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Geology of East-Central Alaska

by

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East-Central Alaska

Illustrations

EAST-CENTRAL ALASKA

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Introduction

East-central Alaska as described in this volume (Fig. 1) is a

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Figure 1 here.

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physiographically diverse region which includes all or parts of the following physiographic divisions (Wahrhaftig, 1965): Northern Foothills (of the Alaska Range), Alaska Range (north of the northernmost strand of the Denali fault system), Tanana-Kuskokwim Lowland, Northway-Tanacross Lowland, and the Yukon-Tanana Upland. The Northern Foothills are largely rolling hills in Pleistocene glacial deposits and dissected Tertiary nonmarine sedimentary rocks. The included part of the Alaska Range is composed of highly dissected terranes of metamorphic rocks which have been intruded by Cretaceous and Tertiary igneous rocks. Mountain peaks reach altitudes as high as 4,000 m, and relief is commonly more than 1,000 m. Glaciers have carved a rugged

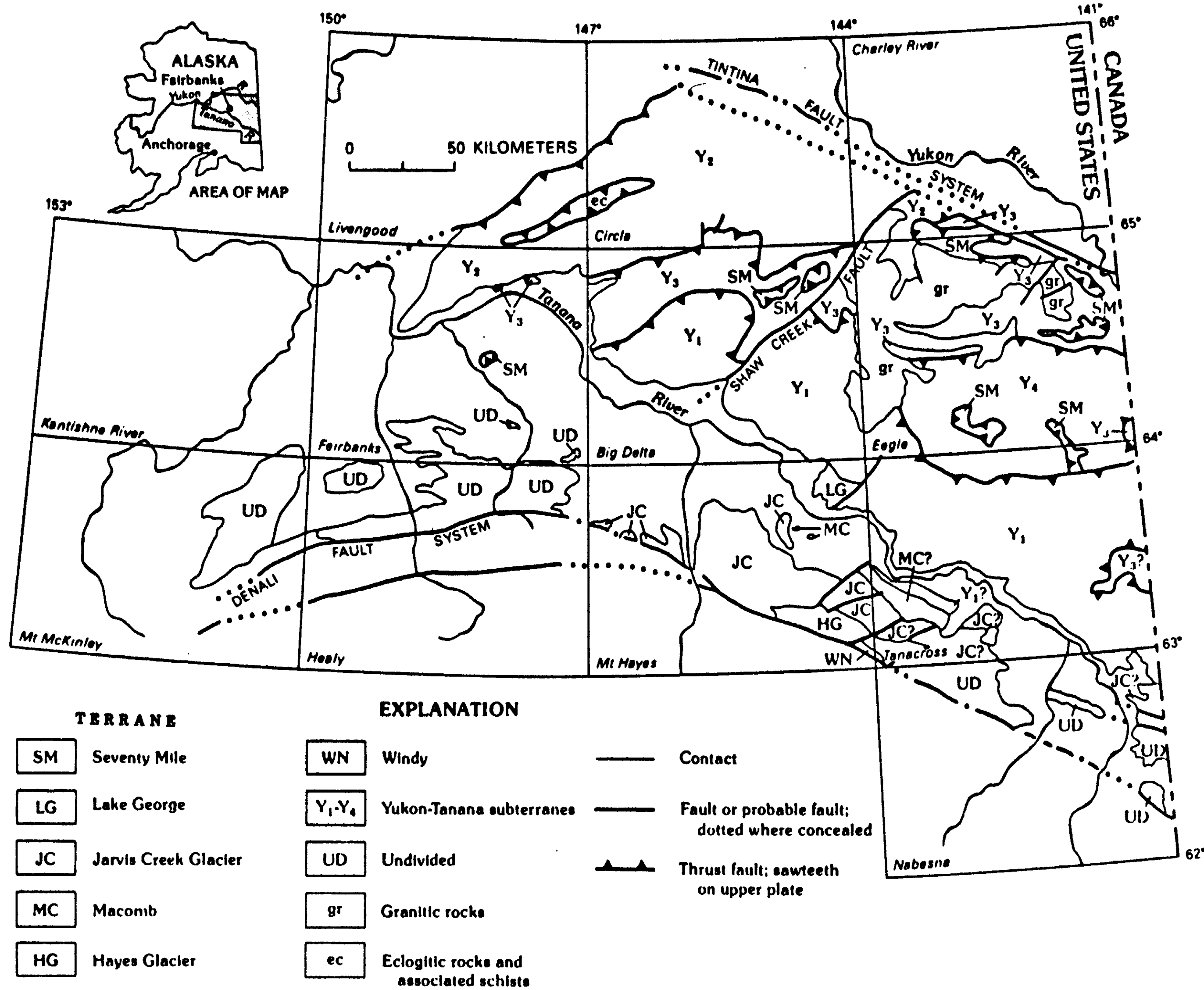

Figure 1. Map of east-central Alaska showing locations of included quadrangles, terranes, and substerranes: Subterránes modified from Churkin and others (1982). Terranes of Mount Hayes quadrangle from Nokleberg and Aleinikoff (1985).

topography. The Tanana-Kuskokwim Lowland is covered with thick glacial, alluvial, and wind-blown deposits. The Northway-Tanacross Lowland consists of three small basins mantled with outwash gravel, silt, sand, and morainal deposits. The Yukon-Tanana Upland, the largest of the physiographic divisions, consists of maturely dissected hills and mountains with altitudes as high as 1,994 m, and relief ranging from a few to hundreds of meters. Some of the highest areas supported small alpine glaciers during the Pleistocene and rugged topography resulted locally.

With the exception of the Alaska Range, outcrops in east-central Alaska are commonly widely scattered and small due to extensive surficial deposits and vegetation. The vegetation ranges from heavy spruce forests along large streams to tundra at elevations of approximately 1,000 m. The region is largely in the zone of discontinuous permafrost. Most of the low-lying areas, as well as the high mountain areas, are in the permafrost regime. Some areas, mostly intermediate in elevation, are permafrost free.

East-central Alaska is composed of a number of accreted terrane (Jones and others, 1984) which have continental, oceanic, and possibly island-arc affinities. The largest terrane, the Yukon-Tanana, has mostly continental affinities. The small Seventymile terrane has oceanic affinities. The southern part of the Yukon-Tanana terrane, which includes the Lake George, Macomb, and Jarvis Creek Glacier terranes (or subterranes) of the Mount Hayes quadrangle, may have island-arc affinities (Gilbert and Bundtzen, 1979; Nokleberg and Aleinikoff, 1985). The Hayes Glacier and Windy terranes in the Mount Hayes quadrangle are also suggested to be tectonic slices of an island-arc or possibly of a submerged continental-margin arc (Nokleberg and Aleinikoff, 1985).

Yukon-Tanana terrane

The Yukon-Tanana terrane (YT) consists largely of the area lying between the Yukon and Tanana Rivers but, as defined by Jones and others (1984), does include some of the Alaska Range and its foothills north of the Denali fault system. Nokleberg and Aleinikoff (1985), for the part of the Mount Hayes quadrangle in the YT, describe the Lake George terrane, which lies north of the Tanana River, and the Macomb, Jarvis Creek Glacier, Hayes Glacier, and Windy terranes, which lie between the Tanana River and the Denali fault. In the context of this paper these terranes, with the exception of the Windy terrane, can be considered subterranes of the YT (W.J. Nokleberg, personal commun., 1984). In the Healy, Mount McKinley, and Kantishna quadrangles isolated, probably fault-bounded exposures of rocks have been included in the Yukon-Tanana terrane. For ease in discussion of stratigraphy and structure, the Macomb, Jarvis Creek Glacier, Hayes Glacier, and Windy terranes and the areas to the southwest and southeast of them will be discussed separately from the part of the Yukon-Tanana terrane between the Yukon and Tanana Rivers. This largest part of the Yukon-Tanana terrane north of the Tanana River will be referred to in the remainder of this chapter as the YTTN. The eastern YTTN also includes the small extension into Alaska of the Stikinia terrane (Jones and others, 1984), which is included as part of the Yukon-Tanana terrane in this paper.

Yukon-Tanana terrane north of the Tanana River

The YTTN has been referred to as the Yukon-Tanana region (Mertie, 1937), the Yukon-Tanana upland (Foster and others, 1973), and the Yukon Crystalline Terrane (Tempelman-Kluit, 1976; Churkin and others, 1982). It is nearly coincident with the previously described physiographic division called the Yukon-Tanana Upland. The YTTN is primarily a terrane of quartzitic, pelitic, calcic, and mafic metasedimentary rocks with some mafic and felsic metaigneous rocks that have been extensively intruded by Mesozoic and Cenozoic granitic rocks and minor amounts of intermediate and mafic rocks. Cretaceous and Cenozoic volcanic rocks are abundant in the eastern part. Late Cretaceous and Tertiary sedimentary rocks were deposited in small widely separated nonmarine basins. The YTTN has been considered a composite terrane by Churkin and others (1982), and many problems related to its complex geologic history are as yet unresolved.

Stratigraphy

Metamorphic rocks

The geology of the YTTN was reported upon by J. B. Mertie (1937) and the stratigraphy was described in some detail. Mertie included many of the metamorphic rocks in the now-abandoned Precambrian Birch Creek Schist, and eventually most of the metamorphic rocks of east-central Alaska became included in this formation. Because usage of the name Birch Creek Schist became so broad, and parts of the formation were found to be younger than Precambrian, the name lost usefulness, and in 1973 Foster and others recommended that it be abandoned. In recent reconnaissance geologic mapping the metamorphic rocks have been divided into many units, but because of the lack of information on age and structural relationships, few new formations have been formally named and described.

The metamorphic rocks within the YTTN vary in such aspects as composition and origin of protoliths, present lithology, structure, and metamorphic history. On the basis of these characteristics and other data, Churkin and others (1982) divided the YTTN into 4 subterranes (Y_1 to Y_4). Although structural details and stratigraphic relationships are poorly known, these subdivisions are useful for descriptive purposes and for discussion of regional relations. These subterranes are used, with minor modifications, in this chapter for discussing the metamorphic rocks of the YTTN (Fig. 1, Table 1).

Table 1 here.

Table 1.--Subterranes of the Yukon-Tanana terrane north of the Tanana River (YTTN)

Subterrane	Included map units (Fig. 2)	Lithology	Metamorphic facies	Distinctive characteristics	Age of protolith
Y_1 (Includes Lake George terrane)	ag	Gneiss, schist, amphibolite, quartzite	Amphibolite (moderate pressure)	Augen gneiss common; marble and other calcareous rocks rare or absent	Mississippian and pre-Mississippian
Y_2	qq	Quartzite and quartzitic schist with small amounts of pelitic schist, calc-silicate rocks, mafic schist, and rare marble	Greenschist (moderate pressure)	Quartzite and quartzitic schists which are commonly recrystalized mylonites with megacrysts of quartz and(or) feldspar	Unknown, may be early Paleozoic
	ps	Pelitic schist, quartzite, marble, and amphibolite	Amphibolite (moderate pressure)	Sillimanite and kyanite-bearing pelitic schists	Unknown, may be early or middle Paleozoic
	ec	Eclogite, amphibolite pelitic schist, and mafic glaucophane-bearing schist	Amphibolite (high pressure)	Occurrence of eclogite and of glaucophane in mafic schists	Unknown
Y_3	ms	Mylonitic schist, semischist, quartz-white mica chlorite schist, quartzite, and minor phyllite, marble, and greenstone	Greenschist (moderate pressure)	Light greenish-gray color characteristic. Abundant mylonitic schists	Unknown, may be Carboniferous or middle Paleozoic
	cp	Calcareous phyllite, phyllite marble, quartzite, and argillite	Low greenschist	Calcareous phyllite with thin-crumbly layers. Weathers leaving a lag gravel of white quartz on surface. Gray and dark-gray quartzite and argillite overlie calcareous phyllite	Unknown, may be early or middle Paleozoic
	sm	Greenschist, calcareous greenschist, quartz-chlorite white mica schist, marble, greenstone, quartzite	Greenschist	Abundant layers and lenses of marble; some schists contain megacrysts of quartz and(or) feldspar	Paleozoic; partly Mississippian
	ws	Quartz-chlorite white-mica schist with minor quartzite, phyllite, and metavolcanic rocks	Greenschist	Marble layers rare to absent. Light green color characteristic. Some schists have megacrysts of quartz and(or) feldspar	Unknown, presumably middle or late Paleozoic
	qs	Quartzite with minor phyllite, carbonaceous quartz schist and graphitic schist	Greenschist	Overall dark gray color characteristic; dark gray quartzite dominant rock type	Unknown, probably Paleozoic
Y_4	gs	Quartzitic and pelitic gneiss and schist, quartzite, marble and amphibolite	Amphibolite	Thick masses and layers of coarsely crystalline marble. Quartz-biotite-hornblende gneiss a characteristic and common rock type	Probably Paleozoic

Subterrane Y_1 (northeastern Mount Hayes, southern Big Delta, southwestern Eagle and northern Tanacross quadrangles).

This is the largest and southernmost subterrane of the YTTN (Fig. 1). The part of this subterrane in the Mount Hayes quadrangle has been termed the Lake George terrane (Nokleberg and others, 1983). The southern boundary of Y_1 in the Mount Hayes quadrangle (the southern boundary of the Lake George terrane) is the largely concealed Tanana River fault (Nokleberg and Aleinikoff (1985), and an extension of this or adjoining faults probably forms the southern Y_1 boundary elsewhere. The northern boundary of Y_1 is probably a thrust fault. The rocks are all metamorphosed to the amphibolite facies, probably at intermediate pressures. Protoliths primarily were quartzitic and pelitic sedimentary rocks and felsic intrusive rocks with some intermediate and mafic intrusive and volcanic rocks. Calcareous rocks, rare to absent in the eastern part of Y_1, occur in very minor amounts in the western part of Y_1. Pelitic rocks are more abundant in the western part of Y_1 and quartzose rocks predominate in the eastern part of Y_1. The dominant rock types include quartz-biotite gneiss and schist, sillimanite gneiss, quartzite, amphibolite, and orthogneiss (unit ag, Fig. 2) including augen gneiss.

Figure 2 here.

Augen gneiss, a widely distributed and characteristic rock type having a granitic composition and blastoporphyritic texture, occurs primarily east of a major high-angle fault, the Shaw Creek fault (Fig. 1) (Dusel-Bacon and Aleinikoff, 1985). Large augen (megacrysts or porphyroblasts) of potassium feldspar range from 1 to 9 cm in longest dimension and have been modified into augen by mylonitization. These augen gneisses, occurring in the Big Delta, Eagle, Mount Hayes, and Tanacross quadrangles, are considered to be a part of deformed and metamorphosed intrusions of porphyritic granite. Dusel-Bacon and Aleinikoff (1985) postulated that these and similar augen gneisses and other orthogneisses in the Yukon Territory are part of an intrusive belt which extends from the central part of the Big Delta quadrangle in east-central Alaska into the Yukon Territory. Most of these augen gneisses were included in the Pelly Gneiss of McConnell (1905); Mertie (1937) used the term Pelly Gneiss for the augen gneisses in eastern Alaska but did not map them separately from the Birch Creek Schist. Other types of augen gneiss also occur in minor amounts in subterrane Y_1.

Sillimanite gneiss is a major rock type around the augen gneiss in the Big Delta quadrangle and occurs in a large area which has been interpreted as a gneiss dome (Dusel-Bacon and Foster, 1983) on the northwest side of the Shaw Creek fault (Fig. 1). Metamorphic grade (second sillimanite isograd) is highest in the central part of the gneiss dome and decreases northward. Triple point conditions for alumina silicate minerals are postulated for the schist on the north flank of the gneiss dome. The gneiss dome is mostly quartz-orthoclase-plagioclase-biotite-sillimanite $\pm$ muscovite gneiss. Cordierite occurs in some of the gneisses. To the north muscovite gradually increases and K-feldspar decreases. North of the Salcha River the pelitic rocks are interlayered with quartzitic schist, quartzite, marble, amphibole schist, and quartzofeldspathic schist.

The rocks of subterrane Y_1 are well foliated, and foliation is folded at least once. Gneissic banding is well developed in the augen gneiss and is concordant with the foliation in the surrounding metamorphic rocks (Dusel-Bacon and Aleinikoff, 1985). Foliation is plastically folded in the gneiss

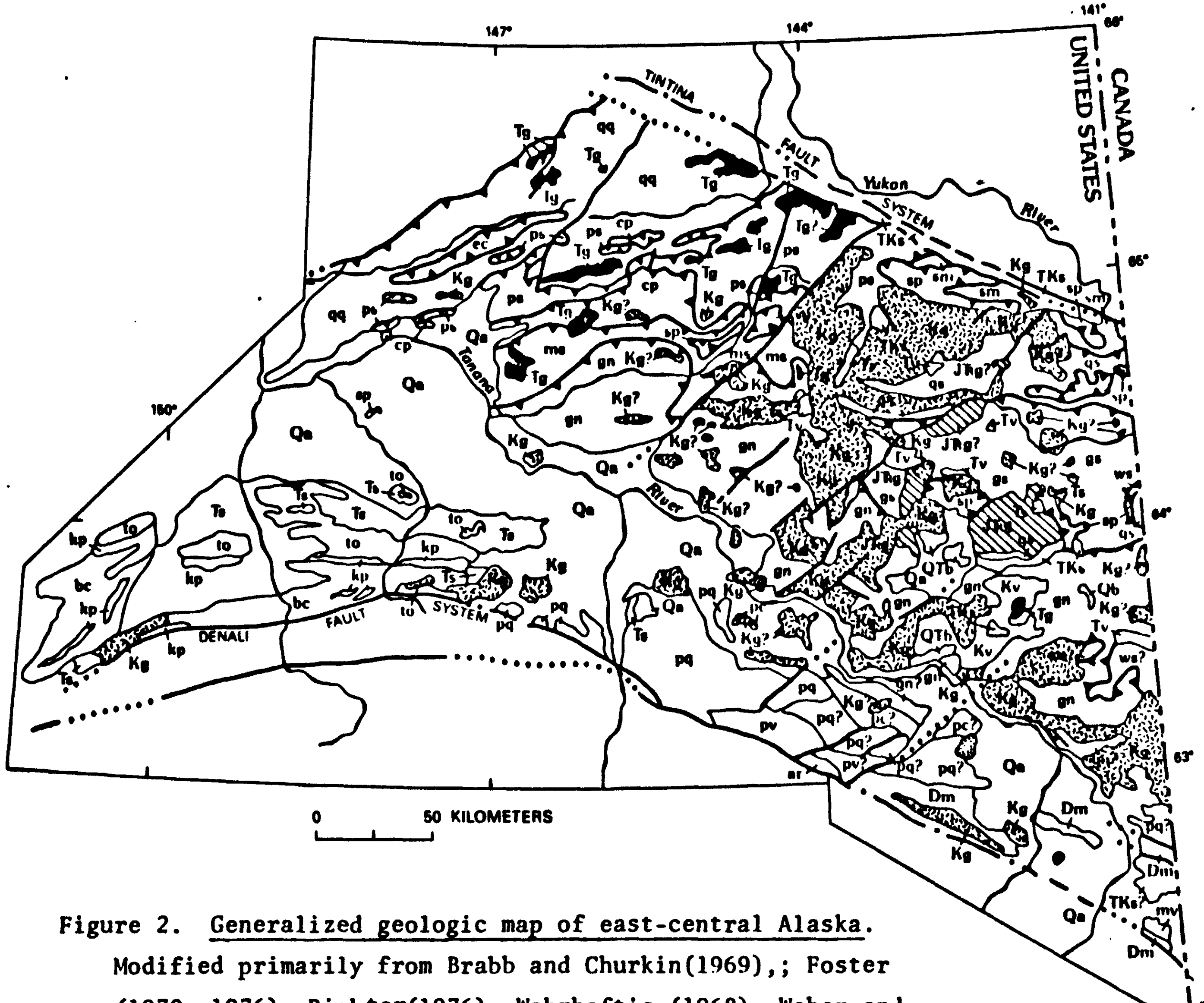

Figure 2. Generalized geologic map of east-central Alaska. Modified primarily from Brabb and Churkin(1969),; Foster (1970, 1976), Richter(1976), Wahrhaftig (1968), Weber and others(1978) Gilbert and Bundtzen (1979), Forbes and Weber (1982), Foster and others (1983), Hall and others (1984), and Nokleberg, W. J. (unpublished data, 1984).

Figure 2.

EXPLANATION

Unconsolidated deposits

- **Qa** Quaternary alluvial deposits: primarily alluvium but includes colluvial, glacial, and eolian deposits

Sedimentary rocks

- **Ts** Tertiary sandstone, conglomerate, shale, coal, and tuffaceous rocks includes informally designated coal-bearing formation of local usage overlain by the Nenana Gravel
- **TKs** Cretaceous and/or Tertiary sedimentary rocks (conglomerate, sandstone, coal, shale, and tuffaceous rocks)

Igneous rocks

Volcanic

- **Qb** Quaternary alkali-olivine basalt
- **QTb** Tertiary and/or Quaternary basalt and gabbro
- **Tv** Tertiary felsic to mafic volcanic rocks
- **Kv** Cretaceous volcanic and volcaniclastic rocks

Plutonic

- **Tg** Tertiary granitic rocks
- **Kg** Cretaceous granitic rocks
- **Trg** Late Triassic and Early Jurassic granitic rocks

Metamorphic rocks

North of Tanana River

Rocks of higher metamorphic grade

- **ps** Pelitic schist, quartzite, marble, and amphibolite
- **gs** Gneiss, schist, quartzite, marble, and amphibolite
- **gn** Gneiss (including augen gneiss and sillimanite gneiss), schist, amphibolite, and quartzite
- **ec** Eclogite and associated rocks

Rocks of lower metamorphic grade

- **cp** Calc-phyllite and quartzite
- **ms** Mylonitic schist, semischist, quartzite, phyllite, marble, and greenstone
- **ws** Quartz-chlorite-white mica schist
- **qs** Quartzite and quartzitic schist
- **sm** Schist, including greenschist, marble greenstone, and quartzite
- **qq** Quartzite, quartzitic schist, mafic schist, and calc-schist
- **sp** Serpentinized peridotite, greenstone and associated metasedimentary rocks including chert of Mississippian, Permian, and Triassic age

South of Tanana River

- **gn** Gneiss (including augen gneiss), schist, amphibolite, quartzite
- **pc** Pelitic schist, calc-schist, and quartz-feldspar schist
- **pq** Pelitic schist, quartzite, and schistose volcanic and plutonic rocks
- **pv** Phyllite and schistose volcanic rocks
- **ar** Argillite, limestone, conglomerate, and other metasedimentary rocks
- **mv** Metavolcanic and volcaniclastic rocks
- **Dm** Metasedimentary rocks of probable Devonian age intruded by diorite and gabbro
- **to** Totatlanika schist of possible Late Devonian to Mississippian age; mostly quartzitic schist and metavolcanic rocks
- **kp** Keevy Peak Formation of possible Ordovician to Devonian age; includes carbonaceous phyllite, quartzite, stretched conglomerate, and white mica-quartz schist
- **bc** Birch Creek schist of former usage; includes quartzitic, graphitic, chloritic, and calcareous schist, marble, and greenstone

- Contact
- Fault or probable fault; dotted where concealed
- Thrust fault or postulated thrust fault; sawteeth on upper plate

dome and some other gneisses. Most of the rocks show varying degrees of mylonitization and post-mylonitization recrystallization. In the Lake George terrane (Mount Hayes quadrangle) Aleinikoff and Nokleberg (1985) described small-scale isoclinal folds in pelitic schist; axial planes parallel foliation and compositional layering but fold an older foliation. A lineation formed by the intersection of the axes of small tight folds with foliations occurs locally in augen gneiss in the Big Delta quadrangle and is especially well developed in the northeastern Tanacross quadrangle.

The only information on the age of the protoliths of the metamorphic rocks in subterrane Y_1 comes from U-Pb dating of zircon. U-Pb analyses of zircon from medium-grained schistose granitic rock from the Mount Hayes quadrangle indicate a Devonian intrusive age, about 360 Ma (Aleinikoff and Nokleberg, 1985a). Detailed study of augen gneiss from the Big Delta quadrangle indicates an intrusive age of Mississippian, about 345 Ma (Dusel-Bacon and Aleinikoff, 1985). U-Pb analyses of zircon from augen gneiss in the Tanacross quadrangle (Aleinikoff and others, 1986) and also of augen gneiss in the southeastern Yukon Territory (Mortensen, 1983) indicate a Mississippian intrusive age. The paragneisses, schists, and quartzites of subterrane Y_1 are interpreted as wall rocks of the orthogneisses; therefore they are Mississippian or older in the Big Delta, Eagle, and Tanacross quadrangles and Devonian or older in parts of the Mount Hayes quadrangle. An early Paleozoic age seems likely for most of them, but a Precambrian age for at least some cannot be ruled out. Both the augen gneiss and some quartzites are shown by U-Pb analyses of zircons to have an inherited Early Proterozoic component (2.1 to 2.3 Ga) (Aleinikoff and others, 1986). The origin of this Proterozoic material is unknown, but a high initial $^{87}Sr/^{86}Sr$ ratio in the augen gneiss supports petrologic indications of involvement of continental crustal material in the formation of these rocks (Dusel-Bacon and Aleinikoff, 1985).

Deformed and recrystallized ultramafic rocks in isolated outcrops (too small to be shown in Figure 2) are infolded with gneisses and schists of subterrane Y_1; most are concentrated in the south-central and southeastern Big Delta and southwestern Eagle quadrangles. Locally preserved textures indicate that some of the ultramafic rocks were originally peridotite (harzburgite). Intense recrystallization has formed elongate oriented olivine with pods of granular magnetite as long as 5 cm. Other metamorphic minerals include hornblende, actinolite, serpentine, chlorite, talc, anthophyllite, and magnesite. The ultramafic rocks probably composed a thrust sheet over part of subterrane Y_1 early in the development of the subterrane and were metamorphosed and deformed with the rocks of subterrane Y_1.

The metamorphic history of subterrane Y_1 is not known in detail. Nokleberg and Aleinikoff (1985) interpreted that the subterrane in the Mount Hayes quadrangle (Lake George terrane) was intensely deformed and regionally metamorphosed at least once, and more likely twice, at conditions of the middle amphibolite facies. Then, during a late stage of the second regional metamorphism and deformation, the Lake George terrane was intruded by Cretaceous granitic rocks, which were subsequently metamorphosed, along with the older wall rocks, under conditions of the lower greenschist facies. The metamorphic history of subterrane Y_1 in the Big Delta, Eagle, and Tanacross quadrangles is based largely on the study of the augen gneiss, adjacent wall rocks, and the gneiss dome. Dusel-Bacon and Aleinikoff (1985) suggested that major amphibolite-facies metamorphism and deformation may have closely followed intrusion of the augen gneiss, on the basis of structural characteristics of the augen gneiss and limited isotopic data on wall rocks.

An Early Cretaceous thermal event caused lead loss in the U-rich zircon fractions from sillimanite gneiss and quartzite and also affected Rb-Sr and K-Ar isotopic systems (Aleinikoff and others, 1986; Wilson and others, 1985). If temperatures only reached greenschist facies in subterrane Y_1, they would have produced minor retrograde effects. However, if amphibolite-facies temperatures were reached, the effects might not be detected because the rocks were already metamorphosed to amphibolite facies. The only recognized petrologic changes that can be attributed to this Early Cretaceous metamorphism outside of the Mount Hayes quadrangle are minor, and no younger metamorphic events have been identified.

Nokleberg and Aleinikoff (1985) interpreted the Lake George terrane and other terranes to the south as shallow to deep parts of a submarine igneous arc of Devonian age. They considered the possibilities of either an island-arc or submerged continental margin arc. Dusel-Bacon and Aleinikoff (1985) suggested that a Mississippian belt of intrusions developed either below or inland from a continental arc, and that in the latter case, the belt of augen gneiss plutons could be analogous to belts of peraluminous plutons that occur inland from continental margins in some orogenic belts.

Subterrane Y_2 (Circle, northern Big Delta, southwestern Charley River, Livengood, and Fairbanks quadrangles)

The Y_2 subterrane is bounded on the north by the Tintina fault system and on the south and west by thrust faults; the eastern boundary is obscured by Mesozoic granitic plutons. The western fault contact is considered as the terrane boundary of the YT (Laird and Foster, 1984; Foster and others, 1983). Subterrane Y_2 is composed of three fairly distinct groups of rocks: one group (unit qq, Fig. 2) consists mostly of quartzites and quartz schists of greenschist to amphibolite facies and has been referred to informally as the Fairbanks schist unit in the Fairbanks quadrangle (Bundtzen, 1982); the second group (unit ps, Fig. 2) consists of amphibolite to epidote-amphibolite-facies schist, quartzite, marble, and amphibolites, some of which has been included in the Chena River sequence (Hall and others, 1984). These two groups of rocks are in thrust contact as indicated by sharp lithologic changes and their map patterns, but thrusting occurred before major metamorphism because metamorphic isograds do not follow the unit contacts (Foster and others, 1983). A third group of thrust-bounded rocks (unit ec, Fig. 2) occurs in the southwestern Circle and southeastern Livengood quadrangles and consists of eclogite associated with amphibolite, impure marble, pelitic schist, and rare glaucophane-bearing schist. These rocks, referred to as the Chatanika terrane by Bundtzen (1982), probably had a metamorphic and deformational history different from that of the remainder of subterrane Y_2 before they were thrust together.

Quartzite and quartzitic schists (unit qq)

This group of rocks crops out over about half of the Circle quadrangle and occurs in the Fairbanks and Livengood quadrangles. Quartzite and quartzitic schist are the most abundant rock types in this unit, but minor amounts of pelitic schist, calc-silicate rocks, mafic schist, and rare marble are interlayered. In the Circle quadrangle, quartzite and quartzitic schist are 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 strained monocrystalline or polycrystalline grains. The matrix is generally a mosaic of strained quartz, minor feldspar and white mica. Locally, chlorite, biotite, and small garnets are present. Most of these rocks are mylonites (Wise and others, 1984); many show syntectonic recrystallization in quartz, especially near fault contacts (Foster and others, 1983).

Mylonitization is particularly evident along the northwestern margin of this unit. Foster and others (1983) and Laird and Foster (1984) interpreted this as a major zone of thrusting; however, some workers (Hall and others, 1984) considered the northwestern contact of this unit to be gradational with a grit unit of the Wickersham terrane of Jones and others (1984). A small area of "grit" and quartzite in the south-central part of the Circle quadrangle was interpreted as a window in the thrust sheet of this unit (Foster and others, 1983).

Quartzitic rocks are interlayered with minor amounts of pelitic schist (quartz + plagioclase + muscovite + chlorite schist commonly with biotite ± garnet or with chloritoid ± garnet). Garnet is absent in the northern part of this unit. Rare, thin marble layers occur. Chlorite schist, locally magnetic, is interlayered and infolded with quartzite and pelitic schist. Interpretation of aeromagnetic data (Cady and Weber, 1983) suggests that magnetic chlorite schists, which are a poorly exposed unit, may be more abundant than is apparent from outcrops in the southwestern part of the Circle quadrangle.

A mafic schist is the dominant rock type in a 190-km^2 area in the east-central part of the Circle quadrangle. Green chlorite-quartz-carbonate schist generally with abundant plagioclase porphyroblasts is interlayered with amphibole (commonly actinolite) + chlorite + epidote + plagioclase + quartz + sphene + biotite or white mica ± carbonate ± garnet schist. The protolith may have been, in part, mafic pyroclastic rocks. Minor marble, quartzite, and pelitic schist are interlayered with the mafic schist (Foster and others, 1983).

The westernmost metamorphic rocks of the Yukon-Tanana terrane form the unit "qq" of the Fairbanks and Livengood quadrangles (Bundtzen, 1982). Although poorly exposed, they have been examined in detail. In the Fairbanks quadrangle, this unit is dominantly quartzite and muscovite-quartz schist ± garnet, biotite, and chlorite. It is estimated to be over 1,000 m thick (Hall and others, 1984). Interstratified near the center of this group of rocks is a 130-m-thick sequence of interlensing felsic schist, micaceous quartzite, chloritic or actinolitic schist, graphitic schist, minor metabasite, metarhyolite, calc-silicate layers, banded gray marble, and quartzite referred to informally as the Cleary sequence (Bundtzen, 1982). These rocks, interpreted to be largely of distal volcanic origin, host lode mineral occurrences in the Fairbanks Mining District (Hall and others, 1984).

Four distinct deformational events are recognized in this unit in the Circle quadrangle (Cushing and Foster, 1984). The first, D_1, produced a penetrative schistosity, S_1, parallel or subparallel to gently dipping axial planes of rarely observed tight to isoclinal recumbent folds. S_1 commonly parallels compositional layering and is everywhere prevalent in the metamorphic rocks. Folds associated with the second deformational event, D_2, are ubiquitous and range from tight to isoclinal with rounded and chevron fold hinges. Amplitudes and wavelengths range from microscopic to several meters. A second schistosity, S_2, developed locally owing to mechanical rotation of S_1. Folds of the third deformational event, D_3, are recumbent, tight to isoclinal. Because fold styles and orientations are very similar, structural features of D_3 are difficult to distinguish from D_2. The fourth deformational event, D_4, is characterized by gentle and open folds that deform all previous structures. Wave lengths and amplitudes are generally less than 50 cm but may be as large as 5 m.

Unit "qq" was subjected to moderate pressure greenschist-facies regional metamorphism that was more intense in the southern part of the unit (Foster and others, 1983). Polymetamorphism of regional extent has not been identified. Rolled garnet and plagioclase grains are common but appear to be explained by one syntectonic growth event. Inclusions of chloritoid found within, but not outside of, garnet grains can be explained by progressive metamorphism through and above the conditions of chloritoid stability (Burack, 1983). Contact-metamorphic effects are superimposed upon the regional metamorphism around most Tertiary plutons; biotite and amphibole have developed across the foliation and garnet is commonly all or partly chloritized.

The ages of the protoliths of this unit are unknown because no fossils have been found. U-Pb determinations on zircon from one quartzite indicate that the protolith included material from an Early Proterozoic source of essentially the same age (2.1 to 2.3 Ga) as that of subterrane Y_1 (J.N. Aleinikoff, personal commun., 1983). The very large quartzitic component of these rocks and abundance of quartz megacrysts have led some workers to suggest that the protolith might have been a part of the Canadian Windermere Supergroup (F.R. Weber, personal commun., 1979).

Pelitic schist, quartzite, marble, and amphibolite (unit ps)

These rocks are mostly medium- to coarse-grained pelitic schist and gneiss with minor interlayers of quartzite, quartzitic schist, marble and amphibolite. Other rocks included in this unit are augen gneiss, calc-silicate, and ultramafic rocks. 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 Circle quadrangle; metamorphic grade decreases northward and westward. A characteristic mineral assemblage of the highest grade rocks is quartz + plagioclase + white mica + biotite + sillimanite $\pm$ potassium feldspar $\pm$ garnet. Metamorphic grade seems to be close to the muscovite + quartz = sillimanite + potassium feldspar $\pm$ H_2O isograd. Other pelitic assemblages in the higher grade part of the unit are: biotite + garnet + staurolite $\pm$ kyanite; biotite + garnet + kyanite; biotite + garnet + kyanite + sillimanite; all with quartz + white mica + plagioclase. Augen gneiss is mostly a biotite felsic gneiss containing augen-shaped potassium feldspar porphyroblasts. A characteristic mineral assemblage is potassium feldspar, commonly microcline, + quartz + plagioclase + brown biotite + white mica. Augen are generally composed of two or more potassium feldspar crystals. Variations in the size of augen, relative proportions of major mineral constituents, and field relations suggest that the augen gneisses do not all have the same origin and that protoliths probably include both igneous and sedimentary rocks. Some augen gneiss occurrences may be folded and metamorphosed sills or dikes (F.R. Weber, personal commun., 1979), but other occurrences, especially those that cap high parts on ridges, could be thrust remnants of subterrane Y_1. 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 $\pm$ chlorite + biotite.

Small scattered outcrops of metamorphosed ultramafic rocks (too small to be shown on Figure 2) consist mainly of actinolite, chlorite, serpentine, magnetite, chlorite, talc, and magnesite. Relict olivine, orthopyroxene, and clinopyroxene are found locally in rocks preserving harzburgite textures. The ultramafic rocks appear to occur discontinuously at or near the edge of thrust plates composed of this unit.

Unit "ps" appears to have a metamorphic and deformational history similar to that described for unit "qq" because isograds and folds are unrelated to contacts between the two units. As in unit "qq", all of the rocks of this unit are polydeformed, but polymetamorphism of regional extent has not been identified. However, contact metamorphism is indicated around some of the Tertiary plutons where pseudomorphs of white mica after staurolite and kyanite porphyroblasts occur.

The age of the protoliths of this unit is unknown. A single U-Pb age of 345 $\pm$ 5 Ma (Mississippian) (J.N. Aleinikoff, personal commun., 1985) was obtained on zircon from one orthoaugen gneiss, an age similar to that obtained on zircon from augen gneiss in subterrane Y_1 (Aleinikoff and others, 1986). Because this dated augen gneiss may be in thrust contact with the associated metasedimentary rocks rather than intrusive into them, its age may not provide an upper constraint on the protolith age of this unit. Although younger protolith ages cannot be ruled out, early and (or) middle Paleozoic ages are reasonable possibilities for this unit.

Eclogite and associated rocks (unit ec)

The only eclogitic rocks known in east-central Alaska occur in a small area in the southwestern part of subterrane Y_2 in bands and lenses intercalated with amphibolite, impure marble, pelitic schist, and mafic glaucophane-bearing schist (Fig. 2). They were first described by Prindle (1913) in what is now the southeastern part of the Livengood quadrangle, but because of very limited exposure, were given little attention until rediscovered in the 1960's (Forbes and Brown, 1961). Swainbank and Forbes (1975) described their petrology. Eclogitic rocks also have been found in the southwestern part of the Circle quadrangle (Foster and others, 1983).

The eclogitic rocks from the Livengood area consist of several combinations of garnet, omphacitic clinopyroxene, amphibole, calcite, phengitic mica, quartz, albite, epidote, sphene, and rutile (Swainbank, in Hall and others, 1984). Bulk chemistry suggests that they may have been derived from marls and graywackes. Recently, glaucophane and kyanite-staurolite-chloritoid bearing assemblages have been found (Brown and Forbes, 1984). Pyroxene-garnet, biotite-garnet, muscovite-paragonite, and aluminosilicate data suggest crystallization temperatures of 600 $\pm$ 50^{o}C at pressures of 13-15 kb (Brown and Forbes, 1984). These eclogites are similar to eclogites from alpine-type orogenic terranes (Group C of Coleman and others, 1965). They occur in northwest trending isoclinal recumbent folds that have been deformed by open or overturned folding along northeast-trending axes.

Eclogite from the Circle quadrangle, which on the basis of garnet composition also falls within Group C of Coleman and others (1965), appears to be from a mafic layer within quartz + white mica + garnet (somewhat retrograded to chlorite) schist and quartzite. Where a contact is visible, foliation has the same orientation in both the mafic and pelitic layers. The mafic layer cuts across foliation and is more massive in the interior, which suggests that its protolith may have been a dike. A typical sample of the mafic layer consists of garnet, omphacite, quartz, clinoamphibole (barroisite to alumino-barroisite), clinozoisite, white mica, rutile, and sulfide (trace). Estimated conditions of metamorphism are $600^{\circ} \pm 50^{\circ}$ C and 1.35 ± 0.15 GPa (Laird, Foster, and Weber, 1984).

Swainbank and Forbes (1975) recognized the probable fault relationships of the eclogite unit es and suggested that it might be a window of older and more complexly metamorphosed rocks surrounded by an upper plate of younger, less metamorphosed rocks, or two terranes separated by a high-angle fault system. More recent examination of field relations and fabric orientations have led to the interpretation that this unit forms the upper plate of a folded thrust (Hall and others, 1984). The eclogite unit is also shown in the upper plate on the Circle geologic map (Foster and others, 1983).

Determinations of age were made by the conventional K-Ar method on several micas and amphiboles from the eclogite-bearing rocks of the Livengood area. A minimum age of 470 ± 35 Ma, determined from an amphibole in eclogite, is interpreted to indicate an early Paleozoic metamorphic event, probably associated with the early recumbent style of folding (Swainbank and Forbes, 1975). Several K-Ar ages of 103 to 115 Ma determined from mica in pelitic schist and garnet amphibolite are associated with a second metamorphic episode and folding about northeast-trending axes (Swainbank, in Hall and others, 1984). Because of the fault relations between the eclogite unit and the remainder of subterrane Y_2, the early Paleozoic radiometric age that was obtained cannot be directly tied to events in other parts of subterrane Y_2 or YT. However, the late event (103 to 115 Ma) is most likely the same event that is widely recognized throughout much of the YT (see Metamorphism, p. 37).

Subterrane Y_3 (Northern Big Delta, Fairbanks, southern Circle, Eagle, Charley River, and eastern Tanacross quadrangles)

Subterrane Y_3 was originally described only in the western part of the YTTN (Churkin and others, 1982), but here is extended to include the greenschist-facies rocks in the northeastern part of the YTTN. In the northern Big Delta, Fairbanks, and southern Circle quadrangles, subterrane Y_3 separates subterranes Y_1 from Y_2. This part of subterrane Y_3 consists primarily of two distinct units of rocks that are in probable thrust contact with each other as well as with subterranes Y_1 and Y_2. The southernmost unit (unit ms, Fig. 2) consists mostly of greenish-gray quartzose mylonitic schist; the more northerly unit (unit cp, Fig. 2) consists of gray calcareous phyllite and gray quartzite. In the eastern part of the Eagle quadrangle, Tanacross quadrangle, and the south-central part of the Charley River quadrangles, subterrane Y_3 includes three other units: one consists of fault blocks and slices of mylonitic schist, greenschist, quartzite, marble, greenstone, and phyllite (unit sm, Fig. 2); a second consists primarily of dark-gray quartzite and gray quartz schist (unit qs, Fig. 2); and the third is characterized by light-green quartz-chlorite-white mica schist (unit ws, Fig. 2). All three are separated from one another and from subterrane Y_4 and Y_1 by thrust faults.

Mylonitic schist (unit ms)

The principal rock types of this unit (Fig. 2) are mylonitic schist, semischist, and quartz-white mica chlorite schist $\pm$ epidote, quartz sericite schist, and quartzite, with minor phyllite, marble, and greenstone.

Mylonitic textures, common throughout the unit, are more intense and more concentrated along the southern margin. Quartzite and quartzitic schist commonly have large gray, blue-gray, and clear glassy quartz grains, and some also have large feldspar grains (mostly microcline). The grains are commonly "eye-shaped" with "tails" of crushed recrystallized quartz. The marbles are fine to coarse grained and interlayered in schist and quartzite. Mafic greenschist and greenstone occur locally, particularly in the eastern exposures of the unit. Rocks of this unit are metamorphosed to the greenschist facies. Foliation, generally well developed, has been folded at least once.

The age of these rocks is unknown. Correlation has been suggested with the Totatlanika Schist, northern Alaska Range, of probable Late Devonian to Mississippian age (Gilbert and Bundtzen, 1979), the Klondike Schist of the Yukon Territory (Weber and others, 1978), and the Macomb terrane of the Mount Hayes quadrangle, northern Alaska Range (W.J. Nokleberg, personal commun., 1985). Although there are some similar lithologies, the lack of data on age of protoliths and on structural relations between units make correlations speculative.

Calc phyllite-black quartzite (unit cp)

A sequence of thin-layered calcareous phyllite, phyllite, and thin, crumbly carbonate layers is overlain by light- to dark-gray quartzite interlayered with dark-gray to black argillite and phyllite. The quartzite is mostly medium grained, and thinly layered to massive. Foliation, incipient cleavage, and small isoclinal folds occur locally.

In the Circle quadrangle, vitrinite reflectance studies (Laird, Biggs, and Foster, 1984) indicate that most of these rocks were subjected to temperatures ($180^{o} \pm 50^{o}$ C) no higher than those normally associated with sediment diagenesis. One sample near a fault has been subjected to temperatures as high as $230^{o} \pm 50^{o}$ C. In the Big Delta quadrangle, some of these rocks near Tertiary granitic intrusions have been contact metamorphosed. The grade of these rocks elsewhere in the Big Delta quadrangle has not been determined but is probably mostly in the same range as those of the Circle quadrangle.

No fossils have been found in these rocks and so their age is unknown, but may be early or middle Paleozoic. Contacts of this unit appear to be at faults except where the contact is with Tertiary granite.

Schist, quartzite, and marble (unit sm)

This is a varied unit of greenschist-facies rocks consisting of greenschist, calcareous greenschist, quartz-chlorite-white mica schist, marble, greenstone, quartzite including gray and dark-gray quartzite, and schist with large quartz and (or) feldspar grains. It crops out in the northeastern part of the Eagle quadrangle south of the Tintina fault. Although this unit includes some rocks similar to those in units "qs" and "ws" (discussed below), it differs in having abundant layers and lenses of marble. The marbles are mostly light gray, medium to coarsely recrystallized, and thin layered to massive; some are 100 m or more thick.

These rocks are commonly highly sheared and fractured and locally brecciated. In places they have a well-developed northwesterly striking foliation. A strong, closely spaced (10 $\pm$ cm apart) fold-axis lineation is locally conspicuous, especially in the more quartzose rocks. In places the resulting structure appears "mullion-like." Small faults with prominent gouge and brecciated zones are abundant. Locally, the unit has the appearance of a mélange.

The stratigraphic and (or) structural position of this unit is not clearly understood, but the unit is probably overthrust by unit "gs", making it the structurally lowest unit in the eastern part of the YTTN. The correlation of these rocks with rocks of the Yukon Territory is unknown. They may be a group of rocks not previously mapped in the western Yukon Territory or possibly a different facies or different part of the section of Green's (1972) unit B and (or) unit A. They are believed to be of Paleozoic age on the basis of a few poorly preserved echinodermal fragments found in marble at several localities in the Eagle quadrangle.

Quartz-chlorite-white mica schist group (unit ws)

The most common rock type in this unit is light-green or light-greenish-gray quartz-chlorite-white mica ± carbonate schist. Generally chlorite is fairly minor. Locally, in the Tanacross quadrangle, biotite may be present. Other interlayered rock types include quartzite, phyllite, and metavolcanic rocks of both mafic and felsic composition. Some schists have scattered coarse grains of gray, bluish-gray, and glassy quartz, commonly with augen shapes. Some quartz grains are single crystals; others are polycrystalline. Feldspar grains also occur in some schists. Locally minor actinolite and epidote may be present. Mylonite and partly recrystallized mylonitic texture occur.

Foliation is generally well developed. In the southeastern part of the Eagle quadrangle, a strong lineation trending and plunging westerly is formed by small, tight, isoclinal folds. These folds are refolded by generally northeast-trending folds that are believed to be related to thrusting. This unit probably also has been affected by a late open folding that is not easily observed in the Eagle quadrangle, but is evident in rocks adjacent to this unit in Canada.

In the Eagle quadrangle, this unit is overthrust by, and in places imbricated with, amphibolite-facies rocks (Foster and others, 1985). In the Tanacross quadrangle its contacts are poorly exposed. The unit is continuous to the east with similar rocks in the Yukon Territory, which are included in Green's (1972) unit B and were termed the Klondike Schist by McConnell (1905).

The age of protoliths of these rocks is unknown, and, because all their contacts are believed to be thrust faults in Alaska, their stratigraphic position is also unknown. Middle or late Paleozoic protolith ages have been postulated (Tempelman-Kluit, 1976).

Quartzite and quartzitic schists (unit qs)

The most common rock type in this unit (Fig. 2) is light-gray to black quartzite, which ranges in grain size from very fine to medium. Quartz grains are almost always highly strained. Outcrops are massive to schistose depending upon the relative amounts of white mica and quartz. Gray phyllite, phyllitic and carbonaceous quartz schist, and graphitic schist layers occur locally.

These rocks generally have a well-developed foliation that regionally strikes approximately east-west with both northward and southward dips ranging from 5° to 60°. Folds, commonly isoclinal, a few millimeters to several meters in wavelength and amplitude deform foliation. Axes of these folds generally trend slightly north of west and have a shallow plunge (0-20°). Small (1-10 cm amplitude and wavelength) asymmetric, rootless folds defined by cream-colored fine-grained polycrystalline quartz may be an early phase of this deformation. An open folding, commonly having a wavelength of about 0.5 m and an amplitude averaging 10 cm, deforms early structures. The axial trend of the open folds is slightly west of north and plunges a few degrees to 25° northwest or southeast.

This unit crops out in a generally westerly trending belt in the east-central part of the Eagle quadrangle and in a small area in the southeastern corner of that quadrangle. The unit continues eastward into Canada as part of Green's (1972) unit A and the Nasina Series of McConnell (1905). A Paleozoic age has been hypothesized (Foster, 1976), although no fossils have been found and contacts of the unit are probably all faults.

Subterrane Y_4 (Eagle and Tanacross quadrangles)

Subterrane Y_4 consists primarily of quartzitic and pelitic gneiss and schist, quartzite, marble, and amphibolite (unit gs, Fig. 2) metamorphosed to the amphibolite and epidote-amphibolite facies. On the north it is in thrust contact with greenschist-facies rocks of subterrane Y_3, on the west it has been extensively intruded by Cretaceous granitic plutons, and on the south a probable thrust fault separates it from subterrane Y_1. On the east it extends into the Yukon Territory of Canada. The unit typically consists of medium- to coarse-grained amphibolite, quartz-amphibole-biotite gneiss, quartz-biotite gneiss, marble, and quartzite. Because the composition of most of the gneiss and schist is quartzose, aluminum silicate minerals are rare; however, kyanite has been found in a few thin sections. White, light-gray, or pinkish-white marbles are medium to coarse grained, but most commonly coarse grained. Quartzite is mostly light gray and tan. In the northwestern part of subterrane Y_4 the unit consists of mostly schist, quartzite, and marble, all complexly deformed and intruded by dikes and plutonic rocks. The metamorphic grade locally may be as low as upper greenschist facies.

Foliation and compositional layering have been deformed into tight, asymmetric folds that are locally isoclinal. Wavelength and amplitude ranges from 0.5 m to several hundred meters. Fold axes have an average trend of N 50° E and generally plunge less than 20° northwest or southeast. A second generation of folding, probably the same open-folding that has affected the rocks of adjacent subterranes, produced open folds with axes trending nearly north-south. The wavelength of these folds is about 0.5 m and their average amplitude about 10 cm. Pre-metamorphic folding has not been definitely recognized, but may be indicated by rarely observed small rootless folds. Thrust slices with zones of gouge, breccia, and small fault-related folds are common throughout subterrane Y_4.

The major regional metamorphism and accompanying deformation of these rocks is believed to have taken place during Late Triassic to Middle Jurassic time on the basis of ^{40}Ar-^{39}Ar incremental heating experiments. Granitic intrusion (Taylor Mountain, Mount Veta, and possibly other plutons) was probably synchronous with metamorphism and preceded thrusting of this unit over units "ws" and "qs" (Cushing, Foster, and Harrison, 1984). The Early Cretaceous metamorphism that affected subterrane Y_1 also affected subterrane Y_4 but was of minor intensity (Cushing, Foster, and Harrison, 1984).

The age of these rocks is poorly known, but they are considered Paleozoic on the basis of a few poorly preserved crinoid columnals (Foster, 1976) in marble. At present there is no evidence for Precambrian protoliths in this unit.

Unfoliated igneous rocks
Plutonic rocks

Unfoliated igneous rocks occur throughout the YTTN and range in composition from ultramafic to felsic, but most are felsic. On the east side of the Shaw Creek fault (Fig. 2) some intrusions are of batholithic proportions, and intrusions of small plutons, dikes, and sills are common in all parts of the YTTN.

Felsic granitic plutons

Three periods of Mesozoic and Cenozoic granitic intrusion are recognized in the YTTN. The oldest, Late Triassic and Early Jurassic (215-188 Ma) in age (unit JTrg, Fig. 2), is found only in the eastern part of the YTTN (subterrane Y_4). The second, in Late Cretaceous time (95-90 Ma) occurs throughout the YTTN but is especially prominent in the central part (unit Kg, Fig. 2). The third, in Late Cretaceous and early Tertiary time (70 to 50 Ma), occurred throughout the YTTN but has particular significance in the northwestern part (unit Tg, Fig. 2).

The Late Triassic and Early Jurassic plutons include those of Taylor Mountain and Mount Veta, and possibly some plutons in the central and eastern parts of the Eagle quadrangle. Taylor Mountain, in the south-central part of the Eagle and northern part of the Tanacross quadrangles, is a batholith about 648 km^2 in area. It is mostly medium-grained, equigranular granite (terminology of Streckeisen, 1976), but locally it is granodiorite to diorite. In places, along the southern and eastern margins, its texture is slightly gneissic. Plagioclase (oligoclase to andesine), sericitized potassium feldspar, quartz, hornblende, and biotite are the major constituents; common accessory minerals are sphene, apatite, and opaque minerals. Plagioclase is generally zoned and sericitized. Quartz is strained, and the margins of some quartz grains are granulated. Hornblende is generally more abundant than biotite. Some biotite has altered to chlorite. The southern contact of the pluton is fairly sharp, and there is little evidence of thermal effects on the amphibolite-facies country rock. However, the country rock along the northeastern contact has been altered by the intrusion, and dikes and sills are numerous. Epidote is abundant in the contact zone. Locally, the margins of these plutons are sheared, crushed, and faulted. Conventional K-Ar dating has indicated an age of around 180 Ma for the Taylor Mountain batholith. ^{40}Ar-^{39}Ar determinations provide an integrated plateau age on hornblende of 209 $\pm$ 3 Ma (Cushing, 1984). A U-Pb determination on sphene gives an age of 212 $\pm$ Ma (Aleinikoff and others, 1981). Thus, the batholith is believed to have been intruded in Late Triassic time.

Characteristic intrusive rocks in the vicinity of Mount Veta are a hornblende plagioclase porphyry. A common mineralogy is that of a quartz monzodiorite, but more felsic compositions also occur. Some phases of the intrusion are equigranular. In some very coarse grained porphyritic phases, a mineral alignment defines a weak foliation. Conventional K-Ar analysis of hornblende from this intrusion yielded an age of 177 $\pm$ 5 Ma (Foster, 1976) and an integrated plateau age of 188 $\pm$ 2 Ma was obtained by the ^{40}Ar-^{39}Ar method (Cushing, 1984). Some other hornblende-bearing plutons nearby have not been dated, but may be of similar age.

Figure 3 presents a plot of fields of normative quartz, albite, and

Figure 3 here.

anorthite for representative granitic rocks in the YTTN. Two fields are plotted for Triassic and Jurassic plutons (Taylor Mountain and Mount Veta). These rocks are characteristically low in quartz, contain abundant hornblende, and in contrast to most granitic rocks in the YTTN, none are corundum normative. Mineralogical and common lead isotope data (J.N. Aleinikoff, personal commun., 1985) are consistent with a dominantly oceanic source for magmas that formed the Triassic and Jurassic plutons.

The Triassic and Jurassic plutons are similar in lithology and age to plutonic rocks of the Klotassin Suite in the Yukon Territory (Tempelman-Kluit, 1976). The Klotassin Suite has been interpreted as the roots of an island arc that formed on the margin of Stikinia (Tempelman-Kluit, 1979), a continental fragment that was joined to North America in Middle Jurassic time (Tempelman-Kluit, 1979). Tempelman-Kluit (1976) has suggested that the granitic rocks of Taylor Mountain may belong to the Klotassin Suite and thus would be a part of the Stikinia terrane (Jones and others, 1984). However, the country rocks (subterrane Y_4) intruded by the pluton of Taylor Mountain are not typical of those which compose the Stikinia terrane in the parts of Canada where it is best known. Although subterrane Y_4 may not be a part of Stikinia this does not preclude correlation of the granitic rocks of Taylor Mountain with the Klotassin Suite. Subterrane Y_4 may have been near or joined to the Stikinia terrane in Triassic or Early Jurassic time and involved in the same plutonic event.

Hornblende-bearing granitic rocks in the southeastern part of the Tanacross quadrangle have been included in the Stikinia terrane (Jones and others, 1984) because they are adjacent to rocks of similar lithology to the east in the Yukon Territory that are included in the Klotassin Suite. However, these granitic rocks in Alaska are also adjacent, on the west, to lithologically similar Cretaceous granites. Neither the Alaskan nor the Canadian hornblende-bearing granites close to the U.S.-Canada border have been dated. More data are needed to determine whether or not these rocks are of Taylor Mountain and Klotassin age and therefore, whether or not the Stikinia terrane extends into Alaska.

Granitic rocks of Cretaceous age occur in bodies that range in size from less than 1 km^2 to plutons of batholithic proportions. Batholiths occur in the southeastern and northwestern parts of the Tanacross quadrangle, the northeastern part of the Mount Hayes quadrangle, and in the western part of the part of the Eagle and eastern part of the Big Delta quadrangle. The plutons range in composition from quartz monzonite to diorite but are dominantly granite and granodiorite (terminology of Streckeisen, 1976). They are equigranular to porphyritic and are generally medium grained. The mafic minerals may be either hornblende or biotite, and most commonly both occur. Primary muscovite is rare and minor when present. Mylonitic textures are locally present, especially along major faults such as the Shaw Creek fault. Alteration of feldspars is slight to moderate, and biotite is commonly partly chloritized.

The age range of this group of intrusions, on the basis of conventional K-Ar analyses, is about 110 to 85 Ma, but most are around 95 to 90 Ma.

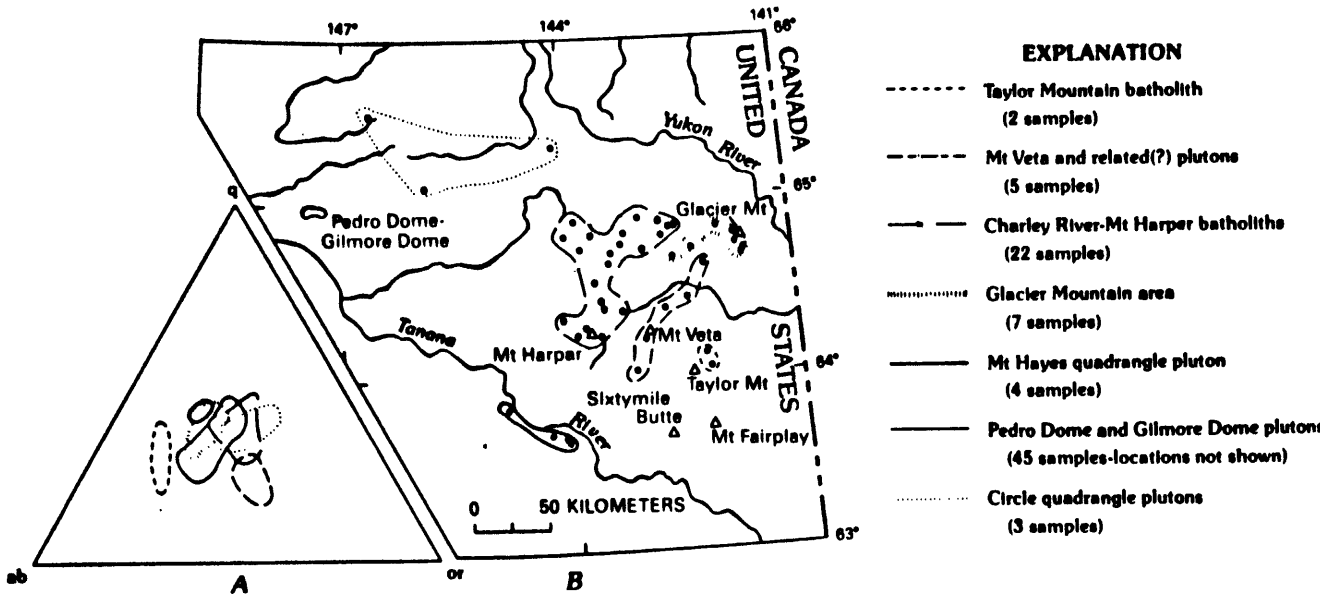

Figure 3. Normative mineralogical data for granitic plutons in the Yukon-Tanana terrane. A, Fields of normative mineralogy for smaples of granitic plutons. B, Localities (dots) of samples used to define the mineralogical fields. Data primarily from Holmes and Foster (1968), Foster, Donato, and Yount (1978), Luthy and others (1981), Blum (1983), and Wilson, F. H., unpublished data, 1984.

Nokleberg and others (1986) described some intrusive rocks of similar age in the northeastern part of the Mount Hayes quadrangle as locally slightly to moderately schistose and slightly regionally metamorphosed, and suggested that these rocks were intruded during the waning stage of a major regional amphibolite-facies metamorphism in the mid- to Late Cretaceous. This Cretaceous metamorphism is not recognized as the major thermal event in other parts of the YTTN. We suggest that this event affected at least some other parts of the YTTN, but was of minor intensity. For instance, in subterrane Y_4 it has been detected by ^{40}Ar-^{39}Ar incremental heating experiments on minerals from amphibolite facies metamorphic rocks (Cushing, Foster, Harrison, and Laird, 1984).

Plots of normative quartz, albite, and orthoclase from samples from individual bodies of Cretaceous granitic rocks fall into distinct compositional fields. Figure 3 shows fields and locations for samples from the batholith(s) in the western part of the Eagle and eastern part of the Big Delta quadrangle (Mount Harper-Charley River), plutons in the northeastern part of the Mount Hayes quadrangle, small granitic bodies near Fairbanks (Pedro and Gilmore Domes), and from granitic bodies in the northeastern part of the Eagle quadrangle (Glacier Mountain). The Cretaceous granitic rocks are more quartz rich than the Triassic and Jurassic granites, and most contain normative corundum. Blum (1983), in a detailed study of the small granitic bodies near Fairbanks, concluded, on the basis of petrography, major-oxide chemistry, and initial strontium isotopic ratios, that those granites formed either from a magma generated by partial melting of metamorphic rocks of continental affinities or from an initially mantle- or lower crustal-derived melt with significant contamination from continental material. Common lead ratios of Cretaceous granitic rocks from widely scattered localities in the YTTN also suggest a mixture of lead from two sources, one a continentally derived radiogenic source, and the other a more primitive oceanic source (J.N. Aleinikoff, personal commun., 1984).

In addition to granitic plutons, several small (generally less than 2 km^2) pyroxene diorite plutons are known in the Big Delta quadrangle. These plutons range in age from about 93 to 90 Ma, based on conventional K-Ar analysis (Foster and others, 1979). Granitic rocks of this general age group are common in many parts of Alaska and the Yukon Territory. In the Yukon Territory they are included in the Coffee Creek Suite (Tempelman-Kluit, 1976).

The youngest intrusions with K-Ar ages of 70 to 50 Ma are most prevalent in the northeastern part of the Big Delta and the Circle quadrangle, although a few others are widely scattered throughout the YTTN. They are primarily granite in composition (terminology of Streckeisen, 1976), but Mount Fairplay in the Tanacross quadrangle ranges from hornblende-augite-biotite diorite through hornblende-augite syenite to hornblende-biotite quartz monzonite (Kerin, 1976). The young plutons, generally fairly small in size (3 km^2 or less), are mostly medium to coarse grained and equigranular to porphyritic. The mafic mineral is generally biotite. They are quartz-rich and corundum normative, characteristics of granites formed from magmas derived from continental crust. A field of normative quartz, albite, and orthoclase for samples of Tertiary granite from the Circle quadrangle is shown in Figure 3.

Mafic and ultramafic differentiates

Bodies of coarse-grained gabbro (grains commonly 5-10 cm long) that appear to be mafic and ultramafic igneous differentiates occur in several different widely scattered localities in subterranes Y_4, Y_2, and Y_1. They are commonly hornblendite to clinopyroxenite with associated biotite (Type III of Foster and Keith, 1974) and, in a few places, very coarse grained gabbronorites and hornblende gabbros also occur in association with coarse-grained ultramafic rocks. Epidote and garnet are locally abundant in the gabbros. Mafic and ultramafic rocks of this type appear to have intruded regionally metamorphosed greenschist- to amphibolite-facies rocks. Margins of some of the mafic and ultramafic bodies are foliated, but there is no foliation within the bodies. Felsic dikes intrude most of the mafic and ultramafic bodies as well as the surrounding metamorphic country rock. The age and relationships of mafic bodies and felsic dikes to each other and to the regional metamorphism and tectonics are not clear. In the central part of the Eagle quadrangle, K-Ar ages from a biotite hornblendite are 175 $\pm$ 5.1 Ma on hornblende and 185 $\pm$ 5 Ma on biotite (recalculated from Foster, 1976). This ultramafic body could have a Late Triassic or Early Jurassic plutonic origin. In subterrane Y_1 in the Tanacross quadrangle, biotite from olivine gabbro associated with a small ultramafic body has a K-Ar age of 66.6 $\pm$ 2 Ma (Wilson and others, 1985).

Ultramafic dikes or small plugs of fresh, unmetamorphosed cumulate-textured pyroxenite and olivine pyroxenite intrude greenschist facies metamorphic rocks in the central Eagke and northwest Circle quadrangles. They could be either differentiates of nearby granodiorite intrusions, or unrelated ultramafic intrusive rocks.

Volcanic rocks

Post-metamorphic volcanism occurred in the Cretaceous, Tertiary, and Quaternary and was most prevalent in the eastern YTTN. All of the unmetamorphosed felsic volcanic rocks originally were considered to be of Tertiary age, but K-Ar age dating has shown that welded tuffs and other felsic volcanic rocks (unit Kv, Fig. 2) covering a large area in the Tanacross quadrangle are as old as Cretaceous (Bacon and others, 1985).

These Cretaceous volcanic rocks occur in and around three poorly exposed calderas in the central part of the Tanacross quadrangle and consist of ash-flow sheets, parts of which are welded, air-fall tuff, lava flows, ash-flow sheets, and small hypabyssal intrusions. Most are felsic and range from rhyolite to dacite in composition. Phenocrysts in rhyolite tuff, lava, and hypabyssal intrusions are quartz, sanidine, plagioclase, clinopyroxene, biotite, iron and titanium oxides $\pm$ allanite. All phenocrysts except quartz, clinopyroxene, and allanite are generally altered. Common alteration minerals are sericite, illite, clinoptilolite, kaolinite, chlorite, quartz, and potassium feldspar (Bacon and others, 1985). Tuffaceous sedimentary rocks occur near the margin of one of the calderas.

Mafic and intermediate volcanic rocks are in close proximity to the felsic ones, and some are also assumed to be of Cretaceous age. However, in a few places where cross-cutting relationships can be seen, the mafic rocks are younger than the felsic ones. Mafic rocks include potassic andesitic lava flows with plagioclase, biotite, clinopyroxene, and in some places hornblende phenocrysts, but detailed mineralogy of most of the mafic lavas is not known.

The K-Ar age of sanidine from welded tuff of the northernmost caldera is 93.6 $\pm$ 2 Ma, and an age for hornblende from rocks of the easternmost caldera is 90 $\pm$ 2.8 Ma (Bacon and others, 1985). These ages suggest that the volcanic rocks are related to the granitic plutons that were intruded during the 110 to 85 m.y. intrusive episode and that they may be roof remnants of some of these plutons. Although the Mount Fairplay intrusive body in the north-central part of the Tanacross quadrangle is partly surrounded by Cretaceous volcanic rocks, it appears to be unrelated to them and has a Tertiary K-Ar age.

Tertiary volcanic rocks (unit Tv, Fig. 2), as yet little studied, range from much-altered rhyolite to basalt in composition. They occur in the Tanacross, Eagle, and Big Delta quadrangles and commonly are associated with hypabyssal dikes and small intrusions. They include lava flows, welded ash-flow tuff and air-fall tuff. Locally, felsic tuff and possibly flows have been faulted, including thrust faulting, and small-scale deformation has resulted from the faulting. Sedimentary rocks, generally of very limited extent, occur locally with volcanic rocks.

Sanidine from a porphyritic rhyolite in the eastern part of the Big Delta quadrangle was dated as 61.6 ± 2 Ma by the K-Ar method (Foster and others, 1979). Ages of 57.8 ± 2 Ma and 56.4 ± 2 Ma on sanidines from welded tuff in the eastern part of the Tanacross quadrangle were also determined (Foster and others, 1979).

Several areas of undated basaltic rocks (unit Qv, Fig. 2) in the Tanacross quadrangle are thought to be of Quaternary age, largely on the basis of physiographic relationships, but Prindle Volcano in the eastern part of the Tanacross quadrangle leaves no doubt of its young age. Prindle Volcano is an isolated cone with a lava flow extending about 6.4 km downslope to the southeast from a breached crater. The cone and lava flow are composed of vesicular alkaline olivine basalt that contains abundant peridotite and granulite inclusions. The basalt consists of clinopyroxene, olivine, and opaque minerals in a fine-grained groundmass believed to contain occult nepheline and potassium feldspar (Foster and others, 1966). The peridotite inclusions range in size from xenocrysts to polycrystalline masses up to 15 cm in diameter. Mineral assemblages include olivine, orthopyroxene, clinopyroxene and spinel in at least five different combinations. The mineral assemblages of the inclusions are characterized by hypersthene and (or) clinopyroxene and plagioclase, but also may include quartz and carbonate with such accessory minerals as apatite, zircon, magnetite and rutile. The well-preserved cone suggests that the eruptive activity occurred during Quaternary time. Indirect evidence, which includes its possible age relationship to a similar cone in the Yukon Territory, and the fact that its lava flow is overlain by white volcanic ash which is probably the White River Ash Bed, suggests that it is post-early Pleistocene, but older than 1,900 years B.P. (Foster, 1981).

A number of unconsolidated volcanic ash deposits have been found in the YTTN, and some are fairly well dated. Most, such as the White River Ash Bed, probably originated outside of the YTTN (see section on Quaternary geology, Volcanic ash).

Sedimentary rocks (YTTN)

The unmetamorphosed sedimentary rocks of the YTTN (unit TKs, Fig. 2) are all of nonmarine origin, of Late Cretaceous and (or) Tertiary age, and of minor extent. They appear to have been deposited in small, disconnected basins, at least some of which resulted from faulting. Some sedimentary rocks are closely associated with volcanic rocks, and most include considerable amounts of tuff. They have been deformed by folding (Foster and Cushing, 1985) and, in some cases, thrusting and high-angle faulting.

The largest area of sedimentary rocks is in the northern part of the Eagle and southern part of the Charley River quadrangle both north and south of the Tintina fault. In some places sedimentary rocks cover the faults of the Tintina system, but in other places they are cut by the faults. These rocks are dominantly conglomerate, but include sandstone, mudstone, shale, breccia, lignite, and coal. Most of the conglomerate consists of well-rounded white and tan quartz and black chert clasts 2 to 13 cm in diameter in a quartzose matrix. Where bedding can be detected, dips as steep as 60^o occur, and most of the rocks dip at least 20^o. The conglomerate and sandstone were not principally derived from the local metamorphic terrane but probably from more distant sources north of the Tintina fault. Pollen and poorly preserved plant fragments and impressions indicate that the rocks may range in age from Late Cretaceous to Pliocene (Foster, 1976).

Several small patches of Tertiary sedimentary rocks (unit Ts, Fig. 2) occur in the southeastern part of the Eagle quadrangle. They are mostly conglomerate and sandstone, but near the town of Chicken also include coal seams, white tuff, and glassy tuff with abundant plant fragments (Foster, 1976).

Folded conglomerate, sandstone, argillite, tuff, tuffaceous argillite, and sandstone with some lignite and carbonaceous layers form a discontinuous belt about 30 km long in the north-central Tanacross quadrangle. Poorly preserved pollen indicates that deposition was in Late Cretaceous(?) time (Foster, 1967), but pollen in some of the deposits is as young as Neogene (Yaeko Igarashi, personal commun., 1985). In addition to Cretaceous and Tertiary pollen, these rocks also contain monosulcate pollen of Devonian age (Foster, 1967), suggesting that at the time of sediment deposition on the underlying metamorphic terrane, this terrane was located where pollen could be derived from unmetamorphosed Devonian rocks (Foster, 1967).

Other sedimentary rocks appear to have been deposited in basins associated with a Late Cretaceous volcanic complex near Mount Fairplay and Sixtymile Butte (Foster, 1967).

In the northeastern part of the Tanacross quadrangle, unconsolidated to poorly consolidated gravel and conglomerate occurs in a small area at about 1,266 m altitude, resting unconformably on metamorphic rocks. It is composed mostly of yellowish-white quartz pebbles and well-rounded, polished chert pebbles 1 to 15 cm in diameter. The chert pebbles are not locally derived. This deposit has been interpreted as most likely late Tertiary in age, but could be of early Pleistocene age (Foster, 1970).

Metamorphism

Regional metamorphism throughout the YTTN ranges from very low grade (about equivalent to burial metamorphism) to amphibolite facies of about the second sillimanite isograd. Changes in metamorphic grade across subterrane boundaries are commonly abrupt and can be attributed to juxtaposition of rocks of different metamorphic grade by faulting, particularly thrust faulting. Gradational changes in metamorphic grade are documented within subterranes Y_1 and Y_2. More than one period of regional metamorphism has not been recognized petrographically, except in the ecologitic rocks, where barroisite is rimmed by hornblende and omphacite is altered to cryptocrystalline material; but further work is needed, especially in consideration of possible evidence from radiometric age determinations of more than one period of regional metamorphism.

Pressures during metamorphism were probably mostly moderate, but the abundance of quartzitic compositions and paucity of pelitic compositions make determining the pressures (and temperatures) of metamorphism difficult. Kyanite is common in the southeastern part of subterrane Y_2 and northern part of subterrane Y_1 and occurs rarely in subterrane Y_4. In the Circle quadrangle (subterrane Y_2), mineral assemblages within pelitic rocks indicate progressive metamorphism along a P-T path similar to Barrovian metamorphism in Scotland (path A, Harte and Hudson, 1979). Medium-pressure metamorphism is also indicated by the amphibole composition in mafic schist (using the criteria summarized by Laird, 1982).

Andalusite + kyanite and andalusite + sillimanite occur in the southeastern part of subterrane Y_2, but it is not clear that the andalusite formed at the same time as kyanite and sillimanite. It may be related to nearby Tertiary plutons. In subterrane Y_1, all three Al_2SiO_5 polymorphs have been identified along the Salcha River (Dusel-Bacon and Foster, 1983), suggesting metamorphism at about 0.4 GPa (using the data of Holdaway, 1971). Sillimanite + andalusite and sillimanite + cordierite farther south (Dusel-Bacon and Foster, 1983, Fig. 2) may indicate low-pressure facies series regional metamorphism.

High-pressure metamorphism has been found in two areas, each fault-bounded. Glaucophane + epidote + chlorite + albite + white mica + sphene + carbonate ± garnet schist occurs in a fault slice in the northern part of the Eagle quadrangle. Eclogite with rare glaucophane has been found in the southwestern part of the Circle and southeastern part of the Livengood quadrangle. The estimated conditions of metamorphism in both areas of eclogitic rocks are similar, about $600^{\circ}C$ and 1.4 GPa (Laird, Foster, and Weber, 1984; Brown and Forbes, 1984).

The highest regional metamorphic grade documented is within the sillimanite gneiss dome of subterrane Y_1. Metamorphic grade reaches and probably surpasses the second sillimanite isograd, and partial melting may have occurred (Dusel-Bacon and Foster, 1983). Temperatures between 655° and $705^{\circ} \pm 30^{\circ}C$ are estimated by garnet-biotite geothermometry. Metamorphic grade decreases to the northeast (into and then below the staurolite stability field) and is garnet grade where in contact with the weakly metamorphosed rocks of subterrane Y_3. Within subterrane Y_2, metamorphic grade decreases gradually from sillimanite + muscovite and perhaps sillimanite + K-feldspar in the southeast to staurolite + kyanite, garnet, and then biotite grade farther north and west.

The lowest metamorphic grade is found in rocks of the southern part of the Circle quadrangle (subterrane Y_3) and the eastern part of the Eagle quadrangle (Seventymile terrane). The quartzite and quartzitic schist (unit cp) of the southern Circle quadrangle have been shown by vitrinite reflectance (Laird, Biggs, and Foster, 1984) to be in the range of normal sediment diagenesis. These rocks are believed to be in thrust contact with garnet- and staurolite-grade rocks. In the Eagle quadrangle, slightly metamorphosed sedimentary rocks occur with greenstone in thrust sheet remnants of the Seventymile terrane.

Contact metamorphism is primarily associated with Tertiary plutons, but in a few places may be associated with Cretaceous plutonism. Around many Tertiary plutons, cross biotite occurs in the regionally metamorphosed rocks. In the southern part of subterrane Y_2, contact metamorphism associated with Late Cretaceous and (or) early Tertiary plutonism has retrograded staurolite and kyanite porphyroblasts to white mica. In the central part of the Circle quadrangle (subterrane Y_2), hornfelsic growth of biotite and amphibole is associated with small felsic intrusions and has overprinted probable garnet-grade regional metamorphism. Contact metamorphism up to sillimanite grade has overprinted staurolite + kyanite-grade regional metamorphism. In the south-central part of the Eagle quadrangle, contact metamorphism is indicated by andalusite in schist near a small Cretaceous or Tertiary pluton.

Limited radiometric age data suggest that time(s) of major regional metamorphism(s) may have differed in the four subterranes of the YTTN. In subterrane Y_1, U-Pb zircon ages indicate that amphibolite-facies regional metamorphism was synchronous with or after intrusion of a belt of felsic Mississippian plutons (now augen gneiss) but before intrusion of Cretaceous plutons (Dusel-Bacon and Aleinikoff, 1985). Metamorphism predates Tertiary and probable Cretaceous plutonism in subterranes Y_3 and Y_2. ^{40}Ar-^{39}Ar incremental heating experiments indicate that major regional amphibolite-facies metamorphism in subterrane Y_4 peaked about 213 $\pm$ 2 Ma, but the extent of the area affected by this event is not known (Cushing, 1984). Conventional K-Ar data indicate a metamorphic event, which apparently was widespread in the YTTN, in the Early Cretaceous (125-110 Ma, Wilson and others, 1985). ^{40}Ar-^{39}Ar data indicate that in the eastern part of the Eagle quadrangle this Early Cretaceous regional event was of low metamorphic grade and relatively minor, although it could have been a major event elsewhere (Cushing, Foster, and Harrison, 1984). Sufficient data are not presently available to delineate and compare the metamorphic events of the four subterranes.

Mineral resources

Gold, primarily in placer deposits, has been the most important mineral resource in the YTTN. It has also been produced from lodes in the Fairbanks district and to a minor extent elsewhere. Small amounts of antimony and tungsten have been produced from lode deposits in the Fairbanks district during periods of high prices. Exploration has identified occurrences of copper-molybdenum porphyry and tungsten skarn. Widespread geochemical anomalies, and scattered occurrences and prospects, suggest that the region may contain granite-related uranium deposits, lode tin deposits (most likely greisen), platinum deposits of mafic igneous association, and sedimentary exhalative zinc-lead deposits.

Coal has been produced to a minor extent for local use, and coal resources in Late Cretaceous and (or) Tertiary sedimentary rocks are unmeasured but may be significant. Geothermal springs are known at three localities (Fig. 4) in the YTTN, and are exploited for recreation and local

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Figure 4 here.

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use at two locations.

Figure 4 shows the distribution of selected deposits, prospects, and occurrences by probable deposit type. Entries were selected to show (1) important deposits, (2) spatial patterns of occurrence, and (3) the different types of occurrence. Patterns in the distribution of particular types of deposits suggest that there is some relation of mineral occurrence to subterranes. Although mining has taken place in the region since the 1890's, it is only in recent years that there has been systematic exploration. New types of mineral deposits have been found, and as the recent discovery of a diamond in a placer deposit in the Circle district (Fairbanks Daily News-Miner, Dec. 11, 1984) points out, unexpected types of deposits undoubtedly await discovery.

Figure 4. Map showing selected mineral deposits, occurrences, and prospects in east-central Alaska. Numbers and letters refer to localities mentioned in text. Data primarily from Berg and Cobb (1967), Cobb (1973), Singer and others (1976), Eberlein and others (1977), MacKevett and Holloway (1977), Barker (1978), Gilbert and Bundtzen (1979), and Nokleberg, W. J., (unpublished data, 1984).

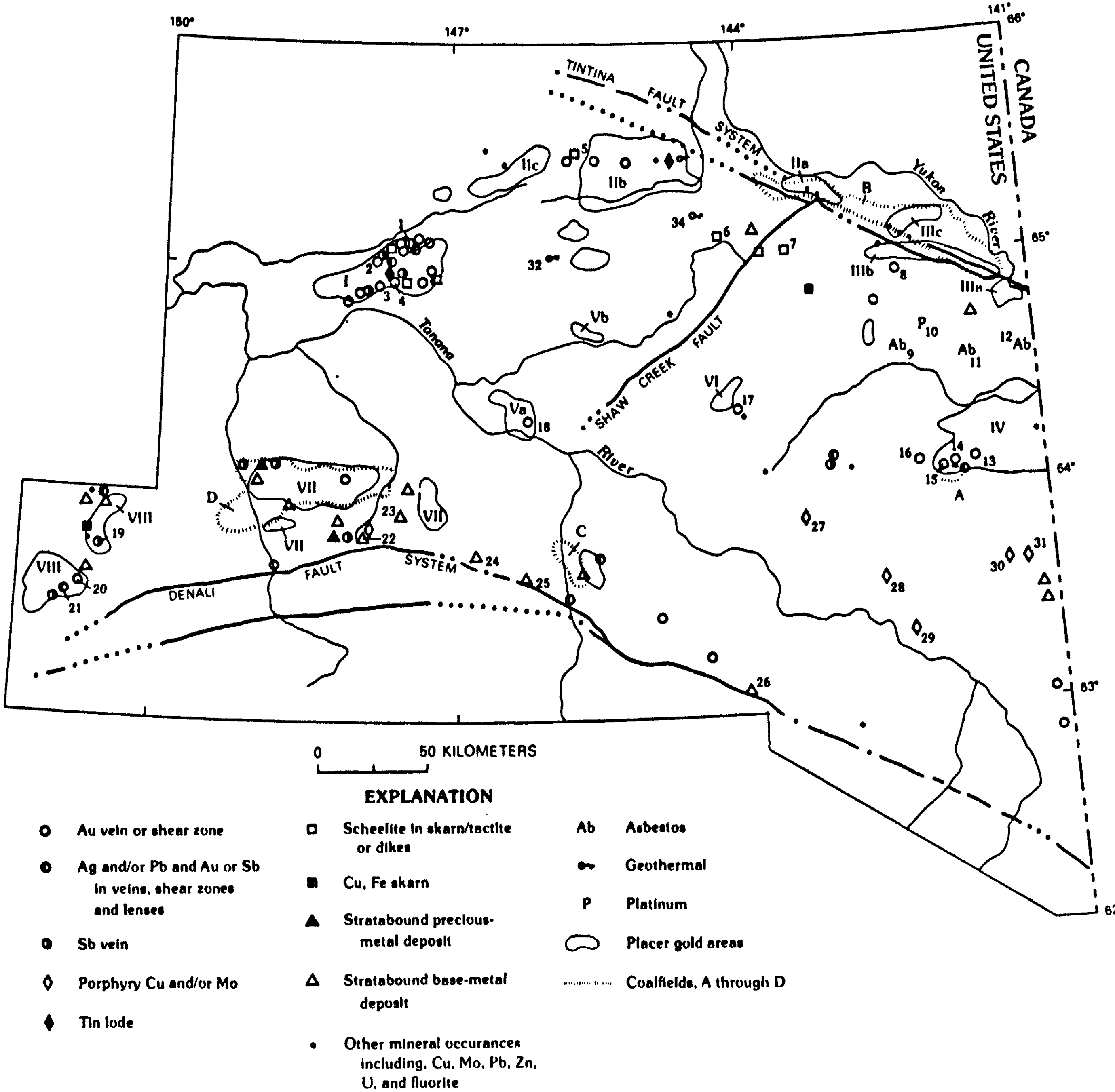

Figure 4. Map showing selected mineral deposits, occurrences, and prospects in east-central Alaska.

Gold placers and lode deposits

Gold has been, and continues to be, the most important mineral commodity in east-central Alaska. A large proportion of the gold has been produced from placers; lode production has been significant only in the Fairbanks district, and in most districts the amount of gold in known lode sources is small relative to that in placers. Gold deposits are found in all of the subterranes of the YTTN, but the greatest production and most extensive placers are in subterrane Y_2. Because geologic characteristics and ore controls vary among the districts, these features are discussed separately for the largest districts.

Fairbanks district

Gold was first discovered in streams of the Fairbanks district (No. I, Fig. 4) in 1902 by Felix Pedro. This district, the largest producer in east-central Alaska, has yielded about 7,750,000 oz of gold from placers and approximately 250,000 oz of gold from lodes (Bundtzen and others, 1984). Production from lodes has been concentrated in four areas: Cleary Hill (No. 1, Fig. 4), Treasure-Vault Creek (No. 2, Fig. 4), Ester Dome (No. 3, Fig. 4), and Gilmore Dome (No. 4, Fig. 4). In each of these areas, placers are closely associated with lodes.

The placers drain and the lodes occur in the quartzite and quartzitic schist unit of subterrane Y_2 (particularly the Cleary sequence of the Fairbanks Schist of Smith and Metz, this volume). In this area, the quartzite unit "qq" has undergone an early isoclinal folding and a later east-northeast trending broad open folding. Cretaceous felsic plutonic rocks (Blum, 1983) have been intruded into the Cleary sequence along the axes of broad anticlinal structures. Lodes, except on Ester Dome, occur primarily as east-west-trending auriferous veins in shears and crushed zones, but locally lodes lie parallel to foliation. Several types of lodes are recognized, including (1) simple pyrite-arsenopyrite-gold quartz veins, (2) gold-sulfosalt-sulfide-quartz veins, and (3) late stibnite veins, and (4) gold-scheelite veins. Smith and Metz (this volume) present geochemical characteristics of some of the vein types. Early workers (Hill, 1933) stressed the structural control of lodes and their relation to granitic intrusions; recent workers (Smith and Metz, this volume) have stressed the association of the lodes with the Cleary sequence and have suggested that, because of inherent geochemical enrichment, it is an important ore control.

Circle district

The Circle district, one of the oldest mining districts in interior Alaska, has produced at least 850,000 oz of gold (Bundtzen and others, 1984), all from placers. The deposits occur in three separate areas (Nos. IIa, IIb, and IIc, Fig. 4) and characteristics of the deposits and probable sources of gold vary with the area.

In the eastern area (most of which lies just outside of the YTTN) (No. IIa, Fig. 4) the principal productive streams (Woodchopper and Coal Creeks) have produced at least 20,000 oz of gold, mostly from stream, but including bench placers. These streams drain a diverse group of rocks including schist and gneiss of subterrane Y_2, phyllite, argillite, and quartzite of subterrane Y_3, Tertiary sedimentary rocks, Cretaceous granite, and unmetamorphosed rocks north of the YTTN. Mertie (1938) believed that the proximal source of the placers was gold in the Tertiary sedimentary rocks.

Most of the district's gold has been produced from stream placers in the eastern half of the central part of the district (No. IIb, Fig. 4). Streams drain the quartzite and quartzitic schist unit of subterrane Y_2 and Tertiary granite. No large lode sources of gold have been discovered, but samples of small limonite-stained quartz veins, arsenopyrite-bearing shear zones, zones of silicified breccia, and felsic dikes contain traces of gold. Mertie (1938) suggested that sources of gold in the streams were auriferous fracture zones, veins, breccias, and felsic dikes that developed and were emplaced above the Circle pluton, and recent work (Menzie and others, 1983) supports this hypothesis.

The western part of the district (No. IIc, Fig. 4) has been the least productive part. Only Nome Creek (which has been considered part of the Rampart district) had substantial production. Total district production, mining method, and length of time of operation suggest that Nome Creek probably produced between 10 and 20 thousand ounces of gold. The streams of this part of the district drain the quartzite and quartzitic schist unit of subterrane Y_2, a biotite granite pluton, and felsic hypabyssal rocks.

Eagle district

Gold was discovered in streams of the Eagle (Seventymile) district between 1895 and 1898. The district includes American Creek and its tributaries, Discovery Fork and Teddy's Fork (IIIa, Fig. 4), the Seventymile River and its tributaries, Flume, Alder, Barney, Broken Neck, Crooked and Fox Creeks (IIIb, Fig. 4); and Fourth of July Creek and Washington Creek and its tributaries, which are mostly north of the YTTN (IIIc, Fig. 4). The district has produced at least 30,000 oz of gold and byproduct silver, all from stream and bench placers. Gold alloyed with platinum was found at Fourth of July Creek and the mouth of Broken Neck Creek, and a few platinum nuggets were reportedly recovered from a tributary (Lucky Gulch) to the Seventymile River (Cobb, 1973). Flume, Alder, and American Creeks drain mafic and ultramafic rocks of the Seventymile terrane and quartzite, marble, phyllite and graphitic schist of subterrane Y_3 (Foster, 1976). Barney, Broken Neck, Fox, Crooked, Fourth of July, and Washington Creeks drain mostly sedimentary rocks of Cretaceous and (or) Tertiary age (Foster, 1976; Brabb and Churkin, 1969).

Mertie (1938) believed that the sources of the placer gold in streams that drain the Seventymile terrane and subterrane Y_3 were quartz veins and mineralized zones that were genetically related to granitic rocks, and work by Clark and Foster (1971) supports this view. Clark and Foster reported anomalous values of gold in hydrothermally altered rocks, including silica carbonate rocks, serpentinite and diorite, and quartz veins adjacent to a northwest-southeast-trending fault zone between Alder and Flume Creeks (No. 8, Fig. 4). They also detected arsenic in soil samples taken across a probable fault that extends northwest-southeast across Teddy's Fork. Sources of the gold in streams that drain the Cretaceous and (or) Tertiary sedimentary rocks may be paleoplacers (Mertie, 1938), but metamorphic rocks, which underlie the sedimentary rocks, and some dike rocks may also be sources.

Fortymile district

Gold was initially discovered on the Fortymile River in 1886 (Prindle, 1905) and on its tributaries between 1886 and 1895 (Mertie, 1938, IV, Fig. 4). Gold production of at least 417,000 oz (Cobb, 1973) has come mostly from stream and low bench placers; however, a few high bench placers have been worked occasionally. The streams of the Fortymile district drain a diverse group of rocks that include quartz-biotite gneiss and schist, quartzite, marble, and amphibolite of subterrane Y_4, quartzite, marble, phyllite, graphitic schist, and greenschist of subterrane Y_3, greenstone, serpentinite, and associated sedimentary rocks of the Seventymile terrane, granodiorite, quartz monzonite, quartz diorite, and diorite of the Taylor Mountain batholith, and various undifferentiated granitic rocks whose age is thought to be Mesozoic or Tertiary (Foster, 1976).

At least three types of small lode sources of gold are present in the Fortymile district. One type, exemplified by the Purdy (Foster and Clark, 1970), Ingle, and Tweeden lodes (Nos. 14, 15, 16, Fig. 4), is gold-bearing quartz + calcite veins in metasedimentary and metavolcanic rocks of the Seventymile terrane and in intermediate composition plutonic rocks that intruded the terrane. Gold has also been detected in altered diorite in the bedrock of Lost Chicken Creek (Foster and O'Leary, 1982) and in metatuff from an outcrop in the South Fork of the Fortymile River (No. 13, Fig. 4). The second type of lode gold occurrence is gold in quartz veins in subterrane Y_4; Mertie (1938) reported such an occurrence along Wade Creek and thought that the veins were related to a granite intrusion at depth. A third type of gold occurrence is gold in and adjacent to crushed zones and faults. Such zones are thought to be a source of gold in Dome Creek and Canyon Creek (Mertie, 1938). The recognition of major thrust faults within the Fortymile region (Foster and others, 1984) provides other possible sites of lode concentrations of gold.

Richardson district

The Richardson district includes scattered gold placers in the western part of the Big Delta quadrangle; the two main areas of gold production are (1) Tenderfoot Creek and adjacent streams, and (2) Caribou Creek and adjacent streams (areas Va and Vb, Fig. 4). Bundtzen and Reger (1977) estimated production at 95,000 oz of gold and 24,000 oz of silver; additional production from residual placers has taken place since 1979 (Eakins and others, 1983).

In the Tenderfoot Creek area, gold has been produced from stream and residual placers; Tenderfoot Creek is the main productive stream. The placers are buried beneath a deep cover of loess. The only known lode source of gold in this area is the Democrat lode (No. 18, Fig. 4), where gold occurs in altered and veined quartz porphyry. A sample of altered quartz porphyry yielded a K-Ar age of 89.1 $\pm$ 2.7 Ma (Wilson and others, 1985, after Bundtzen and Reger, 1977). Bundtzen and Reger regarded this as probably indicating the age of mineralization and noted that the distribution of the quartz porphyry and the gold placers in the Tenderfoot Creek area appears to be controlled by a northwest-southeast-trending lineament.

Gold production from the Caribou Creek (No. Vb, Fig. 4) area has come exclusively from stream placers, mostly along Caribou Creek. No lode sources of gold are known. However, the geochemistry of rock samples (Foster, O'Leary, McDanal, and Clark, 1978) indicates that iron-stained areas adjacent to dikes, plutons, and local shear zones commonly contain anomalous amounts of arsenic, antimony and zinc and in places contain silver, lead, or gold.

Tibbs Creek-Black Mountain area

The Tibbs Creek-Black Mountain area is one of the few areas that has produced lode gold, and this production probably exceeded that from the area's placers (VI, Fig. 4). The Blue Lead, Gray Lead, and Grizzly Bear (No. 17, Fig. 4), the principal mines, were operated mainly in the 1930's, although there was an attempt at further production in the late 1970's. About 1 kg of gold and 0.7 kg of silver were produced from quartz veins that cut metamorphic rocks and Cretaceous(?) granite. The veins are especially abundant and most productive near the contact of the metamorphic and granitic rocks. There are also minor occurrences of antimony and molybdenum nearby. Streams draining the area, such as Tibbs Creek, have had minor placer operations (Menzie and Foster, 1978).

Porphyry copper-molybdenum deposits

Porphyry copper-molybdenum occurrences in the Tanacross quadrangle and in the adjacent Yukon Territory constitute the interior porphyry belt of Hollister and others (1975). A number of occurrences, including Mosquito, Paternie, Asarco, Bluff, and Taurus (Nos. 27, 28, 29, 30, and 31, Fig. 4) are known in the Tanacross quadrangle (Singer and others, 1976) and ten occurrences are known in the Yukon Territory (Sinclair, 1978). The porphyry occurrences in Alaska are confined to subterrane Y_1 and are thought to be associated with Cretaceous and early Tertiary porphyritic, felsic subvolcanic stocks. These stocks were intruded into coeval volcanic rocks, Cretaceous plutonic rocks, and schist and gneiss. The porphyry deposits formed within and adjacent to subvolcanic stocks and breccia pipes. Although early Tertiary volcanic rocks and associated intrusive rocks occur in the eastern part of the Big Delta and western part of the Eagle quadrangle, presently known porphyry occurrences are confined to the Tanacross quadrangle.

The deposits of the interior belt display many characteristics typical of porphyry deposits elsewhere: (1) they are associated with felsic, subvolcanic intrusive rocks; (2) they are surrounded by large areas of hydrothermally altered rocks; (3) common hypogene minerals in the deposits are pyrite, chalcopyrite, molybdenite, and in some cases magnetite; and (4) supergene enrichment is an important control on the grade of mineralization. Deposits of the interior belt differ from other porphyry deposits in their reported lower grades and smaller tonnages (Singer and others, 1976). The inferred resources at Taurus are 50 million tons of 0.3 percent copper and 0.07 percent molybdenum (Chipp, this volume). Taurus reportedly contains a considerable amount of supergene-enriched material. Hypogene ore in deposits of the interior belt is reported to be lower in grade than supergene ore by a factor of 1.5 to 2 (Godwin, 1976; Sawyer and Dickinson, 1976).

Tungsten

Tungsten, mainly as scheelite, occurs within the quartzite and quartzitic schist and the pelitic schist units (qq and ps) of subterrane Y_2; small amounts of tungsten have been produced from deposits hosted by the quartzite and quartzitic schist unit adjacent to Cretaceous granite or granodiorite intrusions northeast of Fairbanks. Though production has been limited to the Fairbanks district, exploration has identified a number of significant prospects elsewhere in subterrane Y_2. Near one prospect, Table Mountain (No. 5, Fig. 4), scheelite is present in sediments of streams that drain the quartzite and quartzitic schist unit and a Tertiary(?) granite intrusion. There, tungsten is present in thin marbles of the quartzite and quartzitic schist unit, probably above a cupola of the intrusion. Scheelite is widely distributed in sediments of streams that drain the pelitic schist unit (Menzie and others, 1983), and in recent years a number of prospects have been identified within this unit adjacent to Cretaceous(?) and Tertiary granitic intrusions, in the southeastern part of the Circle (No. 6, Fig. 4), southwestern part of the Charlie River (No. 7, Fig. 4), and the northwestern part of the Eagle quadrangle (Foley and Barker, 1981).

Published studies of the ore controls of deposits are limited to the Fairbanks district. Byers (1957), who mapped many of the deposits and favored a contact-metasomatic origin for them, stated that the distribution of tungsten mineralization was probably controlled by the occurrence of limestone within the contact zone of porphyritic granite, the presence of local structural irregularities, such as drag folds that localized ore deposition, and the development of tungsten-bearing quartz pegmatites that filled fractures above the porphyritic granite. Metz and Robinson (1980), following the ideas of Maucher (1976), suggested, on the basis of the presence of amphibolite in the footwall of some of the Fairbanks deposits, that the deposits may be remobilized syngenetic deposits.

Petrologic and geochemical studies of the plutons related to the deposits of the Fairbanks district (Blum, 1983) suggest that they formed by remelting of Precambrian crustal material, but did not identify a specific source for the tungsten.

Tin

Cassiterite is widely distributed as an accessory mineral in stream sediments and placer concentrates of the northwest part of the YTTN; however, only a few lode tin occurrences have been identified and little has been published on their characteristics. Nevertheless, cassiterite in stream sediments and the presence of both Cretaceous and Tertiary granites, which are petrologically and geochemically similar to granites (Fig. 3) from tin-bearing regions, suggest that parts of the YTTN that contain such granites may also contain unidentified lode and (or) associated placer deposits (Menzie and others, 1983). Lode deposits, if present, are likely to be large, low-grade greisen deposits, though skarn and vein deposits may also occur. A small amount of tin has been recovered from several creeks in the Circle District as a byproduct of gold mining (P. Jeffrey Burton, written commun., 1983).

Uranium

Anomalous levels of uranium have been detected in springs and stream sediments (Barker and Clautice, 1977; Menzie and others, 1983) in the northwestern part of the YTTN. These anomalies are spatially associated with biotite granites of early Tertiary age (Fig. 3).

Platinum

Anomalous amounts of platinum and palladium were detected in samples of an ultramafic intrusion at one locality (No. 10, Fig. 4) in the Eagle quadrangle (Foster, 1975), and platinum was detected, but in smaller amounts, in other similar mafic to ultramafic intrusive rocks in that quadrangle (Foster and Keith, 1974). Such bodies could serve as sources for platinum in placer deposits.

Stratabound occurrences

Although no stratabound deposits are known in the YTTN, a number of features suggest that such deposits may be present. First, Paleozoic metasedimentary and metavolcanic rocks, which are similar to those in subterranes Y_2, Y_3, and Y_4, host such deposits in other parts of the northern Cordillera. Second, geochemical anomalies in stream-sediment samples occur in several areas. Third, recent exploration for stratabound deposits has located prospects in several subterranes of the YTTN.

In subterrane Y_4, pieces of galena have been reported as float and in streams; prospects for stratabound deposits have been located in the eastern subterranes Y_3 and Y_4. In the western part of the YTTN, the presence of anomalous amounts of zinc, silver, and barium in samples from streams draining the calc phyllite-black quartzite unit of subterrane Y_3 led Menzie and Foster (1978) to suggest that this unit may host stratabound deposits.

Coal

Coal deposits occur in Late Cretaceous and (or) early Tertiary nonmarine sedimentary rock in two areas of the YTTN. One area is near the village of Chicken, in the south-central part of the Eagle quadrangle (A, Fig. 4), and the other is along the northeastern margin of the YTTN and probably extends north of the YTTN (B, Fig. 4). The characteristics of these coal fields are summarized in Table 2; their resources have not been estimated.

Geothermal resources

Three hot spring areas occur in the YTTN, all in the Circle quadrangle (Waring, 1917). The hot springs are hydrothermal convective systems heated by deep circulation along faults associated with early Tertiary granitic plutons (Miller and others, 1975). The Chena Hot Springs (No. 32, Fig. 4) have a maximum measured surface temperature of 67°C and a discharge of approximately 800 L/min; maximum temperature at Circle Hot Springs (No. 33, Fig. 4) is 57°C and discharge is approximately 500 L/min. Reservoir temperatures are calculated to be 100°C and 128°C respectively; thus the springs are classified as intermediate-temperature hydrothermal convection systems (Brook and others, 1979). Springs in the third area (No. 34, Fig. 4) have a maximum measured surface temperature of 61°C (Keith, Presser, and Foster, 1981). Chena and Circle Hot Springs are used primarily for recreational purposes, although minor other uses of the hot water have been made. The third hot-spring area is not developed because of its remote location.

Table 2.--Coal fields of YTTN[1]

Field	Size	Structure	Seam characteristics	Rank	Sulfur content	Development status
Eagle	130 by 3 to 16 km (80 by 2 to 10 miles)	Open folds	Near Washington Creek five seams are at least 1.3 m thick	Subbituminous	Low	None
Chicken		Vertical beds	One seam is at least 6.8 m thick	Unknown	Unknown	Minor past production for local use

[1]Reference: Barnes (1967)

Application of isotopic-dating techniques

Determining definitive ages of the rocks and their time(s) of metamorphism, intrusion, and deformation has been very difficult because of a lack of fossils, poor exposures, and the complexity of the metamorphic and deformational history in the YTTN. Thus, isotopic techniques for dating rocks have become the principal source of data on ages of rocks and times of thermal events.

The first isotopic data for rock samples from the YTTN came from Pb-alpha studies undertaken in the late 1950's (Matzko and others, 1958; Jaffe and others, 1959; Gottfried and others, 1959). In 1960, Stern (Holmes and Foster, 1968) obtained four Pb-alpha ages on plutonic rocks in the northern part of the Mount Hayes quadrangle. K-Ar and Rb-Sr dating methods were applied soon after (Wasserburg and others, 1963). During the next 15 years, many K-Ar ages were determined on both igneous and metamorphic rocks, with the majority on granitic rocks. Ages determined by G.J. Wasserburg, M.A. Lanphere, D.L. Turner, J.G. Smith, F.H. Wilson, Nora Shew, and others were compiled by Dadisman (1980). Little Rb-Sr work was done, partly because of the difficulty of obtaining unaltered material, but recently Blum (1983) reported Rb-Sr data for granitic rocks near Fairbanks. The K-Ar ages are most useful on unmetamorphosed igneous rocks; ages obtained on metamorphic rocks are difficult to interpret. To better interpret the metamorphic rocks, McCulloch and Wasserburg (1978) applied a Nb-Sm method to Alaska Range rocks and Aleinikoff applied U-Pb methods (Aleinikoff and others, 1981) using zircons separated from an augen gneiss and other metamorphic rocks of the YTTN. Rb-Sr work was done to supplement the U-Pb work. Most recently, ^{40}Ar-^{39}Ar incremental heating methods have been used to help unravel the metamorphic history in the eastern part of the YTTN (Cushing, Foster, and Harrison, 1984). Integrated studies of the various types of data for the YT are resulting in new interpretations of the geologic history and making it possible to constrain the ages of many events more closely.

The following conclusions have resulted, largely from K-Ar work based on about 142 age determinations (Wilson and others, 1985):

(1) Three major periods of felsic plutonism occurred after major regional metamorphism, and volcanic rocks were associated with at least one and possibly two of these events. The oldest period of plutonism, during Late Triassic and Early Jurassic time, resulted in the intrusion of a granitic batholith, Taylor Mountain, and other plutonic rocks (Mount Veta, Fig. 3B). Plutonic rocks of this age are presently known in eastern Alaska only in the southern part of the Eagle and northern part of the Tanacross quadrangle.

The second period of plutonism occurred from about 105 to 85 Ma and throughout most of the YT. The largest number of ages determined are between 95 and 90 Ma (Wilson and others, 1985). The largest and most numerous plutons of this age are in the eastern part of the YTTN, largely east of the Shaw Creek fault. The plutons are mostly granitic, ranging from quartz diorite to quartz monzonite. The extensive deposits of welded tuff in the Tanacross quadrangle are largely caldera-fill associated with this igneous event based on K-Ar ages of 90 $\pm$ 2.8 Ma (hornblende) and 93.6 $\pm$ 2.1 Ma (sanidine) from two of the largest areas of welded tuff (Bacon and others, 1985).

The third period of felsic intrusions is indicated by 46 age determinations that range from 70 to 50 Ma (Wilson and others, 1985). These intrusions are generally small and commonly have contact aureoles.

Most are located in the northwestern part of the YTTN northwest of the Shaw Creek fault, but one also occurs in the central part of the Tanacross quadrangle (Mount Fairplay, Fig. 3). Some Tertiary volcanic rocks also were erupted as indicated by a K-Ar date of 57.8 ± 2 Ma in the eastern part of the Tanacross and one of 61.6 ± 2 Ma in the eastern Big Delta quadrangles (Foster and others, 1976, 1979).
(2) Although clear-cut conclusions are more difficult to draw from K-Ar ages of the metamorphic rocks, some important results have been obtained. Wilson and others (1985) studied 59 K-Ar age determinations on metamorphic rocks (43 from the YTTN) and identified two distinct clusters. Eighteen ages (7 from the YTTN) fall between 190 and 160 Ma; 24 ages (all from the YTTN) fall between 125 and 105 Ma. Although there is considerable scatter in the data, the Early Cretaceous cluster includes a number of concordant mineral pairs. Wilson and others concluded that this cluster probably reflects a metamorphic or thermal event which is distinct from the Cretaceous intrusive event and that the metamorphic ages generally are not reset by this later plutonism (F.H. Wilson, personal commun., 1984).
(3) Although the number of determinations is limited and only a few are concordant mineral pairs, the K-Ar data give a fairly strong indication of a Jurassic metamorphic or thermal event (Wilson and others, 1985). As discussed later, ^{40}Ar-^{39}Ar data clearly show such an event in the Eagle quadrangle, but the areal extent and local intensities of this event cannot be determined from the present data.

The U-Pb data from zircons indicate the following:

1) Plutonism occurred in subterrane Y_1 in the Mount Hayes quadrangle (Lake George terrane) at about 360 Ma (Aleinikoff and Nokleberg, 1985a).
2) Extensive granitic intrusions occurred in subterrane Y_1 about 341 ± 3 Ma (lower intercept age) and are now represented by widely distributed augen gneisses (Dusel-Bacon and Aleinikoff, 1985).
3) The augen gneiss contains an inherited component of Early Proterozoic (2.1 to 2.3 Ga) zircons (Dusel-Bacon and Aleinikoff, 1985).
4) U-Pb ages of zircons from metamorphic rocks believed to have volcanic protoliths suggest that they were erupted 360-380 m.y. ago (Dusel-Bacon and Aleinikoff, 1985).
5) Time of metamorphism of the augen gneiss is not conclusively known.
6) Age of the metamorphic rocks interpreted as wall rocks to the augen gneiss is not known, but they clearly contain the Early Proterozoic inherited component.

The Rb-Sr whole-rock isochron obtained from widely separated outcrops of augen gneiss has an age of 333± 26 Ma, confirming the Mississippian intrusive age for the protolith obtained from the U-Pb determinations on zircon. Sm-Nd data also support the presence of an old crustal component in the augen gneiss (Aleinikoff and others, 1986).

Recent ^{40}Ar-^{39}Ar experiments on rock samples from subterrane Y_4 in the eastern part of the Eagle quadrangle have established:

1) A cooling history for the granitic rocks of Taylor Mountain by analysis of three different minerals; hornblende, biotite, and K-feldspar, and confirmed its age. Intruded about 209 ± 3 Ma, it cooled from 500 to 175°C through a period of about 32 m.y. (Cushing, Foster, Harrison, and Laird, 1984).

2) A major (amphibolite facies) metamorphic event reached a peak about 213 ± 2 Ma, followed by igneous intrusions and cooling over a period of some 36 ± Ma. Amphibolite adjacent to the Taylor Mountain batholith has a well-established Triassic integrated plateau age (213 ± 2 Ma) (Cushing, Foster, Harrison, and Laird, 1984).
3) Thrusting occurred during cooling from the peak of metamorphism as indicated by a greenschist-facies greenstone with a metamorphic age of 201 ± 2 Ma that is thrust upon the amphibolite adjacent to the Taylor Mountain batholith. Other evidence of thrusting at about this time is from biotite formed in a thrust zone. The biotite has an integrated plateau age of 187 ± 2 Ma. The time of thrusting is also constrained by the age of a dike (integrated plateau age of 186 ± 2 Ma on muscovite) which cuts deformed metamorphic rocks in the thrust zone and is not deformed or significantly metamorphosed.
4) The Cretaceous metamorphic or thermal event recognized by the K-Ar work definitely affected subterrane Y_4, as shown by minor plateaus.

In summary, radiometric age data now in hand indicate plutonism in the YTTN in Mississippian, Triassic, Cretaceous, and Tertiary time, with volcanism in the Mississippian, Cretaceous, and Tertiary. Major parts of the YTTN may have an Early Proterozoic basement or received material from eroding Early Proterozoic sources. Metamorphism took place during Late Triassic and Early Jurassic time in the eastern part of YTTN (Y_4), but its extent is not known. A Cretaceous thermal event, of low grade at least in subterrane Y_4, was widespread in the YTTN. Deformation that included major thrusting occurred in subterrane Y_4 in Early Jurassic time.

Yukon-Tanana terrane south of the Tanana River

Although exposure in the YT south of the Tanana River is very much better than in the YTTN, local cover by Tertiary and glacial deposits, restricted accessibility in the rugged Alaska Range, and a very complex structural history make it difficult to relate this area to the YTTN and other adjacent areas. Nokleberg and Aleinikoff (1985) divided the Mount Hayes quadrangle into several terranes, some of which, in the terminology of this paper, may be considered subterranes or parts of large terranes with unique lithologic and(or) structural characteristics. Rocks of the Tanacross, Nabesna, Healy and Mount McKinley quadrangles have not been grouped into terranes or subterranes by most previous workers. However, some of the groups of rocks can be recognized as parts of the terranes or subterranes described for the Mount Hayes quadrangle, and Jones and others (1984) have included them in the Yukon-Tanana, Pingston, and Windy terranes (Plate _). The discussion of the area south of the Tanana River begins with the Mount Hayes quadrangle terranes or subterranes, continues with a description of the rocks of the Tanacross and Nabesna quadrangles, and finally ends with the rocks in the Healy and Mount McKinley quadrangles.

Metamorphic rocks
Mount Hayes quadrangle

Rocks in the Mount Hayes quadrangle south of the Tanana River and north of the Denali fault, most of which were included in the Yukon-Tanana terrane by Jones and others (1984), have been divided into the Macomb, Jarvis Creek Glacier, Hayes Glacier, and Windy terranes (Nokleberg and others, 1983).

Macomb terrane

The Macomb terrane consists primarily of medium-grained mylonitic pelitic schist, calc-schist, and quartz-feldspar-biotite schist, intruded by quartz monzonite, granodiorite, quartz diorite, and diorite (unit pc, Fig. 2). The intrusive rocks have been almost completely recrystallized to mylonitic schist (Nokleberg and others, 1983). U-Pb analyses of zircons from the metamorphosed plutonic rocks indicate a Devonian (about 370 Ma) intrusion (Nokleberg and Aleinikoff, 1985; Aleinikoff and Nokleberg, 1985b). All of the rocks are polydeformed and metamorphosed under conditions of the lower amphibolite facies, but in places they have been retrograded to lower greenschist facies. Because no other age data are available, the age of protoliths of the intruded metasedimentary rocks cannot be determined more precisely than either Devonian or pre-Devonian (pre-intrusion).

Jarvis Creek Glacier terrane

The Jarvis Creek Glacier terrane consists of fine-grained polydeformed schist (unit pq, Fig. 2) derived from sedimentary and volcanic rocks. Metasedimentary rocks are pelitic schist, quartzite, calc-schist, quartz-feldspar schist, and marble. Metavolcanic rocks are meta-andesite and meta-quartz-keratophyre with some metadacite, metabasalt, and rare metarhyolite. All are cataclastically deformed, recrystallized, and metamorphosed under conditions of the greenschist facies. U-Pb analyses of zircons from metavolcanic rocks indicate a Devonian extrusive age of about 370 Ma (Nokleberg and Aleinikoff, 1985). The sedimentary protoliths are also considered to be of Devonian age, because they are interlayered with the metavolcanic schist (Nokleberg and Aleinikoff, 1985). Nokleberg and Lange (1985) suggested that the metavolcanic rock-rich part of Jarvis Creek Glacier terrane may be correlative with the Totatlanika Schist (unit to, Fig. 2) to the west in the Healy quadrangle because both groups of rocks include abundant intermediate volcanic protoliths.

Hayes Glacier terrane

The Hayes Glacier terrane consists of two groups of phyllites: one is dominantly metasedimentary rocks with little to no metavolcanic rocks and the other is mainly metavolcanic rocks with moderate to abundant amounts of metasedimentary rocks (unit pv, Fig. 2). Metasedimentary rock types are pelitic, quartzose, and quartz-feldspar phyllites, and minor calc-phyllite and marble. Metavolcanic rocks include meta-andesite, meta-quartz-keratophyre, and sparse metadacite and metabasalt. The rocks are cataclastically deformed and have been metamorphosed under conditions of the lower and middle greenschist facies. An early schistosity is folded into rarely seen small-scale minor isoclinal folds with axial planes parallel to schistosity. The dominant schistosity, which is post-folding, dips moderately to steeply southward. Metamorphosed and deformed gabbro, diabase, and metagabbro dikes also occur and, on the basis of structural relationships, are believed to be Late Cretaceous in age. Lamprophyre dikes and a small alkali-gabbro pluton were emplaced in early Tertiary(?) time.

Windy terrane

The Windy terrane consists predominantly of argillite, limestone, marl, quartz-pebble siltstone, quartz sandstone, metagraywacke, metaconglomerate, andesite, and dacite (unit ar, Fig. 2). Locally abundant megafossils and sparse conodonts indicate a Silurian(?) and Devonian age for these rocks. The rocks are generally slightly deformed with poorly developed schistosity. Locally, deformation is intense and phyllonite and protomylonite have formed in narrow zones. Along its southern margin adjacent to the Denali fault, shearing has been intense and abundant fault gouge has developed. Locally, low-grade metamorphic effects are evident (W.J. Nokleberg, written commun., 1985).

Origin of terranes

The Lake George, Macomb, Jarvis Creek Glacier, and Hayes Glacier terranes, on the basis of field relations and stratigraphic and structural data, are considered to be, from north to south, successively shallower levels of a single, now highly metamorphosed and deformed, Devonian submarine igneous arc (Nokleberg and Aleinikoff, 1985). The arc is interpreted either as an island arc containing a slice of continental crust that contaminated the Devonian magmas, or as a submerged continental-margin arc, with continental detritus being shed into a companion trench and subduction-zone system (Nokleberg and Aleinikoff, 1985). The Windy terrane is also interpreted as of island-arc origin and is considered to be a surface-level slice of a Devonian island arc (W.J. Nokleberg, written commun., 1985).

Tanacross and Nabesna quadrangles

Amphibolite-facies gneiss and schist including augen gneiss (unit ag, Fig. 2) compose the northwestern part of the Alaska Range just south of the Tanana River in the Tanacross quadrangle. The rocks are generally quartzose and commonly garnetiferous; calcareous rocks are rare. The lithology and metamorphic grade of the rocks, including the augen gneiss, are similar to those north of the Tanana River in subterrane Y_1. Quartz-mica schists in the foothills south of the Tanana River in the south-central part of the Tanacross quadrangle (unit pc?, Fig. 2) have similarities in lithology and metamorphic grade to rocks in the Macomb terrane of the Mount Hayes quadrangle.

The rocks in the Alaska Range in the Tanacross quadrangle decrease in metamorphic grade to the south (Foster, 1970), and 10 to 20 km south of the Tanana River they are mostly greenschist-facies quartz-white-mica schist $\pm$ chlorite, quartz-graphite schist, and quartzite (unit pq?, Fig. 2). All or part of these greenschist-facies rocks may be coextensive with the Jarvis Creek Glacier terrane of the Mount Hayes quadrangle.

In the southeastern corner of the Tanacross quadrangle, low-grade metamorphic rocks are largely light-pink, light-green, gray, and tan phyllite with discontinuous layers of marble and quartzite (unit pv?, Fig. 2). Greenstone also occurs. Because these rocks are adjacent to those of the Hayes Glacier terrane and have some similar lithologies, they are tentatively correlated. This group of rocks also appears to be coextensive with similar rocks in the Nabesna quadrangle that have been considered of Devonian age.

In the Tanacross quadrangle, the greenschist-facies schist and phyllite are intruded by dikes, sills, and lenses of altered diorite (not shown on map) which appear to be slightly metamorphosed (Foster, 1970).

Although considerable decrease in grade of metamorphism from amphibolite to greenschist facies is recognized from north to south in the Alaska Range within the Tanacross quadrangle, little difference has been noted in the deformational characteristics. Foliation most commonly strikes northwest-southeast and dips predominantly southwest. Large-amplitude (several hundred meters) folds of layering and (or) schistosity are visible in a few places, but small folds (amplitudes of 1 cm to more than a meter) are common. Sandra H.B. Clark (written commun., 1972) recognized three generations of folds. The earliest set of small, tight to isoclinal folds with well-developed axial plane schistosity, fold the compositional layering. These folds are rarely preserved. A second set of folds deforms schistosity, and they are tight to isoclinal with axial-plane schistosity. The third-generation folds are kink folds and deform both previous generations of folds. Although major faults were not mapped between units in the Tanacross quadrangle, the possible existence of such faults was recognized (Foster, 1970).

In the northern part of the Nabesna quadrangle, a group of greenschist-facies rocks (unit pq?, Fig. 2) consists mostly of quartz-muscovite schist, quartz-muscovite-chlorite schist, graphitic schist, and minor calcareous mica schist. These schists may be coextensive with the Jarvis Creek Glacier terrane. To the south, several groups of slightly metamorphosed sedimentary and mafic volcanic rocks have been mapped (unit Dm, Fig. 2). In the northwestern and north-central part of the quadrangle, this unit consists predominantly of dark-gray phyllite, quartzite, porcellanite, quartz-mica schist, and marble. These rocks have been extensively intruded by mafic diorite and gabbro, which were emplaced after the main period of folding and metamorphism (Richter, 1976). Much of this area is included in the Pingston terrane of Jones and others (1984). Farther south, partly along the north side of the Denali fault, the rocks are chiefly phyllite and metaconglomerate with subordinate quartz-mica schist and quartzite. Scattered along strike are pinnacled outcrops of recrystallized limestone, a few of which contain rugose and tabulate corals of Middle Devonian age. In the east-central part of the quadrangle, probably bounded by faults, are weakly metamorphosed volcanic and volcaniclastic rocks (unit mv, Fig. 2). The western part of this unit consists mostly of andesite and basalt flows; the eastern part is dominantly volcanic sandstone, cherty argillite, quartzite, and tuff. Some of this area is included in the Windy and McKinley(?) terranes of Jones and others (1984). Protoliths of the metamorphic rocks of the Nabesna quadrangle are probably of Paleozoic age; the few fossils that have been found indicate that they may be largely Devonian.

Healy and Mount McKinley quadrangles

Workers in the Healy and Mount McKinley quadrangles have recognized three major groups of metamorphic rocks; none are continuous in actual outcrop distribution with the metamorphic rocks in the Mount Hayes quadrangle. The southernmost group, which is bounded on the south by the Hines Creek strand of the Denali fault system, has been called the Birch Creek Schist of former usage (unit bc, Fig. 2) (Wahrhaftig, 1968; Gilbert and Bundtzen, 1979; and Bundtzen, 1981). North of this unit, a second group of less crystallized rocks composes the Keevy Peak Formation (unit kp, Fig. 2); a third group of lithologically diverse rocks has been included in the Totalanika Schist (unit to, Fig. 2) (Wahrhaftig, 1968; and Gilbert and Bundtzen, 1979). Differences in degree of metamorphism, lithology, and structural history suggest that these units are fault bounded (Wahrhaftig, 1968).

The southernmost unit (bc, Fig. 2) consists predominantly of quartz-white mica schist, micaceous quartzite, and lesser amounts of graphitic schist, porphyroclastic quartz-feldspar schist, chlorite schist, greenstone, calcareous schist, and marble (Gilbert and Bundtzen, 1979). It was completely recrystallized during two or more periods of metamorphism, and the present metamorphic grade is of greenschist facies in the central Healy quadrangle but is higher grade to the west and north in the McKinley quadrangle (Bundtzen, 1981; Wahrhaftig, 1968). In the McKinley quadrangle, Bundtzen (1981) recognized an upper greenschist-to-amphibolite-facies prograde event followed, after an unknown interval, by retrogressive metamorphism under conditions of the lower greenschist facies. Bundtzen suggested that differences in metamorphic grade of this unit from southeast to northwest in the McKinley quadrangle may indicate differing structural levels, with deepest levels to the northwest. The unit is complexly folded and faulted. Its age is unknown, but may be at least partly Paleozoic if rocks that contain echinodermal fragments belong to this unit (Gilbert and Bundtzen, 1979). In the Kantishna region of the McKinley quadrangle, Bundtzen tentatively assigned a Precambrian age to this unit, but recognized that parts of it may be somewhat younger.

The Keevy Peak Formation consists of black or dark-gray carbonaceous phyllite, black quartzite, stretched conglomerate, gray, green, and purple slate, and white mica-quartz schist. Textures are commonly mylonitic and some schists contain large scattered bluish-gray quartz grains, probably porphyroclasts. These rocks are less intensely deformed and recrystallized than those in the southernmost unit "bc", but have been isoclinally folded. Because the Keevy Peak Formation is only slightly metamorphosed, original sedimentary features such as graded bedding, and cross-bedding are preserved locally. Wahrhaftig (1968) indicated that the Keevy Peak Formation lies unconformably on unit "bc". He also stated "Several features suggest that the schist formations of the central Alaska Range have been cut by numerous unmapped thrusts and that many of the mapped lithologic contacts between schists of different units are, in fact, tectonic contacts whose original nature has been obscured by subsequent metamorphism." That probably is the nature of this contact; in fact, Bundtzen (1981) believed that in the Kantishna Hills it is a tectonic contact. Scarce fossils from the upper part of the Keevy Peak Formation are Middle and Late Devonian in age (Gilbert and Redman, 1977). Gilbert and Bundtzen (1979) suggested that the formation may range in age from Ordovician to Devonian.

The most northerly and apparently youngest metamorphosed formation in this area is the Totatlanika Schist, first defined by Capps (1912) and redefined and divided into five members by Wahrhaftig (1968). The characteristic lithology is quartz-orthoclase-sericite schist (and gneiss) (unit to, Fig. 2) that interfingers complexly with a large variety of lithologies in which felsic and mafic metavolcanic rocks predominate. Gilbert and Bundtzen (1979) described three main lithologies: metafelsite, metabasite, and metasedimentary rocks. The metafelsite consists primarily of porphyritic metarhyolite and felsic metatuff, now primarily quartz orthoclase, white mica schist and gneiss. Wahrhaftig (1965) described large augen of potassium feldspar 2.5 to 25 mm in diameter and smaller augen of quartz. Gilbert and Bundtzen (1979) considered these as relict phenocrysts; many of these rocks are probably mylonites (terminology of Wise and others, 1984). The metabasite is primarily metabasalt, probably calc-alkaline, but there are also minor amounts of intermediate composition metavolcanic rocks. Metasedimentary rocks predominate in the upper part of the Totatlanika Schist;

their protoliths included sandstone, siltstone, and tuff. Locally, the rocks are calcareous, and carbonate layers occur. Relict sedimentary textures are recognized in places. A black phyllite, indistinguishable from black phyllite in the Keevy Peak Formation, is interlayered with metavolcanic rocks throughout the Totatlanika Schist.

The Totatlanika Schist has undergone low-grade regional metamorphism, in most places probably no higher than low greenschist facies. A large component of the regional event has been dynamic rather than thermal, as evidenced by extensive development of mylonite (Bundtzen, 1981). Mica crenulations, cleavage, and isoclinal folding are common in the less competent layers of the unit.

A few fossils found in the Totatlanika Schist suggest that it probably ranges from Late Devonian to Mississippian in age. Gilbert and Bundtzen (1979) proposed that it may consist largely of volcanic-arc deposits formed above a subduction zone along the western margin of North America.

Mesozoic igneous rocks

In the Tanacross, Nabesna, and Mount Hayes quadrangles, granitic rocks, probably mostly of Cretaceous age, intrude the metamorphic rocks. They range in composition from quartz diorite to quartz monzonite and are similar in composition and age to granitic rocks that cover large areas of the YT north of the Tanana River. In the Mount Hayes quadrangle they occur in the Macomb, Jarvis Creek Glacier, and Hayes Glacier terranes. Nokleberg and others (1986) considered them to be slightly to moderately metamorphosed and suggested that they were intruded during the waning stage of an Early Cretaceous regional metamorphism.

Only a few small granitic bodies are found in the Tanacross quadrangle south of the Tanana River, but in the Nabesna quadrangle three fairly large plutons occur. They are dominantly quartz monzonite, although they vary widely in composition. Most are foliated and have no phenocrysts (Richter, 1976). The Gardiner Creek pluton (Richter, 1976) in the northeastern corner of the Nabesna quadrangle is probably coextensive with the granitic plutons of the YTTN in the southeastern part of the Tanacross quadrangle.

The Hayes Glacier terrane is intruded also by mafic dikes, commonly much deformed and metamorphosed. They are considered of mid- or Late Cretaceous age (W.J. Nokleberg, written commun., 1985). In the the central part of Jarvis Creek Glacier terrane, an intrusive suite of monzonite, alkali gabbro, lamprophyre, and quartz diorite, of early Tertiary(?) age, is partly surrounded by a ring dike of quartz monzonite. Locally extensive lamprophyre dikes and alkali gabbro are probably temporally associated with this suite. Foley (1982) described two dike swarms of unmetamorphosed potassic alkali-igneous rocks, one near the West Fork of the Robertson River and the other to the east near the Tok River, and suggested that they are the youngest igneous rocks of the area (Late Cretaceous). They include biotite-lamprophyre dikes and sills, associated breccia dikes, and a stock of alkali gabbro and alkali diorite. Some of the mafic rocks of the Mount Hayes quadrangle may be related to those in the southern part of the Tanacross quadrangle (Foster, 1970) and(or) Nabesna quadrangle (Richter, 1976).

Mineral resources

In the southern part of the YT, gold has been produced from placer deposits, and gold, silver, antimony, and lead have been produced from several types of vein deposits. Other types of deposits present in the terrane include skarn or tactite deposits, copper vein deposits, and stratabound auriferous-sulfide bodies. Recent exploration for volcanogenic massive sulfide deposits has identified a number of significant prospects and occurrences. Perhaps the most important mineral resource of this region is coal, which occurs in Tertiary sedimentary rocks. Figure 4 shows the distribution of selected lode deposits, prospects, and occurrences in the southern YT.

Gold placers

Placer deposits of the Bonnifield and Kantishna districts (Nos. VII and VIII, Fig. 4) each yielded about 45 to 50 thousand ounces of gold between their discovery in 1903 and 1960 (Cobb, 1973). The placers are mainly of stream, but include bench type. Sources of the gold are thought to be the various vein and stratabound-lode deposits that occur in the districts.

Vein deposits

Most vein deposits of the southern YT belong to three types identified by Bundtzen (this volume) in the Kantishna district: (1) auriferous quartz-arsenopyrite veins such as the Banjo (No. 20, Fig. 4), (2) galena-sphalerite-tetrahedrite-sulfosalt veins, such as Quigley Ridge (No. 21, Fig. 4), and (3) simple stibnite-quartz veins such as Stampede, Rambler, Glory Creeks and Rock Creek (No. 19, Fig. 4).

Volcanogenic massive sulfide deposits

Most of the volcanogenic-massive sulfide prospects and occurrences are located within the metavolcanic part of the Jarvis Creek Glacier terrane (Lange and Nokleberg, 1984). Important occurrences are known at Anderson Mountain (Freeman, this volume) (No. 22, Fig. 4); near Dry Creek (Gaard, this volume) (No. 23, Fig. 4); Miyaoka, Hayes Glacier, and McGinnis Glacier (Lang and Nokleberg, this volume) (Nos. 24 and 25, Fig. 4); and in the Delta district (Nauman and Newkirk, this volume) (No. 26, Fig. 4). The deposits have many characteristics of deposits associated with felsic and intermediate volcanic rocks that form in island-arc settings.

Coal

Two coal fields, the Nenana and Jarvis Creek (D and C, Fig. 4), occur within nonmarine sedimentary rocks of the Tertiary coal-bearing formation of local usage. The Nenana field, which consists of several separate basins, has been a significant source of coal in Alaska, and both fields, whose characteristics are summarized in Table 3, contain substantial resources.

Table 3.--Coal fields of the southern part of the YT[1]

Field	Size	Structure	Reserves/ resources (tonnes) proven indicated inferred	Seam characteristics	Rank	Sulfur content	Development status
Nenana	Several basins 129 km by 16 to 48 km (80 by 10 to 30 miles)	Open folds and a few faults	780×10^6 5400×10^6 7900×10^6	Separate basins contain 8-9 seams that are at least 1.5 and up to 20 m thick.	Subbituminous	Low	Produces about 800,000 tons/yr for local use. Export planned.
Jarvis Creek	40 km^2 (16 mi^2)	Open folds	0.3×10^6 12.5×10^6	Basin contains 30 seams that vary in thickness from 0.3 to 2.3 m	Subbituminous	Low	Some past production. Presently being developed for local use.

[1]References: Barnes (1967); Eakins and others (1983); Wahrhaftig and Hickcox (1955).

Sedimentary rocks

Tertiary nonmarine sedimentary rocks (unit Ts, Fig. 2) are fairly extensive in the northern part of the Healy and southern part of the Fairbanks quadrangle and also occur in the southeastern Big Delta, northeastern and north-central part of the Mount Hayes, and northeastern part of the Mount McKinley quadrangle. Two distinct units, shown as one composite unit in Figure 2, have been recognized, the coal-bearing formation and the overlying Nenana Gravel.

The coal-bearing formation is an informally designated sequence of local usage consisting of interbedded lenses of poorly consolidated sandstone, siltstone, claystone, conglomerate, and lignitic and subbituminous coal (Wahrhaftig and Hickcox, 1955). The generally uncemented and poorly to moderately consolidated rocks erode readily. Both lithology and thickness vary greatly over short distances, and the range in thickness can be at least partly attributed to deposition on an uneven erosion surface of deeply weathered metamorphic rocks (Wahrhaftig and Hickcox, 1955). The total thickness of the coal-bearing formation reaches several hundreds of meters. Bedding is generally horizontal or has gentle dips. In places the formation has been warped and faulted. The number and thickness of coal beds is variable throughout the formation, but in the Nenana coal field there are a large number and they range in thickness from a few centimeters to 20 m (Barnes, 1967). In most places only a few coal beds are thicker than 60 cm. The coal-bearing formation has long been considered of Tertiary age, but its position within the Tertiary is uncertain. A Miocene age is considered probable (Holmes and Foster, 1968).

The Nenana Gravel consists largely of poorly to moderately consolidated, poorly cemented, fairly well sorted conglomerate and sandstone (Wahrhaftig, 1958). Pebbles in the conglomerate are generally slightly weathered. The formation is more resistant to erosion than the underlying coal-bearing formation and commonly supports steep cliffs 15 to 30 m high (Wahrhaftig, 1958). It varies in thickness but is known to exceed 1,300 m thick in places. It generally has about the same attitude as the coal-bearing formation, although a minor unconformity locally occurs between these units. Thus the Nenana Gravel has also been warped and faulted since deposition. Patches of poorly consolidated gravel on the north flank of the Alaska Range in the Mount Hayes quadrangle may be erosional remnants of the Nenana Gravel (Holmes and Foster, 1968). The exact age of the formation is uncertain. It has been considered Miocene or younger; Pliocene is the most probable age, based on pollen studies (Holmes and Foster, 1968). Most recently, Wolfe and Toshimasa (1980) have considered the Nenana to be late Miocene and early Pliocene on the basis of Clamgulchian stage fossils within the unit.

Geophysical data

Comparatively few geophysical studies for the YT have been published. Aeromagnetic maps are available for most of the quadrangles at scales of 1:250,000 and 1:63,360, and interpretations of the aeromagnetic maps have been made for the Nabesna (Griscom, 1975), Tanacross (Griscom, 1976), Big Delta (Griscom, 1979), and Circle (Cady and Weber, 1983) quadrangles. No regional aeromagnetic interpretation that includes the YT has been made since an early study based on widely spaced (10 miles) flight lines (Brosgé and others, 1970). Available gravity data for the YT are shown on the Bouguer gravity map of Alaska (Barnes, 1977). Gravity maps have been published for the Nabesna and Circle quadrangles at scales of 1:250,000 (Barnes and Morin, 1975; Cady and Barnes, 1983). The density of gravity stations and quality of data are variable throughout the YT. Geophysical methods have been used by private industry in exploration for asbestos, copper porphyry, and other types of deposits. Some of the geophysical work being done on the Trans-Alaska Crustal Transect (TACT) will include parts of the YT.

Seventymile terrane

The Seventymile terrane is a discontinuous belt of alpine-type ultramafic rocks and associated slightly metamorphosed mafic volcanic and sedimentary rocks that have been thrust upon and imbricated with rocks of subterranes Y_3 and Y_4 of the YTTN. Churkin and others (1982) referred to these rocks as the Salcha terrane. The belt trends northwesterly from the Yukon Territory into the northern part of the Eagle quadrangle; in the northeastern part of the Big Delta quadrangle the belt is displaced to the south along the northwest side of the Shaw Creek fault. From there it trends southwestward to the center of the Fairbanks quadrangle (Fig. 5). Five large peridotite bodies

Figure 5 here.

(the peridotites of Boundary, American Creek, Mount Sorenson, Salcha River ("Nail" allochthon of Southworth, 1984), and Wood River Buttes) and three areas of massive greenstone bodies (the greenstones of Wolf Mountain, Chicken, and Ketchumstuk), make up the main part of the Seventymile terrane. (These are labeled 1 to 5 and I to III, respectively, on Figure 5.) Some of these rocks in the Eagle quadrangle have been described previously as parts of a dismembered ophiolite (Foster and Keith, 1974; Keith and others, 1981). Numerous sporadically distributed small lenses of serpentinized peridotite and serpentinite crop out south of the main belt of ultramafic rocks (Keith and Foster, 1973), especially in the Eagle quadrangle, suggesting that they may have come off the sole of the thrust fault at the base of the Seventymile terrane.

Ultramafic rocks

The largest outcrops of the Seventymile terrane are composed mainly of alpine-type ultramafic rocks. The peridotite of Boundary covers approximately 8 km^2, the peridotite of American Creek approximately 31 km^2, the peridotite of Mount Sorenson approximately 41 km^2, the peridotite of Salcha River is 40 km long and covers approximately 80 km^2, and the peridotite of Wood River Buttes covers approximately 6 km^2. The rocks are mainly partly serpentinized harzburgite and dunite, with minor amounts of clinopyroxenite. Chromite, locally present, is nowhere abundant. Secondary magnetite that developed during serpentinization is common. Tectonic inclusions of rodingite occur in the large peridotite bodies. Bodies of coarse-grained cumulate gabbro are associated with the peridotite of Mount Sorenson. Silica-carbonate zones are well developed at the base of the peridotite of Salcha River and locally developed in the peridotite of Mount Sorenson.

Small serpentinite bodies, many of which have relict harzburgite texture, crop out as lenses or pods. Locally, the small bodies have a rind of actinolite and (or) chlorite, or hard slip-fiber serpentine, at the contact with country rock, indicating a tectonic relationship with the adjacent rocks. The distribution of the small outcrops is irregular, and they appear

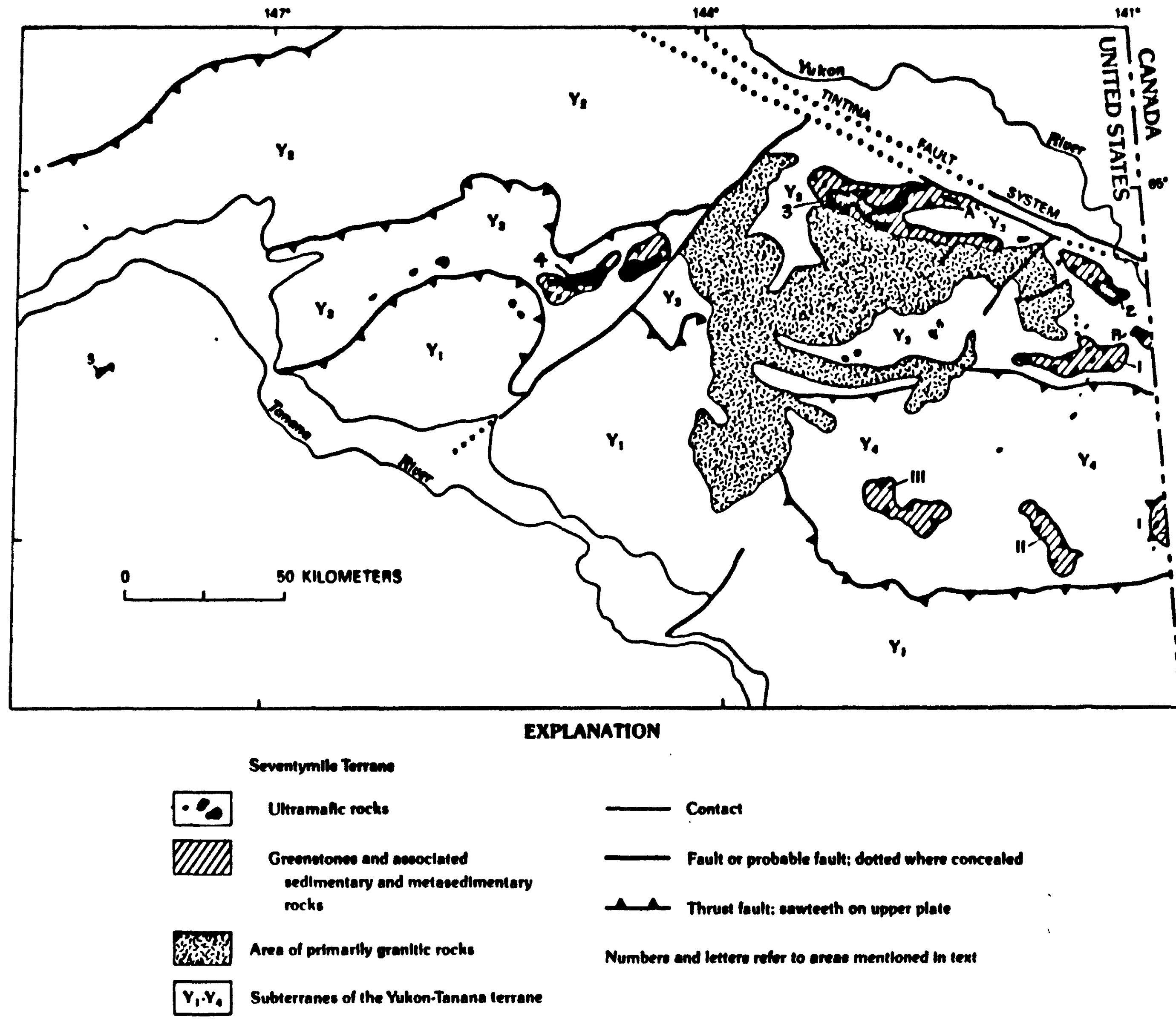

Figure 5. Map showing distribution of ultramafic rocks and associated greenstones, sedimentary, and metasedimentary rocks of the Seventymile terrane. Map after Foster (1976), Weber and others (1978), and Keith and others (1981).

to be thrust upon, infolded, and imbricated with metamorphic rocks of subterranes Y_3 and Y_4. One of these small bodies, the serpentinite of Slate Creek (No. 6, Fig. 5), contains asbestos in potentially commercial quantities (Foster, 1969; Mullins, and others, 1984).

Volcanic rocks

Greenstone bodies, originally basaltic pillow lavas and mafic lava flows, are closely associated with the massive peridotite bodies at all the major outcrops. Large masses of greenstone with minor associated serpentinite and silica-carbonate lenses also crop out as thrust remnants (Nos. I, II, and III, Fig. 5). The greenstones in the south-central part of the Eagle quadrangle (No. II, Fig. 5), which lie upon subterrane Y_4, show thermal effects from the adjacent Taylor Mountain batholith. The greenstones are composed mainly of chlorite, actinolite, epidote, feldspar, magnetite, quartz, and calcite.

Tuff that is metamorphosed to lower greenschist facies and generally contains significant amounts of calcite and chlorite is associated with greenstone in many places.

Associated with the peridotite of Mount Sorenson are diabase dikes and plugs; some are metamorphosed and contain small amounts of pumpellyite and prehnite. Unmetamorphosed basaltic pillow lavas and porphyritic silicic volcanic rocks crop out at the eastern end of the peridotite of Mount Sorenson and are in contact with cumulate gabbro.

At one locality (A, Fig. 5), in the north-central part of the Eagle quadrangle, glaucophane, epidote, and sphene have formed from basaltic lava under blueschist metamorphic conditions (Foster and Keith, 1974).

Metasedimentary rocks

Low-grade metasedimentary rocks within the Seventymile terrane are chert, argillite, sandstone, conglomerate, graywacke, and fine-grained dark-gray limestone. Many were deposited alternately with submarine basaltic lava flows, which now are the greenstones; others were deposited later in local basins. Probably all are submarine in origin and were deposited prior to thrusting of the Seventymile terrane.

Chert is found in close association with some of the greenstones and mafic volcanic rocks. Most is slightly recrystallized with abundant silica veins and veinlets. Radiolarians and conodonts indicate an Early Permian age for a red chert associated with the peridotite of Salcha River (Foster and others, 1978). No fossils have been found in adjacent very low grade metamorphosed graywacke sandstone and conglomerate. Slightly recrystallized chert associated with pillow basalts on the southeast side of the peridotite of Mount Sorenson has not yet yielded fossils. However, Mississippian radiolarians occur in red and gray chert on the north side of the peridotite of Mount Sorenson (D.L. Jones, personal commun., 1984).

Slightly metamorphosed sedimentary rocks north of the Fortymile River (B, Fig. 5) include argillite, volcanic conglomerate, and fine-grained black limestone. An early Late Triassic age (early Early Norian) for a much fractured and deformed carbonaceous limestone is indicated by the conodont *Epigonodollella primita* Mosher (T.R. Carr, personal commun., 1985). Some of these rocks are similar to those near the Clinton Creek asbestos deposit in the Yukon Territory that are considered to be Late Triassic in age by Abbott (1982) on the basis of a conodont. Metasedimentary rocks (tuff, argillite, and limestone) of slightly higher metamorphic grade are associated with greenstones in the south-central part of the Eagle quadrangle (C, Fig. 5).

Metamorphism

Much of the pervasive serpentinization of the ultramafic rocks is associated with hydration during emplacement into the crust. Large peridotite masses show no internal textural effects from regional metamorphism. However, many of the smaller ultramafic bodies locally have foliation and low-grade metamorphic mineral assemblages where they have been imbricated with parts of subterranes Y_3 and Y_4. Metamorphism of mafic volcanic rocks may have occurred, in part, within an ocean basin prior to thrusting. However, thrusting and low-grade regional greenschist metamorphism has had some effect on the rocks, as indicated by cross-cutting veinlets of serpentine (including cross-fiber asbestos), magnetite, chlorite (penninite), actinolite, anthophyllite, and magnesite. Closely associated tuff and sedimentary rocks show effects of low-grade regional metamorphism by a weak but distinct foliation and chloritization of ferromagnesian minerals.

Structural relationships

The Seventymile terrane has been thrust into its present position with respect to the underlying metamorphic rocks of the Yukon-Tanana terrane. Thrust planes are nearly horizontal in most places. Imbricate thrusting of serpentinized peridotite with subterrane Y_4 and units "ws" and "qs" of subterrane Y_3 is prevalent in the central and extreme southeastern part of the Eagle quadrangle.

The alpine-type ultramafic rocks, originally derived from the mantle, were emplaced into oceanic crust (Coleman, 1977) in an ocean basin opening between subterranes Y_1 and Y_4, and also between subterranes Y_1, and Y_2. Later, as the ocean basin gradually closed and the tectonic components of Alaska moved northward into their present positions, some of the rocks of the ocean basin (Seventymile terrane) were obducted southward onto subterrane Y_4, but most were thrust northward as several slices onto subterrane Y_3. The large peridotite bodies were the leading edge of the main thrust sheet, and are structurally the highest part of the Seventymile terrane. These were followed by thrusting of the greenstone and associated metasedimentary rocks. The trace of the former ocean basin is now indicated primarily by the distribution of the rocks of the Seventymile terrane lying in an arcuate belt upon subterrane Y_3 (Fig. 5).

Mineral resources

The Seventymile terrane contains large deposits of asbestos, minor occurrences of gold, and reported minor occurrences of nickel and chromium. The gold occurrences were discussed under the Seventymile district of the YTTN; because present information suggests that the nickel and chromium occurrences are small, they are not discussed further.

Asbestos

Asbestos occurs in two geologic settings within the Seventymile terrane; (1) in large, partially serpentinized ultramafic bodies, many of which have associated greenstone, and (2) in small serpentinite bodies (Keith and Foster, 1973). Large deposits and prospects are confined to the second geologic setting and include the Slate Creek deposit (No. 9. Fig. 4), the Champion Creek prospect (No. 11, Fig. 4) (Mullins and others, 1984), and the Liberty

Creek prospect (No. 12, Fig. 4). Large deposits (Clinton Creek and Caley) occur in the same geologic setting in the Yukon Territory (Abbott, 1982). The Slate Creek deposit has reported reserves of 60 million tons of ore containing 6.4 percent fiber of good quality for asbestos cement products (Mullins and others, 1984) and 67 million tons of indicated and possible ore. The deposits and prospects share a number of common characteristics. The asbestos (chrysotile) occurs as cross fiber in thin (0.03 to 2 cm thick), closely spaced veins in small bodies of serpentinized ultramafic rock that have been completely serpentinized (Foster, 1969; Hytoon, 1979). The margins of many of these bodies contain fibrous actinolite and slip fiber serpentine, indicating that the bodies have been sheared.

The deposits and prospects are confined to a narrow zone that is approximately parallel to the contact of amphibolite-facies rocks with greenschist-facies rocks. This contact was interpreted as a thrust fault by Foster and others (1984). The thrust fault probably was formed in early Middle Jurassic time by the closure of a late Paleozoic and early Mesozoic ocean (Foster and others, 1984), and the small, fractured, completely serpentinized ultramafic bodies that host the asbestos deposits and prospects may be part of the sole of the thrust of the Seventymile terrane.

Quaternary geology of east-central Alaska

A very large part of east-central Alaska is covered by Quaternary deposits. Almost all of the Fairbanks quadrangle is thus covered, and the few natural outcrops occur mostly along rivers and streams and on the highest hilltops. Quaternary deposits are unconsolidated, but many of them are perennially frozen. In the part of east-central Alaska here considered, the largest area of Quaternary deposits is in the Tanana River valley, and widespread eolian deposits on the surrounding uplands also were derived from the Tanana valley. Quaternary deposits have had a major role in the economy of east-central Alaska in many ways, particularly as a source of rich gold placers, and of sand and gravel.

Ancient gravels

Several small areas of unconsolidated, poorly, or partly consolidated gravel are found at high elevations in parts of the northern Alaska Range and in the YTTN of the Tanacross quadrangle. These gravels in the northern Alaska Range resemble the Tertiary Nenana Gravel and have generally been correlated with it. However, some of these gravels may be of early Pleistocene age. In the northern Alaska Range, they occur at elevations just under 1,000 m to 1,200 m. They are generally only a few meters thick, well rounded, deeply weathered, and apparently flat lying. They rest unconformably on metamorphic rocks or on coal-bearing sedimentary rocks (Foster, 1970). Small areas of residuum from metamorphic rocks occur on remnants of an old warped erosion surface that extends southeast from Mount Neuberger (in the Alaska Range 23 km southwest of the town of Tok). The surface is about 1,700 m in altitude near Mount Neuberger but becomes lower to the southeast. The residuum is at least 6 m thick in places. Its age is unknown, but it probably predates the earliest glaciation in this area (Foster, 1970).

Glaciation

Most of east-central Alaska was not covered by glaciers during the Pleistocene. Continental ice sheets were not present, but alpine and piedmont glaciers were abundant in the Alaska Range and small alpine glaciers occupied the upper reaches of many valleys in the highest parts of the YTTN. Glacial outwash was extensively deposited by the large streams, and morainal deposits are conspicuous in many valleys. Silt and sand derived from the dry exposed material in large outwash aprons that were widely deposited in the Tanana River valley were blown northward to form dunes at the northern edge of the valley and a loess mantle on adjacent hills. Material from the Yukon River valley and the alluvial fans of tributaries was blown southward; some of it mantled hills, terraces, and other features in the northernmost part of the area covered by this report. Lacustrine deposits from ice-dammed lakes occur in the Tanana River valley and a few tributary valleys.

Old glaciations of pre-Wisconsin age have been recognized in both the northern Alaska Range and the YTTN. Ten Brink (1983) stated that a broad expanse of piedmont ice spread north from the Alaska Range to cover the ancestral foothills area, probably in late Tertiary time. Two other pre-Wisconsin to early Pleistocene glacial events are also recorded in the Alaska Range. The most extensive and best known Wisconsin-age glaciations are represented in many valleys by two major early Wisconsin advances and four late Wisconsin advances. At least six Holocene ice advances have been recorded, and small glaciers still exist (Table 4).

Table 4 here.

Weber (1983) recognized three pre-Wisconsin glacial episodes in the YTTN, the oldest being pre-Pleistocene in age, and the other two early(?) and middle(?) Pleistocene in age. Two probable early Wisconsin advances were followed by three or four advances in late Wisconsin time. Holocene glacial deposits generally only occur in deep north-facing cirques. Two short (less than 3 km) Holocene glaciers are indicated. No glaciers presently exist in the YTTN (Table 3).

Fluvial, eolian, and lacustrine deposits

The thickest and most extensive fluvial, eolian, and lacustrine deposits of east-central Alaska occur in the Tanana valley. One of the most useful sections is on the northeast side of the Tanana River 50 km southeast of the town of Tok where 40 m of fluvial, eolian, and lacustrine deposits are exposed. Radiocarbon ages indicate that wood from near the base of the section has an age greater than 42,000 years. An ash bed beneath the modern turf is about 1,400 years old (Fernald, 1962; Carter and Galloway, 1984). Some interior valleys also have thick eolian and fluvial deposits, but exposures are limited. Commonly, loess is so thick (more than 60 m in places) that fluvial deposits beneath are rarely exposed. Locally, there are thick carbonaceous silt and peat deposits that are generally perennially frozen. Sand dunes occur north of the Tanana River in the Tanacross and Big Delta quadrangles. The maximum thickness of sediments in the Tanana Valley is not known, but parts of the valley floor are below sea level (Péwé, 1975).

Placer gold occurs in both Holocene gravels and gravels as old as early Pleistocene. Most of the gold-bearing gravels are buried beneath frozen silt and other sediments. Some compose terraces a few to many meters above present

TABLE 4. GLACIAL ADVANCES IN EAST-CENTRAL ALASKA

	YTTN Glacial Sequences (After Weber, 1983)			Northern Alaska Range Glacial Advances (After Ten Brink, 1983)	
	Yukon-Tanana Upland	Mount Prindle area		Local names used and specific valleys by Péwé (1965, 1975) and Wahrhaftig (1958)	Regional informal nomenclature by Ten Brink and others (1983)
HOLOCENE	Ramshorn glaciation		HOLOCENE		Muldrow Foraker II Peters Yanert II Foraker I Yanert I
LATE WISCONSIN	Salcha glaciation	Convert glaciation	LATE WISCONSIN	Donnelly glaciation (Delta River; Péwé, 1965, 1975) Riley Creek glaciation (Nenana Valley; Wahrhaftig, 1958)	McKinley Park glaciation: McKinley Park stade IV McKinley Park stade III McKinley Park stade II McKinley Park stade I
EARLY(?) WISCONSIN	Eagle glaciation	American Creek glaciation	EARLY WISCONSIN	Delta glaciation (Delta River; Péwé, 1965; 1975) Healy glaciation (Nenana River; Wahrhaftig, 1958)	Early Wisconsin III(?) Early Wisconsin II Early Wisconsin I
MIDDLE(?) PLEISTOCENE	Mount Harper glaciation	Little Champion glaciation	PRE-WISCONSIN	Dry Creek glaciation (Nenana River; Wahrhaftig, 1958)	Pre-Wisconsin III
EARLY(?) PLEISTOCENE	Charley River glaciation	Prindle glaciation		Browne glaciation Nenana River; Wahrhaftig, 1958)	Pre-Wisconsin II
PRE-PLEISTOCENE	Goodpaster glaciation			Nenana Gravel (upper part) (late Tertiary) (Nenana River; Wahrhaftig, 1958)	Pre-Wisconsin I

stream levels. High terraces are particularly well developed along the Fortymile and Seventymile Rivers and along the Yukon River.

Talus and landslide deposits, particularly abundant in the Alaska Range, also occur in the YTTN. Rock glacier deposits are locally significant in the Alaska Range (Holmes and Foster, 1968).

Frost polygons are well developed in lowland areas where permafrost is generally present and thaw lakes are common. Patterned ground, including stone polygons and stone stripes, is abundant in upland areas. Solifluction is a major mass movement process on valley slopes. More than 300 open-system pingos are widely distributed mainly north of the Tanana River (Holmes, Hopkins, and Foster, 1968). Most are on south- and southeast-facing slopes near the transition between valley-fill deposits and slope mantle. The pingos are composed primarily of silt, colluvium, and valley-fill material and range from 3 to 35 m in height.

Volcanic ash

Volcanic ash layers ranging in age from early Pleistocene to Holocene are found at several horizons in the Quaternary deposits of east-central Alaska. The most widely distributed is the White River Ash Bed, which originated about 1,400 years ago at the east end of the Wrangell Mountains near the Alaska-Canada border (Lerbekmo and Campbell, 1969). It commonly occurs just beneath the turf but may be buried to a depth of several meters in active stream valleys or beneath recent eolian deposits. Numerous other ashes of unknown origin occur and include some in the Fairbanks area, lower Delta River area, along the Chatinika River 40 km north of Fairbanks (Péwé, 1975), and in the central and southern Eagle quadrangle (Weber and others, 1981). The Sheep Creek Tephra of Westgate (1984, _in_ Porter, 1985), an ash of unknown source and older than 40,000 yr B.P., has recently been identified in four localities in Alaska and Yukon Territory; Eva Creek, near Fairbanks (Péwé, 1975), Canyon Creek in the Big Delta quadrangle (Weber and others, 1981), and Lost Chicken Creek in the Eagle quadrangle (Lee Porter, written commun., 1985), as well as on the Stewart River in Yukon Territory. At Lost Chicken Creek, the ash is associated with _in situ_ fossil mammal remains.

Vertebrate fossils

East-central Alaska is well known for the abundant remains of extinct Pleistocene mammals, found mostly in frozen deposits along rivers and streams. Most of the remains have been uncovered during placer gold mining, and the Fairbanks mining district has been especially productive of fossil vertebrates. At least 45 mammalian genera occupied parts of the area during the late Pleistocene, including the American lion, camels, giant beavers, and ground sloths, of which at least 16 genera have become extinct (Porter, 1985).

Vertebrate fossils were discovered in 1974 along the Richardson Highway near the mouth of Canyon Creek, a small tributary to the Tanana River in the Big Delta quadrangle. Here the Pleistocene fauna includes rodents, woolly mammoth, the Yukon wild ass, western camel, long-horned bison, mountain sheep, wolf, tundra hare, and caribou. Although the fauna is a standard Alaskan Pleistocene assemblage (Guthrie, 1968), it is one of the few central Alaskan mammalian collections that is stratigraphically controlled and radiometrically dated (40,000 years old, Weber and others, 1981). Recently, the fossils from

Lost Chicken Creek, a small tributary to the South Fork of the Fortymile River in the southern Eagle quadrangle, have been intensively collected and studied. This locality has produced over 1,000 fossils from 37 m of unconsolidated sediments which range in age from 50,400 yr B.P. to 1,400 yr B.P. (Porter, 1985). The assemblage includes 16 vertebrate genera among which are the unusual occurrence of gallinaceous birds, wolverine, the extinct American lion, collared lemmings, and saiga antelope. Human involvement may be indicated for some unknown time prior to 11,000 yr B.P. by broken and burned bones of mammoth, bison, horse, and caribou (Lee Porter, written commun., 1985). The Lost Chicken fauna represents a hardy, cold- and dry-adapted biologic community which lived during the middle Wisconsin and late Wisconsin postglacial time.

The stratigraphy, flora, and fauna of the east-central Alaska localities indicate that early Wisconsin time was cool and dry, middle Wisconsin time was wetter, and that glacial climates terminated abruptly between 12,000 and 9,000 yr B.P. (Lee Porter, written commun., 1985). The Holocene had an early period of very warm temperatures (ca. 8,000 yr B.P.) followed by a cool period (ca. 7,000 yr B.P.) (Lee Porter, written commun., 1985).

Geologic history

Determination of the geologic history of east-central Alaska has been hampered by a scarcity of fossils, high grades of metamorphism, and extensive cover by vegetation and surficial deposits. Because of the paucity of definitive information, it is not surprising that geologists working in different parts of the YT put emphasis on different data and arrive at different interpretations. This paper is written within the framework of tectono-stratigraphic terranes, and the interpretation presented here is based to a large extent on regional scale geologic mapping, new data from ^{40}Ar-^{39}Ar incremental heating experiments, and detailed structural studies of rocks in the eastern part of the Eagle quadrangle.

In this synthesis, several groups or packages of rocks included in subterranes Y_1 through Y_4 (described under "Stratigraphy" in this chapter) are considered in terms of their relationships to one another and to the YTTN. Workers in the Mount Hayes quadrangle to the south of the YTTN (Nokleberg and others, 1983; Nokleberg and Aleinikoff, 1985) have also identified packages of rocks and have proposed possible geologic relationships of these packages to each other and to the southern part of the YTTN (subterrane Y_1 and the Lake George terrane; see "Yukon-Tanana terrane south of the Tanana River," this chapter). In most instances, each package of rocks in the YT contains disparate elements that record their pre-Mesozoic histories and, at present, data are insufficient to integrate the details of their histories.

The geologic history recorded in the YTTN probably begins in latest Proterozoic or early Paleozoic time with deposition of continentally derived sediments in several different environments marginal to North America and (or) other continents. These deposits include the very quartzose sediments of unit "qq" (subterrane Y_2), the pelitic schist, amphibolite, and marble of unit "ps" (subterrane Y_2), and the quartzose and pelitic sediments of subterrane Y_1. Probably beginning a little later in time, but perhaps overlapping the depositional periods for subterranes Y_1 and Y_2, the protoliths of subterrane Y_4 were deposited. Other continental margin sediments of Paleozoic age are those of units "qs", "ws", and "cp" of subterrane Y_3; possible forearc sediments of Paleozoic age are those of units "sm" and "ms" of subterrane Y_3.

The first well-dated event in any part of the YT is felsic intrusion in Devonian time (Aleinikoff and Nokleberg, 1985) in the southern part of subterrane Y_1, followed in Mississippian time by extensive porphyritic granitic intrusion (augen gneiss) throughout much of the northern part of subterrane Y_1. Dusel-Bacon and Aleinikoff (1985) postulated that metamorphism was synchronous with intrusion. Subterranes of the YT (mostly continental fragments) are assumed to have been separate entities at this time because the distribution of the augen gneiss is limited to subterrane Y_1, except for possible thrust remnants in the southern part of subterrane Y_2.

From late Paleozoic through Triassic time, basalts and minor amounts of sediments which included chert, graywacke, shale, and limestone accumulated in an ocean basin that separated the continental fragment comprising subterranes Y_2 and Y_3 from subterranes Y_1 and Y_4 Mantle peridotites were tectonically emplaced into the oceanic crust and became a part of the ocean basin suite. Remnants of these mantle and oceanic rocks compose the Seventymile terrane.

During this period of separation, the continental fragments each had a poorly known but complex history of metamorphism and deformation that is implied by their heterogeneous characters. The early histories of individual subterranes will have to be determined separately.

The next well-dated events are represented in subterrane Y_4 and may have been limited to this subterrane. Paleozoic sedimentary rocks were metamorphosed to amphibolite facies in the Late Triassic (about 213 $\pm$ 2 Ma). Intrusion of granodiorite (Taylor Mountain batholith) occurred at 209 $\pm$ 3 Ma, shortly after the peak of metamorphism, and the pluton cooled with the regional geotherm.

During the cooling period, but before approximately 201 Ma, oceanic basalt and associated sediments, probably from the closing ocean basin to the north of subterrane Y_4, were emplaced tectonically. These basalts were then metamorphosed to greenschist facies during the waning stages of regional metamorphism of subterrane Y_4. Deformation, probably related to northwestward movement of subterrane Y_4, produced major northeast-southwest-trending folds in unit "qs" as subterrane Y_4 and remnants of ocean material (Seventymile terrane) were thrust northward onto subterrane Y_3. Complex imbrication of subterrane Y_4 and units "qs"and "ws" of subterrane Y_3 occurred with the collision of these packages of rocks. The thrusting together of subterranes Y_3 and Y_4 occurred after major metamorphism of subterrane Y_4, but before 187 $\pm$ 2 Ma as indicated by ^{40}Ar-^{39}Ar dating of undeformed and unmetamorphosed dike rocks that cut subterrane Y_4. With continued northward movement, further imbrication, shearing, mylonitization, and thrusting occurred within and between the Seventymile terrane and subterrane Y_3.

In the western part of the YTTN, times of thrusting and metamorphism are not as well known as in the eastern part. However, within subterrane Y_2, thrusting of unit "ps" over unit "qq" occurred before major regional metamorphism of subterrane Y_2, and the joining of subterranes Y_2 and Y_3 occurred after the major regional metamorphism of subterrane Y_2. The Seventymile terrane was probably emplaced in the western part of subterrane Y_3 in Jurassic time, the same time as in the eastern part of subterrane Y_3, and closing of the ocean basin that separated subterranes Y_4 and Y_1 from subterranes Y_2 and Y_3 is recorded only by the presence of thrust remnants of the Seventymile terrane on top of subterrane Y_3.

Differences in the sedimentary protoliths of subterranes Y_1 and Y_4, the restriction of augen gneiss to subterrane Y_1, and probable differences in ages of metamorphism of these subterranes suggest that they were not joined until after Early Jurassic time. The presence of a late Early Cretaceous metamorphic event in both subterranes Y_1 and Y_4 provides an upper constraint upon the time of joining of subterrane Y_1 to the rest of the YTTN. The subterranes were further welded together by emplacement of the Cretaceous granitic plutons.

In the eastern part of the YTTN volcanism was associated with Cretaceous intrusion; extensive welded tuffs were erupted and caldera formation took place. Around this time, and perhaps directly or indirectly related to volcanic events and (or) further northwestward movement of the YT, the YT developed a northeasterly trending pattern of fractures and high-angle faults having both strike-slip and dip-slip movement. The best known of these faults is the Shaw Creek fault, which appears to have considerable strike-slip displacement (Griscom, 1979). However, the southeast side seems to be up, and on the basis of reconnaissance field data, M.C. Gardner suggested (written commun., 1983) that the Shaw Creek fault may be a high-angle reverse fault. Some of these faults were reactivated at intervals in Tertiary and Quaternary time. The right-lateral strike-slip Tintina fault system marks the northern boundary of the YT. There is little direct evidence in Alaska of the time, kind, and extent of first and subsequent movements on the Tintina and its subsidiary faults; limited information suggests that, as might be expected, movement occurred at different times on various segments of the fault. In the Eagle quadrangle, for instance, Upper Cretaceous and (or) lower Tertiary conglomerates are broken and pulverized by fault movement at one locality but appear undisturbed at another. In Canada, Gabrielse (1985) suggested, displacements on dextral faults such as the Tintina date from the mid-Cretaceous or earlier to late Eocene or Oligocene. In order to account for discrepancies in the amount of displacement along the Tintina as compared to the northern Rocky Mountain Trench, he suggested the possibility that transcurrent displacement brackets the time of major regional thrusting and folding. If this were the case in Alaska, movement could possibly have begun as early as the Jurassic.

The last major plutonic event was the emplacement of felsic plutons primarily in the northwestern part of the YTTN from about 65 to 50 Ma. At about the same time volcanic rocks, probably both mafic and felsic, and perhaps shallow felsic intrusions were emplaced, primarily in the eastern part of the YTTN. A late folding event with some thrusting is evidenced by folding of Upper Cretaceous or Paleogene nonmarine sedimentary rocks and Neogene sedimentary and volcanic rocks. A late open-folding, which may be the result of this or some pre-Tertiary folding event, is also recognized throughout the YTTN in the metamorphic rocks. The youngest significant structural event, probably in Pleistocene time, is most evident in the northeastern part of the YT, where uplift and probable northward tilting (Mertie, 1937) is indicated by entrenchment of the Fortymile and Seventymile Rivers and resulting development of extensive high-level terraces.

Prindle Volcano, in the eastern part of the Tanacross quadrangle, is a manifestation of Pleistocene or Holocene alkali-olivine basaltic volcanism. Because its lava contains spinel-bearing peridotite and granulite inclusions (Foster and others, 1966), it also suggests that extension is taking place at deep crustal and upper mantle levels. Prindle Volcano lies at the northern end of a belt of occurrences of alkali-olivine basalts that extends along the western continental margin of North America.

In general, we tend to follow the succession of events for the YT that was suggested by Tempelman-Kluit (1979) for part of the Yukon Territory to the southeast and that also may tie in a general way to parts of the history suggested by Monger and others (1982) for parts of the Canadian Cordillera still farther south. Applying Tempelman-Kluit's model (1979), the amphibolite-facies rocks of subterrane Y_4 might be considered as part of Stikinia (Stikinia terrane), and the Taylor Mountain granitic intrusion related to the Klotassin Suite of the Yukon Territory. More likely, a terrane of different origin than Stikinia (subterrane Y_4) was in existence at the same time as the intrusion of the Klotassin Suite but lay farther north. Later both Stikinia with the intruded Klotassin Suite and subterrane Y_4 with the Taylor Mountain and other Triassic and Jurassic intrusions were joined with other terranes to form terrane I of Monger and others (1982). Subterrane Y_3 would correlate with Tempelman-Kluit's cataclastic unit, and the Seventymile terrane would have originated in the closing of the Anvil Ocean. Although tentative correlations can thus be made, some details in lithologies and timing of events differ. For instance, closing of the Anvil Ocean is postulated for Middle Jurassic time in Canada and may have been a little earlier in Alaska.

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