zpεgq). The trace fossil Oldhamia was found in the D-6 quadrangle (map no. 2, table 2) and suggests a Cambrian or possibly Hadrynian (late Precambrian) age (Hofmann and Cecile, 1981, p. 288).

Zpεgq GRIT, QUARTZITE, AND ARGILLITE--Grit and quartzite mostly gray or greenish gray, but may be tan, brown or dark gray. Ranges from fine- to coarse-grained, rarely conglomeratic, and equigranular to bimodal. Boxwork of quartz veinlets common. Quartz grains glassy, frosted and clear, translucent blue-gray, white, gray, or smoky. Feldspar grains locally abundant. Grains commonly angular or subrounded; locally well-rounded. Largest clasts are most commonly quartz, feldspar, polycrystalline quartz and feldspar, and rarely argillite. Matrix is generally quartz + white mica ± chlorite. Weakly metamorphosed; locally sheared. Bedding generally obscure. Argillite is gray to black, greenish gray, olive gray, tan or brown. Locally axial plane cleavage, commonly not parallel to layering and crinkled. Rare thin layers of gray and dark gray limestone, weathering, brown and gray dolomite. Slightly contact metamorphosed in places near Lime Peak. The trace fossil, Oldhamia, was found in the west central C-6 quadrangle (map no. 0, table 2), and suggests a Cambrian or possibly Hadrynian (late Precambrian) age (Hofmann and Cecile, 1981, p. 288).

AREA NORTH OF TINTINA FAULT ZONE
Circle Terrane
(Churkin and others, 1982)

MzZc CIRCLE VOLCANICS AND ASSOCIATED ROCKS--Comprised of diabasic gabbro, basalt, diorite, ultramafic rock, chert, and tuff. Gabbros dark gray or greenish gray, weathering brownish gray; fine to coarse grained; diabasic hypidiomorphic granular; composed of plagioclase, clinopyroxene, olivine, magnetite, and ilmenite. Secondary minerals include chlorite, serpentine, quartz, and amphibole. Gabbro mostly occurs in small massive outcrops in the Crazy and Little Crazy Mountains. Along the Yukon River layered gabbros with diabasic texture crop out; most of the diabasic gabbros are probably plugs, sills, and dikes.

Basalt or andesitic basalt, dark greenish gray, weathering brown or brownish-gray. Aphanitic groundmass composed of plagioclase, olivine, clinopyroxene, and magnetite; local glomeroporphyritic clots of plagioclase and clinopyroxene; texture mostly ophitic. Vesicular in places with vesicles filled with chlorite and calcite. Mostly flows, much weathered, including local spheroidal weathering. Rare basaltic volcanic

breccia and basaltic (?) tuff. In places diorites apparently intrude gabbro and basalt. Diorites are medium greenish-gray, medium- to coarse-grained; hypidiomorphic granular; mostly altered to chlorite-actinolite, and calcite.

Minor amounts of tuff are interlayered along the Yukon River as are a few layers of limestone. Local layers and lenses of cumulate mafic and ultramafic rocks occur in the Crazy Mountains, and on Birch Creek in the D-1 quadrangle. Cumulates consist of clinopyroxene and plagioclase; olivine and clinopyroxene; olivine, clinopyroxene, and plagioclase; and clinopyroxene, plagioclase, and magnetite.

Chert, mostly light to dark gray, but locally white, tan, red, or black. Occurs in layers a few centimeters to a few meters thick interlayered with basalt and diabasic gabbro, and rarely with medium-gray and black argillite; one exceptionally large outcrop about 170 m long in the Little Crazy Mountains exposes a section of 2.5 m of gray and bleached white ribbon chert with layers ranging from 2 to 18 cm thick but averaging 5 cm in thickness. Radiolarians from the chert have Late Mississippian, Pennsylvanian, and Triassic ages (map nos. 18, 19, 20, 21, 22, 24, 27, 36, and 37, table 2). Cherts of all these ages have a similar interlayering with basaltic lava and similar associations with the intrusive rocks; occurrences of different ages cannot be distinguished in the field.

Circle volcanics are similar in lithology to rocks of the Rampart Group and Mertie (1937) included them in this group, although the intrusive rocks were excluded. Mertie considered the Circle Volcanics Carboniferous in age. Brabb and Churkin (1969) called similar rocks, along the Yukon River in the Charley River quadrangle, Circle Volcanics and indicated that on the basis of limited potassium-argon age determinations some of the intrusive rocks could be as young as Triassic. However, they provisionally assigned the Circle Volcanics to the late Paleozoic. The Circle Volcanics and associated rocks unit (Mzвc) of this report includes Mertie's Circle Volcanics with the associated mafic intrusive rocks and is probably correlative with parts of the Rampart Group.

PMc CHERT, ARGILLITE, AND QUARTZITE--Chert mostly black, gray, and dark gray but includes light gray, green and white, banded. Rare argillite, shale, slate, and siltstone mostly gray, dark gray, and black; quartzite mostly gray. Chert, argillaceous rocks and quartzite are interlayered. Unit forms a poorly exposed east trending belt in the east Crazy Mountains; which may be in fault contact with the argillite, grit, and quartzite unit (Pzpєɔ) to the south. May be part of the Circle Volcanics and associated rocks unit (Mzвc) or in conformable, unconformable, or fault contact with them. Age based on radiolarians probably Carboniferous. Albaillella sp. and Paronaella impella Ormiston and Lane of Late Mississippian age occur in the western part of the unit (map no. 23, table 2); 7 km east the chert locality of map no. 28 (table 2) contains Spongodiscaceid gen. nov. (tetrahedral) (Holdsworth and Jones, 1980) of latest Late Mississippian or Early Pennsylvanian age; in two other localities (map nos. 25 and 29, table 2) very poor Spumellariina of possible Carboniferous age occur.

Crazy Mountains Terrane
(Churkin and others, 1982)
West Crazy Mountains

MzPzd DIORITE--Green, olive green or greenish brown; medium to very coarse grained, porphyritic; locally has plagioclase phenocrysts as much as 10 mm long, partly altered to sericite, and clinopyroxene phenocrysts as much as 8 mm long partly altered to chlorite, in a groundmass of plagioclase laths, chlorite, white mica, apatite, ilmenite and sphene. Calcite locally abundant as elongate, rounded pods that probably resulted from intrusion into limestone. Rock is mostly massive but locally has a metamorphic fabric. Rock is much altered and appears to have been subjected to low-grade regional metamorphism. Age uncertain.

Pzcg CHERT PEBBLE CONGLOMERATE--Conglomerate clasts are light gray and black chert, white and light gray quartz, reddish-brown and gray quartzite, and some gray slate. The chert and quartz pebbles predominate; most are fairly well rounded and range in diameter from 1 to 8 cm. Locally clasts of dark gray, or greenish gray slate, or tan argillite as much as to 20 cm long. Minor interlayers of gray or tan coarse sandstone and dark gray or olive-gray shale or argillite. Bedding rarely detectable in conglomerate. On northern contact of conglomerate, an outcrop of dark gray limestone (map no. 11, table 2) contains echinodermal debris and conodonts.

The conodonts indicate a late Early Devonian age, but the relation of this limestone to the conglomerate is not known, because a sharp valley, which may indicate a fault, separates the limestone from the conglomerate. The limestone may be a remnant of the limestone unit (Dl). The conodont color alteration index indicates that the limestone reached a temperature of 300 to 350°C.

Pzcc CHERT, CONGLOMERATE, AND LIMESTONE--Chert and chert-pebble conglomerate are the most characteristic rock types but other sedimentary rocks are interbedded. Chert dominantly gray or black; massive in a few places forming outcrops 30 to 50 m high, but commonly brecciated. Some interlayered chert-pebble conglomerate with mostly gray and black chert clasts and a few white, red, and green chert fragments; most clasts fairly angular but locally well-rounded and up to 13 cm across; minor chert arenite and black shale interlayered in the conglomerate; also interlayered calcarenite with chert fragments and sandy and conglomeratic limestone. Limestone gray, interlayered with gray shale. Locally abundant black or gray slate and argillite, siliceous argillite, gray siltstone, and rarely brown weathering dolomite interlayered with chert. Some beds resemble thin turbidites and pelagic interbeds appear bioturbated. A medium-gray fine-grained limestone in the D-4 quadrangle (map no. 7, table 2), apparently interlayered in a part of the section containing chert, argillite, and sheared conglomerate contains echinodermal debris and conodonts (table 2). The conodonts are late Late Devonian in age, but the amount and part of the section to which this age applies is unknown. It probably is

not representative of all of the rocks included in this unit. Unidentifiable echinodermal debris was also found in the D-5 quadrangle (map no. 6, table 2) and in the D-4 quadrangle (map nos. 8, 12, and 14, table 2). Poorly preserved radiolarians (Spumellariina) of indeterminable age were found in the D-4 quadrangle (map nos. 9, 13, 15, and 16, table 2). Rocks in this unit are commonly highly sheared and are slightly metamorphosed; some of the argillite has distinct flakes of white mica. The conodont color alteration index indicates that the limestone reached 300 to 350° C.

Dl LIMESTONE--Mostly medium gray with some yellowish-gray mottling; locally recrystallized, generally massive, but fairly thin-bedded locally. In the west Crazy Mountains occurs in small widely separated outcrops which may be erosional and(or) faulted remnants.

One outcrop in the Circle D-4 quadrangle (map no. 17, table 2) has stromatoporoids, corals, and conodonts. The corals restrict the age to earliest Early Devonian. This fossiliferous limestone appears to be slightly older than a fossiliferous limestone in the east Crazy Mountains (map no. 30, table 2) in which corals restrict the age to late Early Devonian. Both of these limestones are similar to Tolovana Limestone (Thomas Dutro, Jr., oral communication, 1981) and are probably correlative with at least parts of it in the Livengood quadrangle.

Zpea ARGILLITE, GRIT, and QUARTZITE--Argillite, shale, slate and phyllite, commonly olive green or gray, rarely maroon and green. Grit and quartzite commonly gray, dark gray or olive green; mostly fine-grained; commonly have clear glassy quartz grains. Chert is gray, black, white, and gray and green banded; locally brecciated. Marble, mostly in thin interlayers, ranges from dark to light gray and is mostly fine-grained. Gray dolomite, that weathers brown, occurs as rare interlayers. Rocks of the unit slightly metamorphosed. Unfossiliferous; age uncertain, but on the basis of tentative correlation with lithologically similar rocks in the east Crazy Mountains considered of probable Cambrian or Hadrynian (late Precambrian) age. Black limestones with quartz grains which are characteristic of this unit in the east Crazy Mountains are not found in the west Crazy Mountains.

East Crazy Mountains

Zcg CHERT PEBBLE CONGLOMERATE--Mostly gray; clasts are dominantly chert but minor quartz and quartzite and rare argillite and siltstone fragments occur. Size of clasts range from medium sand to pebbles 8 cm in diameter; chert clasts commonly light and dark gray; rarely bright green or white; minor white quartz clasts. Most clasts fairly angular, but locally more rounded; a few interlayers of black shale and gray sandstone. Siltstone clasts are flat, medium dark gray with brown weathering rinds. Locally large (.3 m long and 15 cm thick) shale fragments and gray sandstone fragments occur. Matrix, commonly minor in amount, is mostly fine-grained siliceous sand. Bedding or layering in conglomerate generally not visible.

Conglomerate locally somewhat sheared. Some chert pebbles in conglomerate contain poorly preserved radiolarians (Spumellariina) (map nos. 31, 32, and 34, table 2), of indeterminable age.

D1 LIMESTONE--Mostly medium gray, but locally dark gray with some yellowish-gray mottling; weathers light gray; fine-grained; locally recrystallized; generally massive but thin-bedded in places; commonly white calcite veinlets and small veins lace the outcrop; solution pitted surface characteristic; rillenstein, stylolites and other small solution features occur. Locally, a few dark gray, smooth surfaced dolomite beds interlayered.

Gray limestone forms large steep-sided outcrops on the ridges separated by covered intervals. One limestone unit can be traced from a fairly broad outcrop area, in the eastern east Crazy Mountains into a narrow band which extends westward for more than 19 km.

Covered and poorly exposed intervals between limestone outcrops include minor gray and black shale, siltstone and argillite, gray chert, maroon siltstone, and quartzite. Light gray to white, very fine grained dolomite tentatively included in the northeastern part of the unit; in places has a boxwork of white quartz veinlets; locally breccia cemented by quartz. Indeterminate bryozoans, conodonts and the two-holed crinoid ossicle Gasterocoma bicaula Johnson and Lane present in the Circle C-2 quadrangle (map no. 30, table 2). The most likely age is Emsian (late Early Devonian). Unit is similar in age and lithology to parts of the Tolovana Limestone of the Livengood quadrangle. Limestone, 18 km east of locality 30 in the C-2 quadrangle (map no. 35, table 2), is tentatively included in this unit and contains conodonts indicating a middle Early Devonian age.

Limestone of this unit probably unconformable to the adjacent rocks, but some contacts may be faults.

Zpča ARGILLITE, GRIT AND QUARTZITE--Fine-grained rocks, range from argillite to slate and phyllite and are dominantly black, olive gray or tan, and less commonly maroon, green, and mottled maroon and green; interlayered throughout unit with grit and quartzite; the most abundant rock types in this unit in the east Crazy Mountains. Grit and quartzite medium gray, dark gray, or olive gray; coarse to fine-grained; some equigranular but some grain sizes are conspicuously unequal; locally arkosic; interlayered or infolded with marble. Marble, dark gray or black and has scarce to abundant quartz grains; boxwork of white calcite veinlets characteristic; probably several different horizons of black marble. Chert, interlayered mostly in the more southerly exposures of the unit, is light gray, gray, olive gray, white, greenish, gray, green, and black. The trace fossil Oldhamia is found in olive-colored argillite in two places (map localities 26 and 33, table 2).

Rocks of unknown age and affinities but lithologically resembling most closely rocks in this unit, include argillite which crops out south of the chert pebble conglomerate unit (Zcg) in the eastern part of the east Crazy Mountains; green argillite cut by white quartz veinlets, green and gray phyllite,

and minor gray quartzite poorly exposed along the Steese Highway south of Twelve Mile House; and dark gray, fine-grained and finely bedded limestone at VABM Crazy (eastern C-1 quadrangle). Some of the phyllite along the Steese Highway contains chloritoid growing across the foliation.

Rocks of this unit only slightly metamorphosed, but folded. Considered of Cambrian or Precambrian age on basis of Oldhamia. Pb/U ages[2/] determined on zircons separated from a quartzite near VABM Crazy were very discordant and indicate that the sedimentary source included Precambrian material (Aleinikoff and others, in press).

Preacher Block

Pzc CHERT AND ARGILLITE--Chert, gray, black, and banded, interlayered with gray, green, olive, black, gray, and tan argillite, rare gray marble, white quartzite and white calcareous quartzite; locally intruded by dark greenish-gray to black diorite and gabbro, varieties of which include olivine-clinopyroxene-hornblende cumulate gabbro, and hornblende-titanaugite gabbro; generally altered (or metamorphosed). A few poorly preserved radiolarians (Spumellariina) in chert (map nos. 4 and 5, table 2), possibly of Mississippian age.

Pzl LIMESTONE AND CHERT--Unit includes limestones cropping out in both the northern and southern parts of the Preacher block which may be of significantly different ages. No fossils found.

Limestone in the eastern part of the Preacher block forms a cliff over 350 m high along Preacher Creek; medium dark gray near top and light gray elsewhere; weathers medium gray with orange patches; mostly fine-grained, partly recrystallized; blocky fracture; locally argillaceous. Includes a few thin (3 cm thick) bands of black chert. Tan, millimeter-thick siliceous laminae and pisolites near the top. Stylolites present in some very fine-grained or argillaceous limestone. Some surfaces etched by solution have wavey lines which suggest algal structures.

Limestone in the western part of the Preacher block ranges from light to dark gray and appears to be interlayered with black, gray, and mottled chert, tan and gray argillite, basalt with calcite amygdules, and gabbro. The limestone commonly is massive, but thinly bedded in places; locally has boxwork fractures filled with white calcite. In the southwestern part of this block the limestone is mostly light gray, fine to medium grained and massive, but much jointed. Forms tor-like outcrops 10 m high.

2/ Red zircons: 206Pb/238U = 1,723 m.y.; 207Pb/235U = 1,949 m.y.; and 207Pb/206Pb = 2,198 m.y.

Gray zircons: 206Pb/238U = 427 m.y.; 207Pb/235U = 748 m.y.; and 207Pb/206Pb = 1,888 m.y.

Zpca ARGILLITE, GRIT AND QUARTZITE--Argillite, maroon and green; commonly has slaty cleavage. Interlayered greenstone and minor greenish gray grit and quartzite. Mostly very poorly exposed. Impressions or burrows resembling Planolites (Hoffman and Cecile, 1981) found. Maroon and green argillites are similar to those mapped in other parts of the quadrangle; therefore considered of probable Cambrian or Hadrynian (late Precambrian) age.

Zpcb BASALT AND LIMESTONE--Basalt, dark-greenish or bluish gray, medium fine-grained, calcareous; pillows well-developed locally; nearly horizontal, essentially undeformed and right-side up. Thin (3-6 cm) limestone layers in basalt near exposed base; limestone is medium gray or dark gray and laminated. Amygdules filled with fine-grained black material occur near top of basalt and opaline material locally fills fractures. Greenish brown breccia of calcareous basalt with a matrix of light gray translucent opaline material overlies the amygdaloidal basalt. A thickness of 135 m ± of basaltic rock is exposed. Basalt is overlain by black, moderately coarse crystalline limestone cut by a boxwork of white calcite veinlets. Limestone has a petroliferous odor when struck by a hammer and breaks on shiny black cleavage planes. Above the limestone, possibly in fault contact, is a section of tan dolomite, brown dolomite, and dolomite with gray chert fragments overlain by gray shale, gray recrystallized chert, and calcareous basalt. Age uncertain; tentatively considered of early Paleozoic or late Precambrian age because several distinctive lithologies in this unit such as the black limestone and brown dolomite have not been found in rocks younger than early Paleozoic in this quadrangle.

AREA SOUTH OF TINTINA FAULT ZONE
Yukon Crystalline Terrane
(Churkin and others, 1982)

Da AUGEN GNEISS--Biotite felsic gneiss containing augen-shaped potassium feldspar porphyroblasts. The gneiss occurs as scattered small masses up to 1 km across on ridge crests, and as layers in schist and quartzite a few centimeters to over a meter in thickness.

A characteristic mineral assemblage is potassium feldspar, commonly microcline, + quartz + plagioclase + brown biotite + white mica. Biotite may be somewhat rutilated and partly altered to chlorite. Myrmekite common. Plagioclase discontinuously and continuously zoned. Augen are mostly composite, composed of two or more potassium feldspar crystals with quartz + biotite ± white mica in the feldspar. Quartz, biotite and myrmekite occur around the edges of augen. Protolith probably a felsic igneous rock; spacially associated with light green calc-silicate rocks (shown by symbol ≈ on map).

U/Pb age of 387 ± 43 m.y. (Devonian) on zircon from one augen gneiss is interpreted as the age of the protolith (John Aleinikoff, written communication, 1981).

The augen gneiss occurrences may be remnants of folded and metamorphosed sills or intrusive sheets. Alternatively, some of

the augen gneiss, especially that which caps high points on ridges, may be thrust remnants. Variations in the size of augen and the relative proportions of major mineral constituents suggests that the augen gneiss may not all have the same origin and protoliths, and protoliths could include both igneous and sedimentary rocks.

Zq QUARTZITE, META-ARGILLITE AND PHYLLITE--Black, dark gray or gray; dark color probably due to carbonaceous material; commonly contains minor white mica and may be calcareous; quartzite mostly medium grained, thinly layered to massive; meta-argillite may be slaty; in places has thin layers of white quartz grains parallel to layering, as well as abundant white quartz veins, veinlets, and lenses, some of which cut across foliation and layering; small, isoclinal, folds locally deform layering. Metamorphosed to greenschist facies (probably chlorite grade in pelitic layers). Stratigraphically overlies phyllite, calcareous phyllite, and marble unit (Zm).

Zm PHYLLITE, CALCAREOUS PHYLLITE, AND MARBLE--Phyllite, gray, with thin interlayers of crumbly, impure marble, and black or gray quartzitic phyllite. Mostly thin-layered and poorly exposed; white quartz ± calcite veins and veinlets common; white quartz with tan carbonate in small lenses; areas underlain by rock of this unit commonly characterized by abundant, small, scattered chunks of white quartz ± carbonate. The common occurrence of quartz + plagioclase + calcite + muscovite + Mg-chlorite phyllite indicates greenschist facies metamorphism below the stability of tremolite (chlorite zone). May include rocks of the quartzite, meta-argillite, and phyllite unit (Zq) as these two units were not differentiated in much of the region, particularly along the East Fork of the Chena River. Basal contacts are mapped as a thrust fault because of local sharp contrasts in metamorphic grade and structural complexity.

ZpCs PELITIC SCHIST--Mostly medium- to coarse-grained pelitic schist and gneiss with minor interlayered quartzite and quartzitic schists; subordinate coarse-grained, white and cream-colored marbles in layers a few centimeters to 20 meters thick; calc-silicate, light green or light greenish gray, commonly occurs adjacent to augen gneiss (Oa) outcrops. Minor dark green and greenish black amphibolite in layers a few centimeters to a few meters thick. Interlayered pelitic schist, amphibolite, calc silicate, and thin-layered marble commonly occur near the northern contact of this unit with quartzite and quartizitic schists unit (ZpCq).

Regional metamorphism ranges from amphibolite to epidote-amphibolite facies (sillimanite + potassium feldspar to garnet grade in pelitic schist and gneiss) with the highest grade rocks occurring in the southeastern part of the quadrangle; grade decreases northward and westward. A common pelitic assemblage to the north and west of the highest grade rocks is quartz + white mica + biotite + garnet + chlorite ± plagioclase. Mafic schist is hornblende + plagioclase + quartz + epidote ± chlorite ± biotite. Calc-silicate assemblages include: tremolite/actinolite + epidote + plagioclase + quartz + carbonate; and plagioclase + biotite + epidote + carbonate + quartz. Characteristic (dominant) mineral assemblage of highest

grade rocks (lined pattern) is quartz + plagioclase + white mica + biotite + sillimanite ± potassium feldspar ± garnet. Metamorphic grade appears to be close to the muscovite + quartz = sillimanite + potassium feldspar + H_2O isograd. Sillimanite-bearing gneiss and schist also occur in minor amounts in other pelitic rocks.

Quartzite (dotted pattern), gray-brown weathering, with minor interlayers of pelitic and quartzitic schists occurs mostly as platy, coarse rubble which "klinks" when struck with a hammer; outcrops rare. Composed primarily of quartz with biotite, white mica and plagioclase. Locally contains garnet or potassium feldspar.

Other pelitic assemblages in the higher grade part of the unit are: biotite + garnet + staurolite ± kyanite; biotite + garnet + kyanite; and biotite + garnet + kyanite + sillimanite; all with quartz + white mica + plagioclase. Some garnet porphyroblasts are rolled. Intercalated mafic schist generally has the assemblage hornblende + plagioclase + quartz ± biotite locally with garnet or carbonate. Calc-silicate assemblages include: amphibole + clinopyroxene + quartz + plagioclase + epidote ± biotite ± microcline; garnet + amphibole + clinopyroxene + epidote + quartz; and clinopyroxene + carbonate + quartz + plagioclase ± epidote ± biotite. Somewhat lower pressure facies series regional metamorphism is indicated by garnet + staurolite + andalusite + quartz + white mica + plagioclase schist in southern A-2 quadrangle.

Metamorphism is primarily prograde but retrograde metamorphism is seen in the southern part of the quadrangle where staurolite, kyanite, and andalusite porphyroblasts are pseudomorphed by white mica. Cross micas indicate metamorphism after formation of foliation. This metamorphism is spatially related to the granitic plutons. Hot spring activity associated with plutonism may have resulted in formation of steeply dipping to vertical, intersecting laumontite veins in the northern A-1 quadrangle (Keith and others, 1981, p. 828-829).

The outcrop pattern and contact relations suggest that the pelitic schist unit (Zpes) is in thrust contact with the quartzite and quartzitic schists unit (Zpeq). Folding and metamorphism took place in these units after this thrusting and was followed by more thrusting.

Zpems GARNET-MUSCOVITE SCHIST--Characterized by brown-weathered, medium- to coarse-grained, muscovite-garnet-quartz-plagioclase schist, locally with chlorite ± biotite or chlorite ± chloritoid. Distinguished by layers with up to 70 percent muscovite and abundant (as much as 20 percent), millimeter-size garnet. Metamorphosed mafic dikes generally composed of amphibole + garnet + chlorite + plagioclase + carbonate ± quartz ± white mica ± epidote occur and a few locally reach eclogite facies (Eclogite unit). Unit extensively sheared where in thrust fault contact with quartzite and quartzitic schists unit (Zpeq) along the Steese Highway and near Twin Buttes.

Zped DOLOMITE AND MARBLE--Dolomite, gray to cream-colored, weathers tan, brown, or gray; massive; folded and lineated, but bedding not apparent; much fractured, breaks into small fragments; marble is

gray or greenish gray and interlayered in calcareous greenish-gray and gray quartzite and greenish gray and gray calcareous phyllite, and greenish gray calc-silicate. Local sulfides, Dolomite and marble occur in an isolated mass about 1/4 km^2 in an area in the B-6 quadrangle. Rock of this unit commonly brecciated and much fractured and in probable fault contact with quartzite and quartzitic schists unit (Zpeq).

Zpeq QUARTZITE AND QUARTZITIC SCHISTS--Quartzite and quartzitic schists are dominant rock types, but minor pelitic schist, calc-silicate, mafic schist, and rare marble is interlayered. Quartzite and quartzitic schists are generally gray or greenish gray; may be fine to coarse grained and equigranular, or fine to coarse grained with rare to abundant megacrysts of quartz and less abundant feldspar, ranging from less than a millimeter to over a centimeter in diameter. Megacrysts are clear, white, gray, blue gray or black, and may be single strained crystals or a group of strained crystals. Areas with meagcrysts are shown by symbol ⁰o . The matrix for the large grains is generally a mosaic of strained quartz, minor feldspar and white mica, and locally minor chlorite, biotite and small garnets. Some rocks, especially those near the northeastern fault contact of the unit are mylonites, many of which show syntectonic recrystallization in quartz. Post-metamorphic shearing is common. Some of the rocks of this unit are believed to be sheared and recrystallized bimodal sandstone perhaps similar in protolith to the grit, quartzite, and argillite unit (Zpeqq). Others may be derived from different kinds of protoliths such as quartzite, arkosic quartzite, and felsic igneous rocks, but are now so sheared and cataclasized that their original lithologies are uncertain.

Locally, very coarse grained quartz or quartz and feldspar grains compose most of the rock, for example, in the northern A-3 quadrangle metamorphosed coarse-grained, well foliated quartz + feldspar arenite is interlayered with quartzite and quartz-rich pelitic schist. Single quartz grains and polycrystalline quartz are commonly glassy and gray, black or bluish gray. This coarse-grained meta-arenite is probably less than 15 m thick on most ridges in this area, but similar rock may be much thicker to the northeast.

The dotted pattern in the B-4 quadrangle indicates an area of light to medium gray, fine- to medium-grained, relatively pure quartzite with a few, scattered, clear, light gray, quartz megacrysts. Minor amounts of white mica and chlorite, and rare, small biotite flakes occur. Brown specks, possibly weathered carbonate, occur locally.

Quartzites are interlayered with minor amounts of pelitic schists (quartz + plagioclase + muscovite + chlorite schists commonly with biotite ± garnet or with chloritoid ± garnet and locally carbonate). Some garnet porphyroblasts are rolled. Garnet is absent in the northern part of this unit. Quartz + plagioclase + muscovite + biotite schists with garnet + staurolite or with kyanite occur interlayered with quartzite and quartzitic schist locally within the higher grade rocks in the southeastern part of the quadrangle. Rare fairly pure to very impure, thin to thick-layered marble is also interlayered.

North of the coarse meta-arenite in the A-3 quadrangle is a light green and greenish gray calc silicate (shown by the symbol ~~) with thin interlayers of crumbly, greenish-gray marble, light green, calcareous quartzite, gray and greenish gray phyllite and fine-grained quartzitic schist, some with large quartz and feldspar clasts and with garnet. Calc-silicate and mafic schist occur locally near Table Mountain.

Greenschist (shown by the symbol ~~~) in the vicinity of Clums Fork and Birch Creek, A-3 and B-3 quadrangles is tentatively included in this unit. The greenschist is green or greenish gray, medium grained and massive to foliated. The assemblage actinolite or actinolitic hornblende + plagioclase + quartz + chlorite + epidote + sphene ± carbonate ± rare biotite or stilpnomelane is common. Relict igneous textures preserved locally. Schist probably mostly derived from mafic rocks, including dikes.

Locally (mostly in the northeastern B-6, southeastern C-6, and southwestern C-5 quadrangles), the quartzitic rocks are cut by metamorphosed mafic to felsic dikes and small areas of metavolcanic rocks occur. Dike rock is mostly dark green and calcareous; phenocrysts of feldspar commonly visible.

The magnetic chlorite schist subunit (Zpeqm) is interlayered and infolded with quartzite and pelitic schist of the quartzite and quartzitic schists unit (Zpeq) and differs from them primarily in having more magnetite. Green, quartz - white mica - chlorite magnetite schist is interlayered with light and dark gray banded quartzite and minor, thin-layered marble. Plagioclase, biotite, and garnet are common. Unit represents a sedimentary sequence recrystallized under epidote-amphibolite facies (garnet zone) conditions. Similar in lithology to some of the Cleary sequence in the Fairbanks quadrangle (Bundtzen, 1982). Rocks of the subunit are mostly poorly exposed, but their aeromagnetic expression suggests other occurrences, either at or near the surface, on trend with the mapped outcrops.

Regional metamorphism of the quartzite and quartzitic schists unit (Zpeq) as a whole represents a medium-pressure facies series and ranges from low amphibolite facies (staurolite and kyanite zone in pelitic layers) to greenschist facies (chlorite zone in pelitic layers). Grade generally decreases northward. Metamorphism is primarily prograde, but evidence for retrograde metamorphism is seen in the southern part of the quadrangle where, around granitic plutons (TKg), pseudomorphs of white mica after staurolite and possibly after kyanite occur in the pelitic layers. Contact metamorphism of quartzitic rocks has produced hornfelsing. Contact metamorphosed calc-silicate layers 7.5 km northeast of Twelve Mile Summit (B-4 quadrangle) contain grossularite + hedenbergite + quartz + calcite; actinolite/tremolite + calcite + epidote + diopside + quartz + plagioclase; and chondrodite/clinohumite + forsterite + dolomite + calcite + chlorite + serpentine. Contact metamorphosed mafic schist in this area contains actinolite + plagioclase + quartz + biotite, locally with minor chlorite or carbonate and trace epidote.

Age of protoliths unknown. Pink zircon from a metamorphosed quartz arenite at Porcupine Dome (B-4 quadrangle) gives a 206Pb/238U age of 1558 m.y., a 207Pb/235U age of 1797 m.y. and a 207Pb/206Pb age of 2086 m.y (John Aleinikoff, oral communication, 1982). The protolith apparently included Proterozoic material, but the age of the sediments in which the zircon was deposited remains unknown.

$\mathcal{P}p\epsilon m$ MAFIC SCHIST--Green, chlorite-quartz-carbonate schist, commonly with abundant plagioclase porphyroblasts; associated with amphibolitic schist and minor marble, quartzite and pelitic schist. Crops out in a zone about 5 km wide and 38 km long in the northeastern part of the Yukon crystalline terrane and to the west of the zone forms interlayers locally in quartzite, quartzitic schist, and pelitic schist of the quartzite and quartzitic schist unit ($\mathcal{P}p\epsilon q$).

Plagioclase may compose as much as 60 modal percent of the rock and commonly forms 30 modal percent. Some plagioclase grains contain straight inclusion trains, parallel or at an angle to foliation; others are rolled. Some garnets have "S" inclusion trails. Amphibole-rich layers have the characteristic assemblage: amphibole (commonly actinolitic) + chlorite + epidote + plagioclase + quartz + sphene $\pm$ biotite or white mica $\pm$ carbonate + garnet.

Protolith may in part have been mafic pyroclastic rocks depositionally interbedded with rocks of the quartzite and quartzitic schists unit ($\mathcal{P}p\epsilon q$). Greenschist to epidote-amphibolite facies (biotite to garnet grade in pelitic schist).

$\mathcal{P}p\epsilon gr$ GRIT AND QUARTZITE--Tan or gray; medium to coarse quartz, minor feldspar, and polycrystalline quartz clasts occur in a matrix of carbonate, fine-grained quartz, chlorite, white mica and feldspar. Carbonate may be iron-rich and iron oxides may rim the iron carbonate. Zircon and(or) tourmaline may be present as a minor accessory mineral. Clasts mostly angular and unoriented; locally there is some granulation at grain boundaries and grains are embayed by fine quartz, white mica and carbonate. Quartz generally strained.

Very low metamorphic grade. Differs from grit, quartzite, and argillite unit ($\mathcal{P}p\epsilon gq$) in having a very calcareous matrix and in being slightly more metamorphosed, but may be correlative.

Ultramafic, Mafic, and Eclogitic Rocks

$\mathcal{P}p$ SERPENTINIZED PERIDOTITE--Gray, green, and greenish gray to greenish black, generally weathers brown; fine to coarse grained. Generally foliated, folded and locally sheared; some very magnetic; sheets of actinolite on some shear surfaces; white magnesite locally common on fracture surfaces and in small pods or lenses. Peridotite occurs generally in pods, lenses or masses generally only a few hundred square meters in area in widely scattered areas in the A-1, A-2, A-4, and B-1 quadrangles. Appears to be infolded with mafic and pelitic schists and in places with marble and quartzite (pelitic schist unit, $\mathcal{P}p\epsilon s$). Secondary actinolite, chlorite, calcite, and

magnetite formed during regional metamorphism are abundant in addition to serpentine and magnesite. Dark green amphibole schist commonly in close association with the ultramafic rocks.

Pzg GREENSTONES--Mostly coarse diabasic gabbros containing amphibole and clinopyroxene and minor secondary quartz; metamorphic sphene, actinolite, chlorite, and epidote occur in several places. Locally contains abundant coarse magnetite grains. Massive greenstones crop out in several places along Preacher Creek, and greenstones in each outcrop differ from each other in mineralogy and texture. Most are too small to be shown on map with the exception of two of the largest outcrops on Preacher Creek in the northern C-4 quadrangle.

Pze ECLOGITE--Medium green, medium grained, massive to foliated; comprised of garnet, clinopyroxene (omphacite), quartz, clinoamphibole (barroisite), phengitic muscovite, and minor rutile and sulfide. Occurs as mafic layers within quartz-white mica-garnet-plagioclase-chlorite-biotite schist and quartzite of the garnet-muscovite schist unit (PpCms). Exposed near Twin Buttes in northwestern A-6 quadrangle. Exposures are all small, and contact relationships are only visible at one place where the mafic layer cuts across foliation, suggesting that its protolith was a dike. The extent and relationships of these high pressure metamorphic rocks are not known.

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Table 1. Table showing mineralogy and age of granitic plutons in the Circle quadrangle.

Pluton	Location (by quadrangle)	Estimated Mode (in percent)						Other Minerals	Age (m.y.) (by K/Ar method)			Reference
		Potassium Feldspar	Plagio-clase	Quartz	Horn-blende	Bio-tite	Musco-vite		Bio-tite	Horn-blende	Musco-vite	
1. Victoria Mountain	D-6	35	30	25	7	3		Opaques, including magnetite	65.3 ±0.65	65.5 ±1.03		Wilson and Shew, 1981
2. Lime Peak	C-6	30	25	40	0	4	1	Tourmaline	56.7 ±0.95			Wilson and Shew, 1981
3. Quartz Creek	B-6,C-5, C-6	40	25	30	1	4	1	Tourmaline	65.9 ±1.38			Wilson and Shew, 1981
4. Mt. Prindle	B-5,B-6	35	20	35	0	5	5	Opaques, topaz, and tourmaline	59.5 ±1.8			Holm, 1973
5. Chena Hot Springs	A-3,A-4	25	30	35	0	10	0	Sphene, allanite, epidote-clinozoisite, tourmaline, apatite, and chlorite	58.7 ±0.85 58.2 ±1.7 58.9 ±2.7	(by fission-track method)		Wilson and Shew, 1981 Biggar and Forbes, 1990
6. Big Windy Creek	A-1,A-2	35	35	25		3	2		60.6 ±0.6		60.5 ±0.6	Wilson and Shew, 1981
7. Circle Hot Springs	B-1,B-2	35	25	35		5	Very minor	Tourmaline	60.5 ±1.8			Wilson and Shew, 1981
8. Yukon Fork	B-1	25	35	30	0	10	Minor amounts in places	Garnet and tourmaline	62.4 ±1.34			Wilson and Shew, 1981
9. Circle A-2 quadrangle	A-2	35	25	30		5-10	Very minor		64.4 ±0.48			Wilson and Shew, 1981

Table 2. Table listing fossils found in the Circle quadrangle

Map No.	Field No.	Quadrangle	Fossils Found	Age	Reference or source of identification
0	79ATx471	C-6	Oldhamia	Probable Cambrian or Late Hadrynian	Hofmann, H. J., and Cecile, M. P., 1981
1	80AWr223	C-6	Conodont fragments (bar fragment and simple cone fragments)	Ordovician through Triassic	Denkler, Kirk, and Harris, A. G., 7/8/82, written communication
2	81AWr132	D-6	Oldhamia	Probable Cambrian or Late Hadrynian	Hofmann, H. J., and Cecile, M. P., 1981
3	81AWr130	D-6	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
4	81AFr296D	C-5	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
5	81AWr236C	C-4	Radiolaria: Spumellariina	Indeterminable, possibly Mississippian	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
6	81AWr70	D-5	Echinodermal debris in limestone; limestone underlain by argillite containing corals and echinodermal debris		
7	81AFr7067G	D-4	Echinodermal debris and poorly preserved medium-spired gastropod. Also the following conodonts: 1 Palmatolepis sp. indet. juvenile element, 6 P elements of Polygnathus webbi Stauffer, 4 M (apatognathiform elements), 3 M (symprioniodiniform elements, 3 Al elements, 39 indet. bar, blade, and platform fragments	Middle through Late Famennian (late Late Devonian) (as indicated by conodonts)	Denkler, Kirk, and Harris, A. G., 6/8/82, written communication
8	79AWr451	D-4	Echinodermal debris?		
9	81AWr71	D-4	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
10	81AFr148	D-4	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
11	81AFr151D	D-4	Indeterminate echinodermal debris and the following conodonts: 5 Belodella devonica (Stauffer) s.f. elements, 8 Belodella triangularis (Stauffer) s.f. elements, 4 Coelocerodontus sp. indet. elements, 12 P elements of Pandorinellina steinhornensis cf. P.S. Miae (Bultynck) (anteriormost denticles are higher than the holotype and topotype material figured by Bultynck), 9 incomplete P elements of Pandorinellina or Ozarkodina of Early Devonian aspect, 2 posterior platform fragments of Polygnathus dehiscens Philip and Jackson or P. gronbergi Klapper and Johnson, 3 P elements of Polygnathus sp. indet. (deformed or incomplete elements), 25 Panderodus spp. indet., 2 M elements, 2 Al elements, 1 Pelekysognathus serratus Jentzsch 1 element, 94 indet. simple cone, bar, blade, and platform fragments	Late Early Devonian Dehiscens through Gronbergi zones	Harris, A. G., and Denkler, Kirk, 6/8/82, written communication
12	81AWr73	D-4	Echinodermal debris, coral, and algae in limestone		
13	80ATx174	D-4	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 7/13/81, written communication
14	80ATx165, 80ATx171	D-4	Echinodermal, bryozoan and pelmetazoan debris in conglomerate and chert arenite		
15	80ATx163	D-4	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 7/13/81, written communication
16	80ATx162	D-4	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 7/13/81, written communication

Table 2 (cont.)

Map No.	Field No.	Quadrangle	Fossils Found	Age	Reference or source of identification
17	80AWr312	D-4	Stromatoporoid: Amphipora sp., Tabulate corals: Auloporoid? sp., Striatopora sp. (in sense of Oliver, 1975, pl. 10) Syringopora sp.; heliolitid coral: cf. Pseudoplasmopora sp., rugose corals: cf. Spinolasma sp., undetermined sp. in limestone (Oliver). Conodonts are: 1 Panderodus sp. elements, 1 indet. simple cone fragment, 6 indet. phosphatic fragments (Denkler and Harris)	Middle Ordovician to Middle Devonian (indicated by conodonts) earliest Early Devonian (indicated by corals)	Oliver, W. A. Jr., 2/12/81, written communication; Denkler, Kirk, and Harris, A. G., 7/8/82, written communication
18	80AFr20788	D-3	Radiolaria, casts of Spumellariina	Indeterminable, probably Late Paleozoic	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
19	81AFr217	D-3	Radiolaria, Capnodoce sp. aff. C. anapetes Deflandre, Capnodoce sp., ?Canoptum sp., Quasipetasus sp.	Late Triassic	Blome, C. D., 12/2/81, written communication
20	81AFr2228	D-2	Radiolaria, Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
21	81AFr223	D-2	Radiolaria, Paronaella impella Ormiston and Lane, Albaillella sp., Spongotripus sp.	Late Mississippian	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
22	81AFr2288	D-2	Radiolaria, ?Archaeospongoprunum japonicum Matsuoka and Nishimura, Triassocampe sp.	Middle to Late Triassic	Blome, C. D., 12/2/81, written communication
23	80AWr91C	C-3	Radiolaria, Albaillella sp., Paronaella impella Ormiston and Lane	Late Mississippian	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
24	80AFr242	C-3	Radiolaria, not yet described	Late Triassic	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
25	80AWr279A	C-3	Radiolaria, Spumellariina, poorly preserved	Indeterminable, possibly Carboniferous	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
26	68ACn1082	C-3	Oldhamia	Probably Cambrian or Late Hadrynian	Hofmann, H. J., and Cecile, M. P., 1981
27	80AFr172	D-3	Radiolaria, not yet described	Late Triassic	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
28	80AWr272	D-2	Radiolaria, Spongodiscaceid gen. nov. (tetrahedral) Holdsworth and Jones (1980)	Latest Late Mississippian or Early Pennsylvanian	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
29	80AFr2084	C-2	Radiolaria, Spumellariina, poorly preserved	Indeterminable, possibly Carboniferous	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
30	80AFr307	C-2	Crinoid stem discs, Gasterocoma bicaula Johnson and Lane; tabulate corals: Alveolites sp., Favosites spp., Pachyfavosites sp., Striatopora sp. (in sense of Oliver, 1975, pl. 10), Thamnopora sp., rugose corals: Martinophyllum sp., cf. Patriophyllum sp., Ptenophyllid spp., Spongonaria sp., cf. Taimyrophyllum, undetermined sp., bryozoans: undetermined. Conodonts are: 1 I element of Icriodus sp. indet., 1 mid-platform fragment of Polygnathus sp. indet., 1 mid-platform fragment of Panderinellina sp. indet., 5 Panderodus sp., 1 A_1 or A_2 elements	Late Early Devonian through Middle Devonian indicated by conodonts but the corals restrict the age to late Early Devonian (Emsian)	Oliver, W. A., Jr., 2/12/81, written communication; Denkler, Kirk, and Harris, A. G., 7/8/82, written communication
31	80ATx93	C-2	Radiolaria, Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 7/13/81, written communication
32	80ATx91	C-2	Radiolaria, Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 7/13/81, written communication
33	68ACn1134	C-2	Oldhamia	Probably Cambrian or Late Hadrynian	Hofmann, H. J., and Cecile, M. P., 1981
34	80ATx102	C-2	Radiolaria: Spumellariina, poorly preserved	Indeterminable	Jones, D. L., and Murchey, Benita, 7/13/81, written communication

Table 2 (cont.)

Map No.	Field No.	Quadrangle	Fossils Found	Age	Reference or source of identification
35	80AWr304	C-2	Echinodermal debris and the following conodonts: 1 P element of *Pandorinellina exigua* cf. *P. E. exigua* (Philip) or *P. E. philipi* (Klapper), 2 P elements of either *Pandorinellina* sp. or *Ozarkodina* sp., 2 P elements of *Ozarkodina* sp. indet., 1 P element of *Polygnathus pirenese* Boersma, 2 *Belodella devonica* (Stauffer), 3 *Panderodus* sp. elements, 4 indet. platform fragments, 1 A_2 element, 2 O elements, 17 indet. bar, blade, and platform fragments	Middle Early Devonian as indicated by conodonts	Dutro, J. T., Jr., 2/11/81, written communication; Dentler, Kirk, and Harris, A. G.,7/8/82, written communication
36	80AFr20698	C-1	Radiolaria: Spongodiscaceid gen. nov. (Holdsworth and Jones, 1980)	Latest Late Mississippian or Early Pennsylvanian	Jones, D. L., and Murchey, Benita, 11/2/81, written communication
37	80AFr2070	C-1	Radiolaria: *Spongotrigus* sp., Spongodiscaceid gen. nov. (tetrahedral (Holdsworth and Jones, 1980), "Parahagiastrilds" gen. nov. (Holdsworth and Jones, 1980)	Latest Late Mississippian or Early Pennsylvanian	Jones, D. L., and Murchey, Benita, 11/2/81, written communication

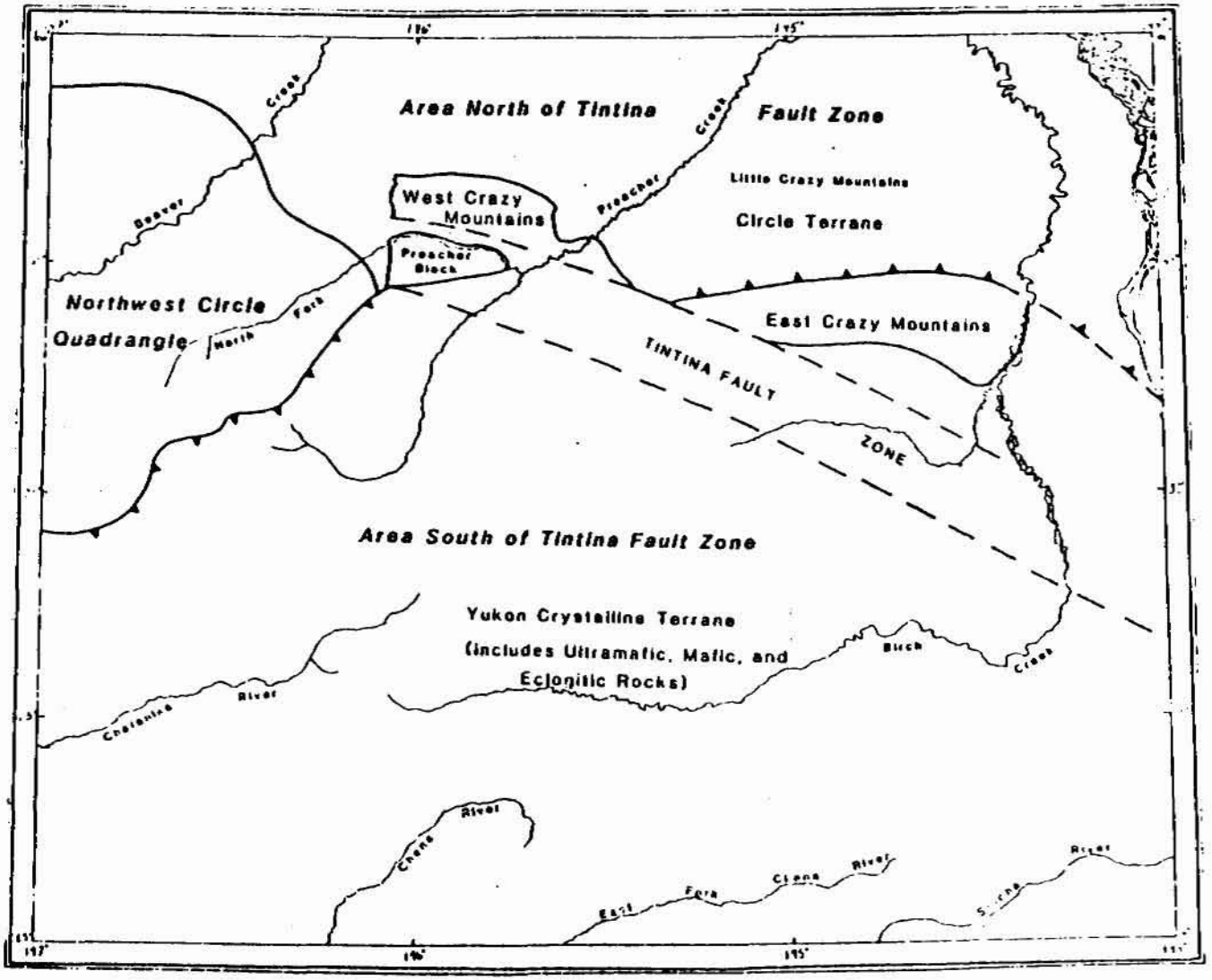

Figure 1.--Map showing location of areas used in describing map units of the Circle quadrangle.

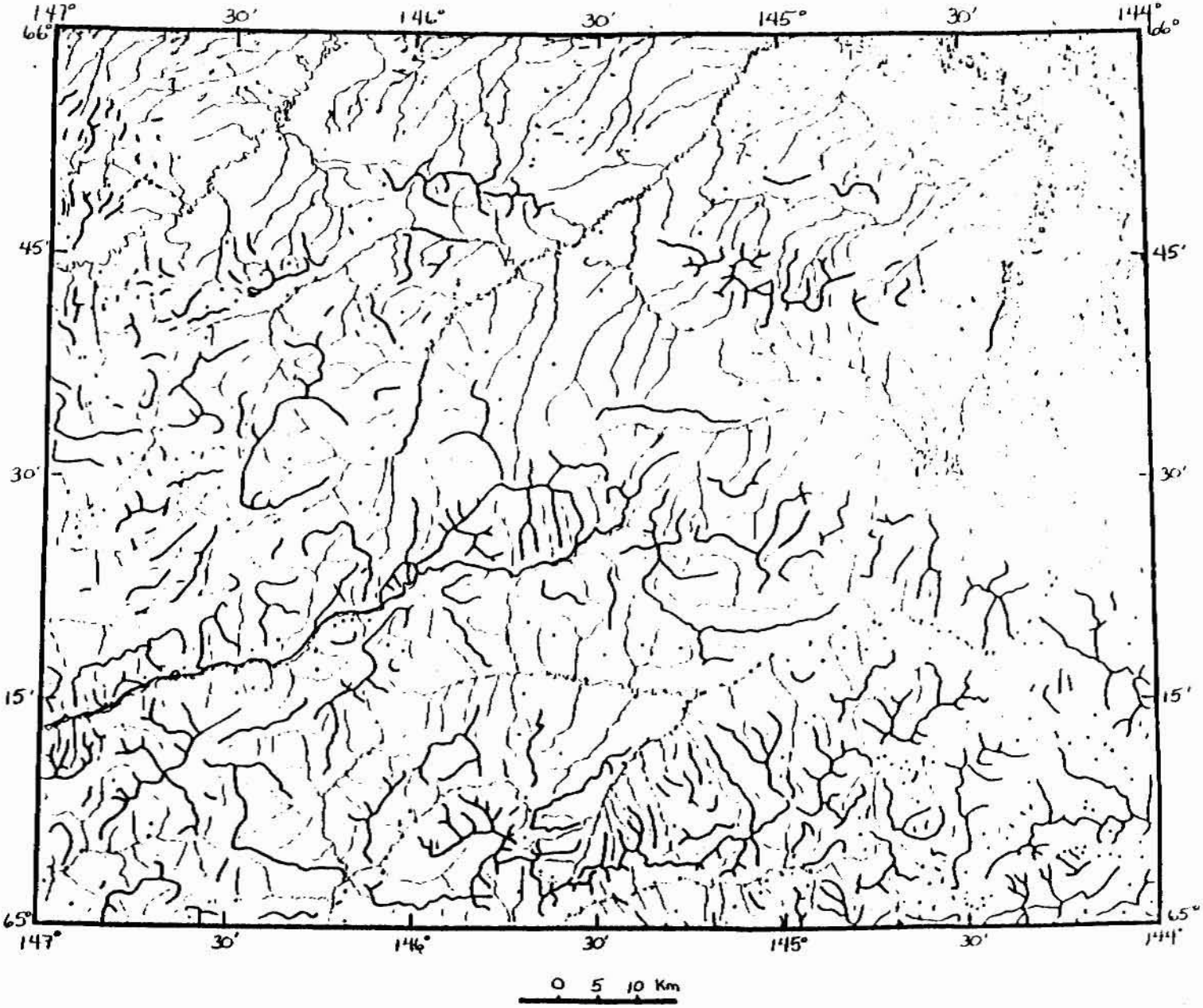

Figure 2.--Map showing location of field observation points (dots) and foot traverses (lines) in the Circle quadrangle.