3.00

STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES

METAMORPHIC ROCKS OF TOKLAT—TEKLANIKA RIVERS AREA, ALASKA

By
W.G. Gilbert and Earl Redman

GEOLOGIC REPORT 50

Published by

DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

COLLEGE, ALASKA
1977

STATE OF ALASKA

Jay S. Hammond, *Governor*

Robert E. LeResche, *Commissioner, Dept. of Natural Resources*

Ross G. Schaff, *State Geologist*

Cover: Looking southwest across East Fork Toklat River along the Wyoming Hills fault.

Available from Alaska Division of Geological and Geophysical Surveys, P.O. Box 80007, College, 99708; 323 E. 4th Ave., Anchorage, 99501; P.O. Box 7438, Ketchikan, 99901; and Pouch M, Juneau, 99811 —

ERRATA

The following errata are for the Alaska Division of Geological & Geophysical Surveys Geologic Report 50, "Metamorphic rocks of Toklat-Teklanika Rivers area, Alaska," by W.G. Gilbert and Earl Redman, which was recently sent your organization.

- Page 11. The lower "S_2" in figure 12 should read "S_1."
- Page 13. The second reference should read:
  Bundtzen, T.K., Smith, T.E., and Tosdal, R.M., 1976, Progress report: Geology and mineral deposits of the Kantishna Hills, Alaska: Alaska Div. Geol. and Geophys. Surveys Open-File Rept. 98, 80 p.
- Plate 1. Heavy lines on cross sections caused by printing error.

CONTENTS

ILLUSTRATIONS

TABLES

METAMORPHIC ROCKS OF TOKLAT—TEKLANIKA RIVERS AREA, ALASKA

By W.G. Gilbert[1] and Earl Redman[2]

ABSTRACT

Two contrasting metamorphic terranes are juxtaposed along the western extension of the Hines Creek fault. The northern terrane is polymetamorphic and includes Precambrian-early Paleozoic(?) metasedimentary rocks of the Birch Creek Schist in fault contact with a Middle or Late Devonian series of metasedimentary rocks and metafelsites. Metavolcanic rocks in the northern terrane suggest that mid-Paleozoic andesitic volcanism affected at least 5,000 square kilometers in central Alaska.

The northern part of the southern terrane is composed of weakly metamorphosed Triassic(?) siliceous marble in fault contact with Cretaceous(?) slate to the south. Both the siliceous marble and slate are extensively intruded by gabbro.

The northern terrane was affected by an early period of deformation and recrystallization in the lower greenschist facies; this deformation may have affected the southern terrane. A second, weaker deformational event also affected the northern terrane.

INTRODUCTION

PRESENT STUDY

This description of pre-Cenozoic metamorphic rocks between the Teklanika and Toklat rivers in the west-central Alaska Range (fig. 1) is part of an ongoing study of the geology and tectonic history of the region (Gilbert, 1975; Gilbert and Redman, 1975; Gilbert, Ferrell, and Turner, 1976). Field investigations of the area were conducted during the summers of 1973 and 1974. Petrographic examination was made of 63 thin sections, and modal compositions were determined by counting of 100 points per thin section.

PREVIOUS WORK

Metamorphic rocks in the study area were first mapped by Brooks (1911) as belonging to the Birch Creek Schist, the Tatina Group, and the Tonzana Group. Further mapping by Capps (1919) restricted the rocks in the northern terrane of this study to the Birch Creek Schist and the Tonzona Group, and assigned the rocks in the southern terrane to the Tatina Group. Subsequent reconnaissance studies have referred to the rocks in the southern terrane as undifferentiated Paleozoic rocks (Capps, 1932; Reed, 1961) and have included all rocks of the northern terrane in the Birch Creek Schist (Capps, 1940; Reed, 1961; Hickman, 1974).

[1]Alaska DGGS Mining Geologist, College, AK 99708.
[2]Geologist, Cities Service Mineral Corp., Anchorage, AK 99501.

SUMMARY OF GEOLOGY

Two northeast-trending metamorphic terranes transect the study area and are juxtaposed along the western extension of the Hines Creek strand of the Denali fault system. The northern terrane is composed of two polymetamorphic rock units: an older series of metasedimentary rocks, which is part of the Birch Creek Schist, and a younger series of carbonaceous phyllites, pelitic and psammitic phyllites and quartzites, and metafelsites. Fossil evidence suggests that the age of the younger series is, in part, Middle or Late Devonian. The northern part of the southern terrane is composed of weakly metamorphosed siliceous marble in fault contact with slate and metasandstone to the south. Both units in the southern terrane are extensively intruded by gabbro.

NORTHERN TERRANE

BIRCH CREEK SCHIST

Micaceous quartzite and sericite-quartz schist of the Birch Creek Schist are present in a northeast-trending band, 3 to 5 km (kilometers) wide, which extends from the northeast corner of the Healy C-6 quadrangle to the west side of the East Fork Toklat River canyon (pl. 1). Scattered exposures are also found on the northwest side of the Wyoming Hills. This belt of rocks is part of a more extensive terrane that continues east and north (Capps, 1919; Wahrhaftig, 1968; Wegner, 1972; and Hickman, 1974) and west (Capps, 1919; Morrison, 1964) (fig. 1). From a distance the rocks are light gray to tan and form prominent tors by differential weathering along joints and cleavage. A conspicuous orange-weathered zone marks the Birch Creek Schist for 30 to 50 m (meters) beneath the overlying Coal-Bearing Group.

Quartz- and mica-rich banding in quartzite, schist, and phyllite may in part represent original compositional layering, but this layering reflects two periods of metamorphism. The compositional layering defines a prominent foliation (S_1), which displays prominent

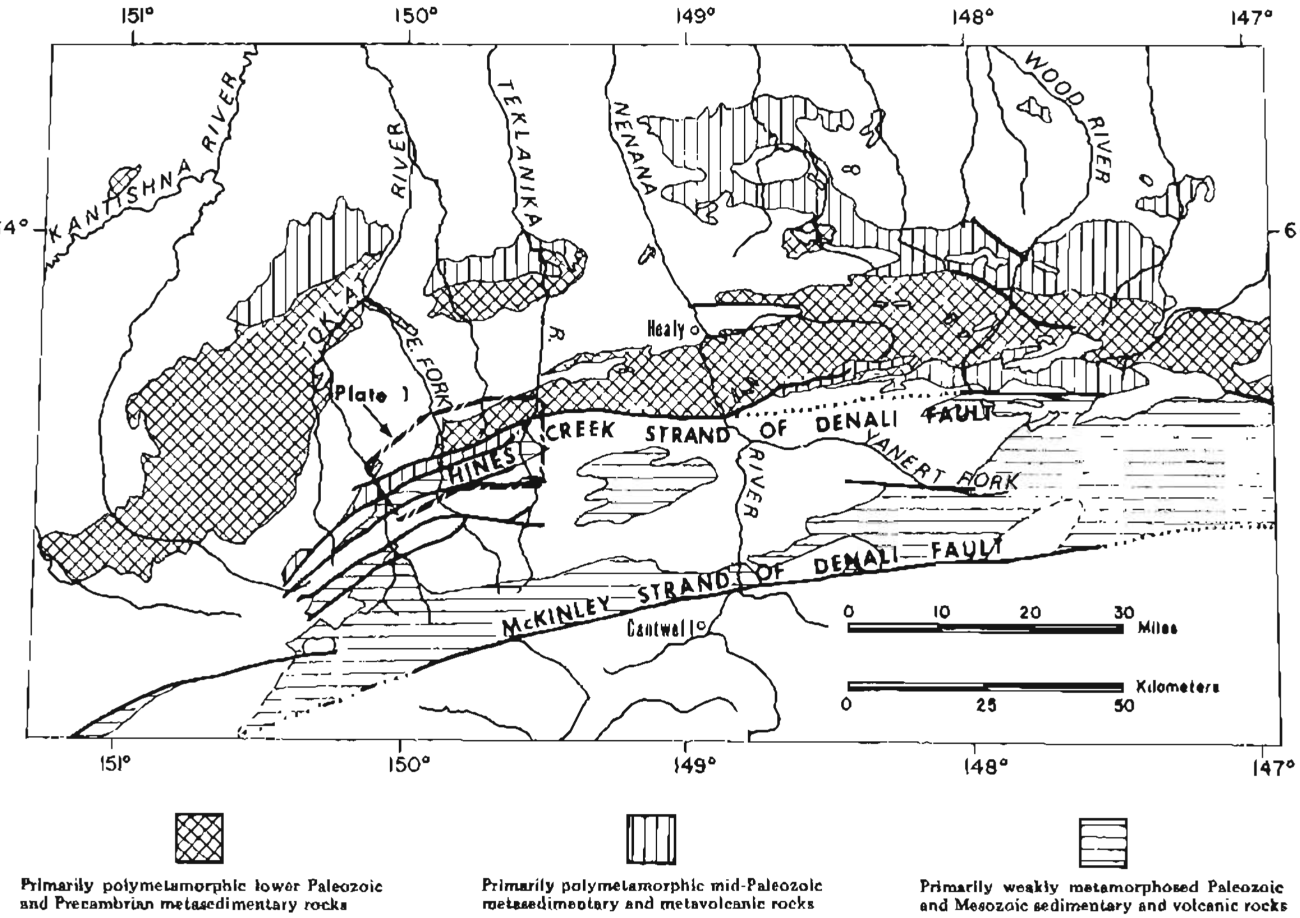

Figure 1. Metamorphic rocks north of Denali Fault system in west-central Alaska Range, and location of this study.

folds (F_2) and is cut by well-developed cleavage (S_2). Locally, the schistose rocks of the Birch Creek Schist grade to phyllite, and the unit is similar in composition and deformational style to quartz-rich portions of the Wyoming Hills sequence (p. 3). It is difficult to differentiate the two rock units where they are in contact. The Birch Creek Schist, however, is more homogenous, is slightly more schistose, and exhibits better developed F_2 folding and S_2 cleavage than the Wyoming Hills sequence.

The dominant rock type in the Birch Creek Schist is a gray-, pink-, or green-weathering white micaceous quartzite (70 percent) that tends to split into layers 1.0 mm (millimeter) to 1.0 cm (centimeter) thick. Gray sericite-quartz schist (20 percent) (fig. 2) and light- to medium-green chlorite-actinolite schist and phyllite (10 percent) are other common lithologies. Chlorite-actinolite schist and phyllite are more abundant (15 percent) in the eastern and southern parts of the outcrop belt than in the north and west (5 percent). In a 1-km-wide belt just north of the Wyoming Hills fault near the Teklanika River (pl. 1), chlorite-actinolite schist and phyllite and chlorite-sericite quartz schist make up 30 percent of the exposures. Black carbonaceous phyllite, light-green orthogneiss, and tightly folded layers of medium- to light-gray marble up to 1.0 m thick are minor components of the Birch Creek Schist.

Micaceous quartzite and sericite-quartz schist in the Birch Creek Schist are metamorphosed quartz-rich pelitic and psammitic sediments. These rocks are characterized by the presence of quartz + sericite ± albite ± chlorite ± biotite ± tourmaline ± Fe-poor epidote ± tremolite ± calcite. Incipient biotite, derived from chlorite and sericite in three of the samples, suggests that these rocks have reached the lower part of the greenschist facies (fig. 2). Xenoblastic quartz (38-81 percent) and albite (0-8 percent) up to 1.0 mm long are dimensionally oriented parallel to the foliation and generally form layers as thick as 4.0 mm. Sericite and muscovite (5-41 percent), chlorite (0-8 percent), and biotite (0-1 percent) form discontinuous wavy bands up to 3.0 mm thick that parallel quartz-rich layers. Fe-poor epidote (0-18 percent) locally forms irregular aggregates in quartz-rich layers. Calcite (0-4 percent) occurs as either irregular masses or as idioblastic rhombohedra as long as 0.3 mm. Tourmaline generally occurs as minor scattered subidioblastic crystals randomly oriented in both the quartz and mica-rich layers (fig. 2). Sphene, zircon, iron oxides, and tremolite are rare accessory minerals.

Minor green schistose metabasite within the Birch Creek Schist contains quartz + chlorite + epidote + actinolite, and a light-green orthogneiss (metadiorite?) seen in the southeast corner of NE1/4, sec. 1, T. 14 S., R. 11 W. contains quartz + albite + chlorite + Fe-poor epidote + tremolite. Xenoblastic quartz and albite form bands parallel to layers of sheaflike and fibrous tremolite or actinolite, and chlorite. Subidioblastic epidote occurs throughout these rocks.

All examined specimens of the Birch Creek Schist were completely recrystallized during the first recorded metamorphic event (F_1). Quartz, albite, sericite, chlorite, biotite, epidote, and tremolite-actinolite formed synkinematically and segregated into compositional bands, whereas epidote, tourmaline, and calcite are common postkinematic minerals. The second metamorphic event (F_2) developed prominent folds and slip cleavage (S_2) in the Birch Creek Schist, but produced no major thermal effects.

The Birch Creek Schist is in fault contact with the Wyoming Hills sequence (pl. 1). The Cantwell Formation and the Coal-Bearing Group unconformably overlie the Birch Creek Schist in the northern and western parts of the study area, respectively. The contact between the Birch Creek Schist and the Nenana Gravel east of the Teklanika River is not exposed, but because the contact follows the eastward projection of the Wyoming Hills fault, the contact is mapped as a fault. Tertiary(?) igneous rocks cut the Birch Creek Schist; dikes of Tertiary(?) quartz porphyry are found in no other pre-Tertiary unit in the study area.

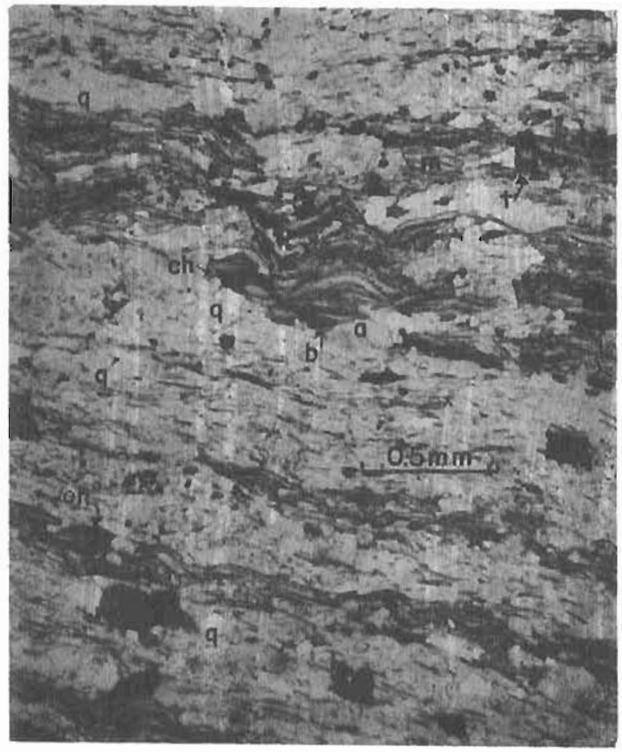

Figure 2. Photomicrograph of sericite-quartz schist in Birch Creek Schist; q=quartz, m=muscovite, ch=chlorite, b=biotite, a=albite, t=tourmaline. Plane light.

WYOMING HILLS SEQUENCE

Carbonaceous quartzose phyllite, marble, quartzose phyllite, and quartzite form a belt 4-6 km wide across the northern half of the Healy C-6 quadrangle and eastern part of the Mt. McKinley C-1 quadrangle (pl. 1). These rocks are well exposed in the southern part of the Wyoming Hills, and are here informally referred to as the Wyoming Hills sequence. These rocks can be subdivided into at least two different units, a lower carbonaceous unit and an upper quartzose unit. The Wyoming Hills sequence is tightly folded, faulted, and structurally thickened; in the Wyoming Hills, it has a structural thickness of about 1,600 m.

The Wyoming Hills sequence is polymetamorphic with crosscutting fold axes, foliation, and cleavage reflecting at least two deformational events. The first deformational event recrystallized the sequence in the lower greenschist facies and produced isoclinal folds and a well-developed axial plane schistosity (S_1) defined by micaceous minerals or carbonaceous material or both. A slip cleavage (S_2) along which shearing and incipient recrystallization have taken place is moderately well developed parallel to the axial surfaces of second-generation folds (F_2).

CARBONACEOUS UNIT

The carbonaceous unit is composed of carbonaceous quartzose phyllite and quartzose phyllite and crops out in three areas: 1) in a northwest-dipping band in the Wyoming Hills, 2) on the limbs of a syncline extending for 5 km northeast of the East Fork Toklat River, and 3) in a band 1.0 km wide and 3.0 km long trending west from the Teklanika River in the northeast corner of the study area (pl. 1). In the Wyoming Hills the unit has an apparent structural thickness of about 1,130 m. There the dominant rock type is a dark-gray, pyrite-bearing, iron-stained carbonaceous quartzose phyllite (fig. 3). In this area discontinuous intercalations of light-green fissile quartzose phyllite, 6 to 20 m thick, form 10 percent of the unit.

East of the East Fork Toklat River, the carbonaceous unit is more quartz-rich and contains about 50 percent carbonaceous quartzose phyllite, 35 percent light-gray quartzite and quartzose phyllite, and 15 percent marble. Light-gray weathering, dark-gray fossiliferous marble layers are concentrated near the top of the carbonaceous unit and are mapped separately where they predominate. Individual layers of marble, carbonaceous phyllite, and quartzose phyllite are approximately 30 m thick and pinch and swell along strike.

In the carbonaceous phyllite xenoblastic quartz (50-80 percent) is the most abundant constituent, commonly forming a mosaic of crystals less than 0.01 mm across. Alternating layers of quartz and of finely divided carbonaceous material (5-15 percent) and quartz are up to 3.5 mm thick (fig. 3). Ribbon-textured quartz is found in the carbonaceous bands and probably was formed by intrafolial shearing. Where S_2 slip cleavage is well developed, carbonaceous material is commonly realigned parallel to cleavage. Subidioblastic laths of sericite and muscovite (3-35 percent) and chlorite (0-5 percent) lying parallel to S_1 are found throughout the rocks but tend to be concentrated in carbonaceous layers. Idioblastic pyrite cubes less than 0.15 mm across or subidioblastic carbonate-apatite crystals less than 0.02 mm long locally form up to 3 percent of these rocks. The quartzose phyllite and quartzite in the carbonaceous unit are similar to those

Figure 3. Photomicrograph of carbonaceous quartzose phyllite of carbonaceous unit. Dark layers are carbonaceous material, light layers are quartz, and dark spots are carbonate-apatite. Plane light.

described for the quartzose unit. Rocks of the carbonaceous unit are probably mainly metamorphosed organic-rich siliceous shales.

The original stratigraphic relationship between the carbonaceous unit and the quartzose unit is not clear, but because the carbonaceous unit appears to underlie the quartzose unit, it is considered to be the older of the two. In the western portion of the map area, the carbonaceous unit is in contact with the siliceous marble unit along the northwest-dipping Hines Creek fault.

QUARTZOSE UNIT

Quartzose phyllite and quartzite of the quartzose unit crop out in an irregular northeast-trending band up to 4 km wide extending from the west bank of the Teklanika River through the Wyoming Hills (pl. 1). The unit probably continues west of the Toklat River. The maximum structural thickness of the unit, just west of the Teklanika River, is about 2,700 m. In the Wyoming Hills the lower and middle part of the quartzose unit consists of 35 percent light-gray quartzite, 30 percent light-gray quartz phyllite, 10 percent light-green quartz phyllite, 10 percent light-green quartzite, and 10 percent carbonaceous phyllite; light-gray fine-grained marble, light-green orthogneiss, and metaconglomerate are also present but make up less than 5 percent of the unit. In the Wyoming Hills the upper 100 m of the quartzose unit is composed of black carbonaceous quartzose phyllite similar to that found in the carbonaceous unit.

Between the Teklanika and East Fork Toklat Rivers, the quartzose unit contains 40 percent light-gray phyllitic quartzite, 25 percent light-gray (graphitic) quartzose phyllite, 20 percent light-gray to black quartzite, and 10 percent light-green (chloritic) quartzose phyllite; discontinuous layers of light-gray-weathering dark-gray silty marble up to 15 m thick make up the remaining 5 percent of the unit. Individual layers of marble and phyllite can be traced for up to 3 km. The quartzose unit is composed of two distinct rock types, psammitic and pelitic metasedimentary rocks and metafelsite. Light-gray rocks are generally metasedimentary rocks and light-green quartzite and phyllite are generally metafelsite.

Quartzites are composed primarily of quartz (80-95 percent) and sericite and muscovite (4-7 percent) (fig. 4). Quartz generally forms a mosaic of xenoblastic strained crystals that are less than 0.05 mm long and which have a directional orientation. Quartz porphyroblasts 0.3-0.8 mm long are also present. Recrystallization and annealing of quartz is complete. In one quartzite specimen the quartzose groundmass contains 7 percent albite. Sericite forms both as scattered idioblastic laths and as discontinuous layers up to 10.0 mm long and 0.2 mm thick parallel to S_1. Common trace constituents are tourmaline, chlorite, carbonaceous matter, iron oxides, apatite, zircon, and calcite. The

Table 1. *Geochemical analyses from two metafelsites, 73WER-64 and 73WER-240, and one metaplutonic rock 73WER-243, in the Wyoming Hills. (Rapid rock technique by Skyline Labs., Inc. Wheat Ridge, CO.)*

Oxide	Sample (Wt. %)		
	73WER-64	73WER-240	73WER-243
S_1O_2	76.4	72.6	48.0
TiO_2	0.42	0.50	1.5
Al_2O_3	12.5	14.1	15.3
Fe_2O_3[1]	1.7	2.0	10.7
MnO	0.015	0.021	0.15
MgO	0.92	1.5	7.3
CaO	1.1	0.12	6.3
Na_2O	2.3	1.8	1.5
K_2O	1.9	4.3	3.7
P_2O_5	0.02	0.03	0.05
H_2O+	1.5	2.2	4.2
H_2O-	0.4	< 0.1	< 0.1

[1]Total Fe.

mineralogy of quartzose phyllites is similar to the quartzites except that the phyllites contain more sericite (4-35 percent) and finely divided carbonaceous material (up to 50 percent) and less quartz (45-60 percent).

Light-green blastoporphyritic metafelsite intervals, now intercalated with quartzose metasedimentary rocks, were probably originally rhyolites or rhyodacites (table 1). In these rocks quartz (30-65 percent), sericite and muscovite (0-57 percent), albite (0-15 percent), and microcline (0-15 percent) are the most abundant constituents (fig. 5). Quartz is present as relict phenocrysts 2.0-7.0 mm across, commonly exhibiting β quartz outlines and resorption channels, set in a recrystallized quartzo-feldspathic groundmass. Albite is both scattered in the groundmass and forms xenoblastic porphyroblasts, which are commonly poikiloblastic with quartz inclusions. Microcline is present as irregular relict phenocrysts up to 3.0 mm across and occasionally exhibits replacement perthite and resorption tectures. Sericite forms layers up to 1.0 mm thick consisting of laths less than 0.004 mm long. Sericite layers generally define S_1 layering, although they are occasionally reoriented along S_2 slip cleavage. Subidioblastic-xenoblastic epidote forms postkinematic and synkinematic clusters and individual laths from plagioclase. Occasionally calcite has replaced plagioclase or has formed secondary veinlets. Scattered xenoblastic aggregates of iron oxide minerals (0-4 percent), together with zircon and sphene, are common accessory minerals.

One green phyllite interval, probably a metabasalt contains metamorphic quartz + albite + actinolite + chlorite + epidote. In this interval flattened quartz and plagioclase with actinolite and chlorite define a prominent S_1 foliation, and xenoblastic epidote porphyroblasts up to 0.4 mm long have grown and rotated in actinolite-rich layers. Finely disseminated opaque minerals are present throughout the rock, and calcite veinlets fill postkinematic fractures.

Metasedimentary rocks of the quartzose unit and the Birch Creek Schist have very similar mineralogy and metamorphic history. The major difference between the units is a slightly less well-developed metamorphic fabric and the presence of a large meta-igneous component in the Wyoming Hills sequence.

The original contact between the quartzose unit and

Figure 4. Photomicrograph of phyllitic sericite-bearing quartzite in quartzose unit; q=quartz, s=sericite, a=albite. Crossed nicols.

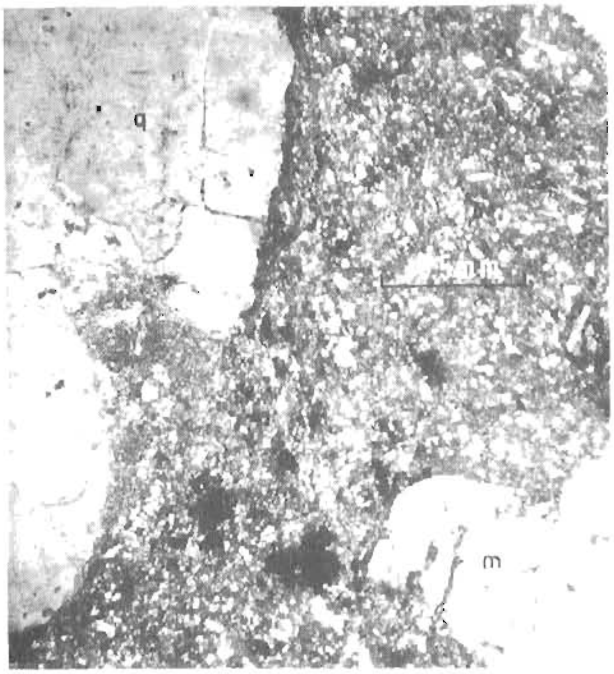

Figure 5. Photomicrograph of metafelsite showing relict resorbed phenocrysts of quartz and microcline; q=quartz, m=microcline. Crossed nicols.

the carbonaceous unit has been blurred by metamorphism, but is apparently a depositional contact or unconformity. The quartzose unit is in fault contact with the Birch Creek Schist on the north and with the siliceous marble unit of the southern terrane on the south (pl. 1).

METAPLUTONIC ROCKS

Several metamorphosed intrusions, ranging from hornblende quartz diorite to augite gabbro, cut the Wyoming Hills sequence (table 1). The rocks generally contain quartz + albite + sericite + tremolite + epidote + chlorite ± calcite. Blastoporphyritic hornblende quartz diorite near peak 4836 indicates that some of the plutons were shallow and hypabyssal (pl. 1). There relict phenocrysts of hornblende and plagioclase are set in a fine-grained quartzo-feldspathic groundmass (fig. 6).

In the metaplutonic rocks xenoblastic chlorite (2-20 percent) and tremolite (5-45 percent) have generally formed from hornblende or augite. Chlorite commonly has replaced hornblende or augite and is replaced in turn by tremolite. Tremolite has also replaced plagioclase and commonly defines the S_1 foliation. Xenoblastic albite porphyroblasts (10-35 percent) are generally derived from relict phenocrysts or groundmass. Xenoblastic epidote (1-5 percent) forms scattered crystals and clusters that commonly replace mafic minerals or plagioclase. Fine subidioblastic laths of sericite (5-25 percent) and calcite are common in plagioclase. Relict iron oxides (ilmenite?) are generally partly altered to leucoxene.

AGE AND REGIONAL CORRELATION

The northern terrane contains rocks of Precambrian to Late Devonian age and is part of the crystalline basement complex underlying interior Alaska between the Denali and the Tintina fault systems (King, 1968). Rocks of the Birch Creek Schist have yielded no fossils in the map area and their age is tentatively considered Precambrian to early Paleozoic. Fossils were found at four localities in marble beds at or near the top of the carbonaceous unit in the Wyoming Hills sequence. The ages of these fossils, summarized in table 2, indicate that the carbonaceous unit is Middle or Late Devonian in age. Rocks of the quartzose unit appear to overlie the fossil-bearing unit and are probably Late Devonian or Mississippian in age.

East of the map area is a series of schistose metafelsite and metasedimentary rocks, and greenstones which are, in part, Devonian in age (Wahrhaftig, 1968; Hickman and Craddock, 1976). These rocks form a belt up to 7.0 km wide that extends from Montana Creek, 8.0 km northeast of McKinley Park station, for at least 70 km to the east (fig. 1). This belt contains lithologies similar to those found in the Wyoming Hills sequence, including a lower carbonaceous member (Hickman, 1974). The Wyoming Hills sequence was probably once continuous with this belt.

The Keevy Peak Formation and Totatlanika Schist are metamorphosed clastic metasedimentary rocks, tuff,

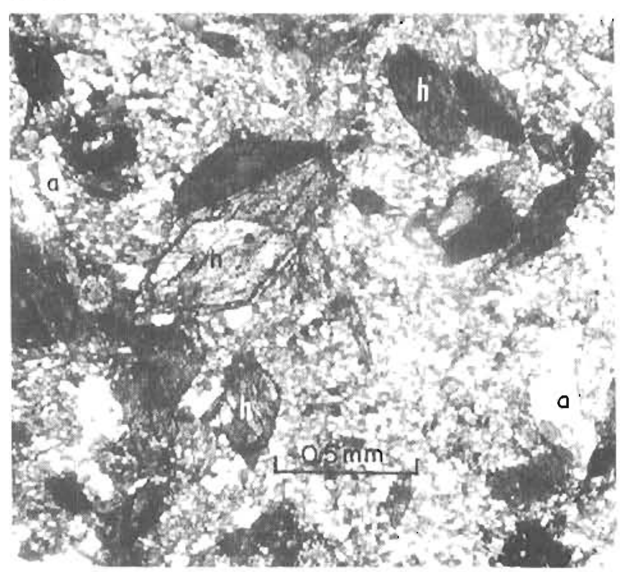

Figure 6. Metamorphosed hypabyssal quartz diorite exhibiting well-preserved relict igneous texture; h= hornblende, a=albite. Crossed nicols.

felsite, basalt, and carbonate, and form a discontinuous belt across the north slope of the central Alaska Range (fig. 1) (Wahrhaftig, 1968). These rocks are of uncertain mid-Paleozoic and older age and unconformably or tectonically overlie the Birch Creek Schist (Capps, 1940; Wahrhaftig, 1968; Bundtzen, 1976; Gilbert, 1977). In detail, however, the Totatlanika Schist appears to be more pyroclastic than the Wyoming Hills sequence and its upper part, at least, is more weakly metamorphosed.

This study expands the area of known mid-Paleozoic volcanic rocks in the central Alaska Range. If the present areas where these rocks now occur were once continuous, the area of mid-Paleozoic andesitic volcanism may have covered more than 5,000 km^2.

SOUTHERN TERRANE

SILICEOUS MARBLE

A folded sequence of thin-bedded dark-gray siliceous marble, phyllitic marble, and carbonaceous slate can be traced from the eastern boundary of the map area east of Teklanika campground to the western boundary of the map area in the Wyoming Hills (pl. 1). The outcrop belt is 1.5 to 3.0 km wide, and in the Wyoming Hills the sequence reaches a structural thickness of 3,300 m.

Individual fine-grained marble beds are 0.1 to 5.0 m thick, weather to a yellowish-brown rough surface, and display fine laminations. Occasional black chert nodules are scattered throughout the marble. The phyllitic marble is highly fissile and usually occurs in beds 0.01 to 4.0 m thick; beds of 10 m or more are uncommon. Whereas the marble is resistant and stands out in bold relief, phyllitic marble weathers to loose debris. In some areas concordant quartz layers form up to 40 percent of the section, and crosscutting sparry calcite veins and veinlets are common. Near the margins of gabbro and diorite intrusions, both marble and phyllite are silicified, except in the Wyoming Hills, where very coarse-grained marble surrounds intrusions. The unit has been weakly metamorphosed by a single metamorphic event and displays prominent cleavage and isoclinal folds.

The siliceous marble unit is composed of calcite crystals (53-83 percent) and quartz grains (5-29 percent) 0.01 to 0.50 mm across, and lesser amounts of carbonaceous material (2-20 percent) and sericite (0-3 percent) (fig. 7). Fissility increases as quartz and carbonaceous material increase and calcite decreases. Quartz grains exhibit angular to subangular detrital outlines and occasionally very incipient recrystallization, whereas calcite is xenoblastic. The texture of the rock varies from a mosaic of equidimensional calcite and quartz in siliceous marble, which locally exhibits fine bedding laminations marked by concentrations of heavy minerals (generally magnetite, with minor zircon),

Table 2. *Fossils*

Locality (plate 1)	Fossils	Age
	Northern Terrane	
1[a]	Possible *Amphipera* sp. *Disphyllum?* sp. cf. *Grypophyllum* sp.	Devonian, probably Middle Devonian
2[a]	*Disphyllum?* sp.	Probably Middle or Early Late Devonian (Frasnian)
3[a]	*Disphyllum?* sp. *Phillipsastraea* sp. *Tabulophyllum* sp.	Late Devonian (Frasnian)
4[b]	Echinoderm clastic particles, some of which are pelmetezoan columnels	Ordovician to Permian or possibly younger.
	Southern Terrane	
5[c]	Conodants	Triassic
6[d]	*Inoceramus* cf. *concentricus* (possibly allochthonous)	Mid-Cretaceous

[a]Identified by W.A. Oliver, Jr., U.S. Geological Survey
[b]Identified by J.T. Dutro, U.S. Geological Survey
[c]Reported by Hickman and Craddock, 1976
[d]Identified by D.L. Jones, U.S. Geological Survey.

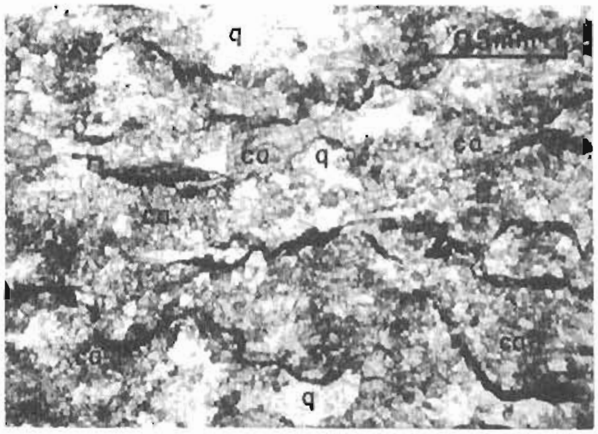

Figure 7. Photomicrograph of siliceous marble. Dark layers=carbonaceous material, ca=calcite, q=quartz. Plane light.

to phyllitic marble; the rock has a prominent cleavage where carbonaceous material and sericite are concentrated. Feldspar grains are present in trace amounts, and some grains identified as quartz in thin section may actually be untwinned feldspar.

The siliceous marble unit is in fault contact with the Wyoming Hills sequence on the north and with the slate unit on the south. The unit is cut by numerous diorite and gabbro intrusions and is overlain unconformably by the Paleocene Cantwell Formation.

SLATE UNIT

The slate unit is composed of dark-gray slate and fissile metasiltstone, metasandstone, and metaconglomerate which crop out in a northeast-trending band, 1.0 to 4.0 km wide, across the southern part of the map area (pl. 1). The easily eroded unit forms a topographic low. Near the Teklanika River the amount of topographic relief and the width of the outcrop belt suggest a structural thickness of 2,400 m for the unit.

Slate and fissile metasiltstone are the dominant lithologies, but metasandstone in beds up to 15 cm thick makes up about 10 percent of the unit. The rocks commonly display fine sedimentary laminations and crossbedding, and a phyllitic sheen. Calcareous siltstone, silty marble, and granule metaconglomerate are present as minor interbeds. The unit is commonly silicified around the margins of diorite and gabbro intrusions. A single metamorphic event has tightly folded the unit and produced rarely observed isoclinal folds and moderately to steeply dipping axial-plane cleavage. Cleavage is generally parallel to bedding, but in a few outcrops bedding is crosscut by cleavage.

Subangular silt-size quartz grains compose slightly more than half of the slate and metasiltstone; sericite and carbonaceous material make up the rest (fig. 8). Carbonaceous material either outlines small cross beds and layering in the rocks or, together with sericitized argillaceous material, is concentrated along cleavage surfaces.

Light-gray metasandstone was originally very fine to medium-grained volcaniclastic litharenite (Folk, 1974). It is composed of subangular clasts of quartz (15-40 percent), feldspar (5-20 percent), felsite (15-55 percent), chert (10-30 percent), siltstone (5-10 percent), phyllosilicate (3-10 percent), metamorphic clasts (0-10 percent), carbonate (0-5 percent), and carbonaceous material (0-5 percent). These rocks generally display a less pervasive cataclastic planar fabric than the more fissile metasiltstone, but do have broken and stretched grains lying parallel to the cleavage; quartzose grains are partially annealed. Secondary sericite, chlorite, and calcite (commonly present in crosscutting veinlets) are present in both slate and metasandstone.

The slate unit is in fault contact with the siliceous marble unit on the north and with the Cantwell formation on the south. In the eastern part of the map area, the unit is intruded by numerous diorite and gabbro intrusions. Along the Teklanika River the unit is unconformably overlain by the basal conglomerate of the Cantwell Formation.

GABBRO

Numerous northeast-trending intrusions of dark gray-green fine- to medium-grained gabbro and minor diorite occur throughout the siliceous marble unit and also cut the slate unit in the eastern part of the map area (pl. 1). The largest mapped body covers 1.0 km^2, and many bodies are present which are too small to map.

The gabbro is composed of plagioclase (40-60 percent), augite (25-40 percent), serpentine and chlorite

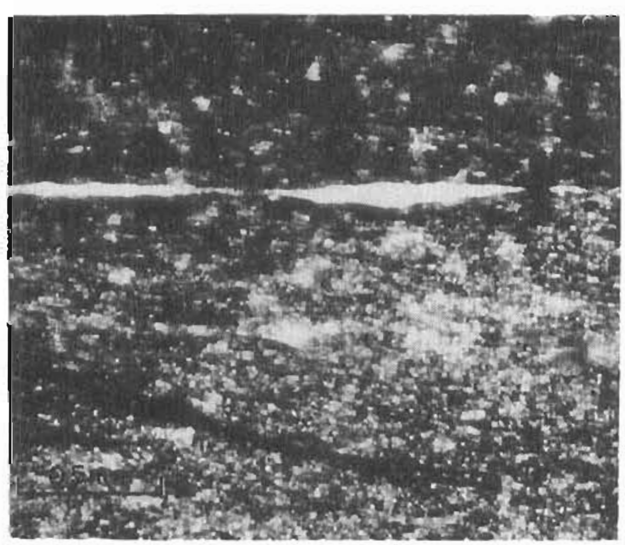

Figure 8. Photomicrograph of cross-bedded metasiltstone of slate unit. Plane light.

(10-20 percent), iddingsite (3-6 percent), quartz (0-7 percent), and trace amounts of olivine, opaque minerals, epidote, and apatite (fig. 9). The gabbro has an ophitic texture, with subhedral plagioclase laths 0.2-2.0 mm long almost completely altered to clay minerals. Anhedral augite crystals 0.3-3.0 mm across commonly include and are surrounded by clusters of fibrous serpentine and masses of chlorite and occasionally epidote. Iddingsite is generally intergrown with augite and very rarely contains a core of olivine. Quartz is interstitial and probably a late-stage magmatic derivative. Fine-grained gabbro exhibits cataclastic textures with augite commonly in shattered aggregates. Medium-grained gabbro does not show cataclasis but rather has a hypidiomorphic granular texture.

AGE AND REGIONAL CORRELATION

All rocks in the southern terrane are considered to be pre-Cenozoic. Triassic conodonts are reported from one locality in the eastern part of the siliceous marble unit (Hickman and Craddock, 1976; Hickman, pers. commun.), whereas a single specimen of *Inoceramus* found in rubble in the slate unit just east of the study area suggests a mid-Cretaceous age for that unit (table 2).

The marble and slate units are cut by numerous diorite and gabbro intrusions and are unconformably overlain by the Paleocene Cantwell Formation. Reed (1961) assigns the gabbro to the Triassic, but Hickman and Craddock (1976) favor a late Mesozoic age.

Figure 9. Photomicrograph of gabbro in southern terrane; p=plagioclase, au=augite, s=serpentine. Plane light.

Correlation with other areas is difficult because of the lithologic similarities between rocks of different ages. Hickman and Craddock (1976) consider the eastern part of the southern terrane to be part of an Upper Triassic series of argillite, limestone, and chert-pebble conglomerate that continues for 30 km east of the map area. Undifferentiated Paleozoic argillite, slate, sandstone, chert, and fossil-bearing Devonian limestone, which are intruded by Triassic(?) gabbro and overlain by Triassic(?) metabasalt, are present 5.0 km south of the study area (Reed, 1961) (fig. 1). Thus, the southern terrane is part of an extensive series of weakly metamorphosed Paleozoic and Mesozoic rocks found throughout the Alaska Range south of the Hines Creek strand of the Denali fault system.

STRUCTURE

Structures in the metamorphic terranes described in this study reflect 1) an early period of folding and dynamothermal metamorphism, 2) a later period of folding and dynamic metamorphism, 3) early Tertiary folding, and 4) late Cenozoic block faulting. The northern terrane exhibits structures from all tectonic episodes, whereas the southern terrane has structures from all but the second tectonic event.

NORTHERN TERRANE

The earliest structures preserved in the northern terrane are axial-plane foliation (S_1) and rarely observed isoclinal folds (F_1). The isoclinal folds have large amplitude-to-wavelength ratios; amplitudes are as large as several tens of meters. The general attitude of the primary foliation (S_1) is similar to most structural trends in the west-central Alaska Range, generally striking along an azimuth of 60° and dipping moderately southeast or, less commonly, northwest (fig. 10).

Overprinted on the earliest preserved tectonic features are structures from a later dynamic metamorphic episode. Open to subisoclinal folds (F_2) have wavelengths that range from microscopic to several tens of meters, but small crenulations are most commonly observed (figs. 11 and 12). The lower limbs of F_2 antiforms and synforms are commonly thinned or sheared. F_2 folds occasionally obliterate earlier tectonic features in the Birch Creek Schist, but are less well developed in the Wyoming Hills sequence. As shown in figure 13, F_2 fold axes trend approximately S. 55° W. and plunge approximately 70°. A slip cleavage (S_2) has formed parallel to F_2 axial surfaces, along which a micaceous schistosity has developed locally and which has a general azimuth of 60° and a gentle dip (fig. 14).

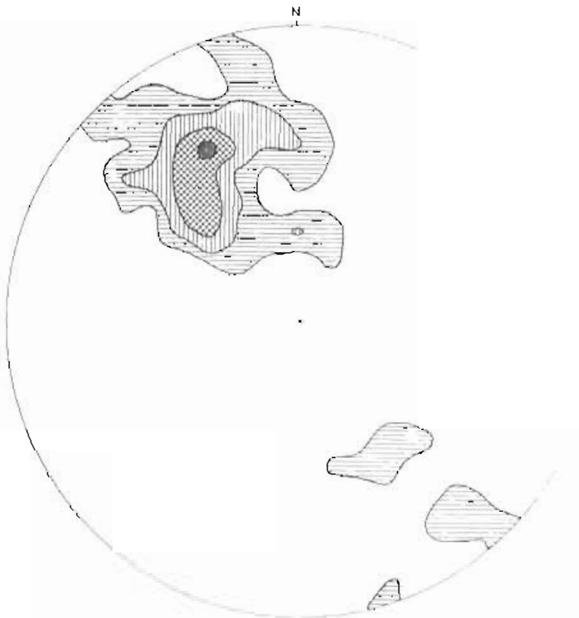

Figure 10. Lower hemisphere equal-area plot of 216 poles to S_1 foliation and cleavage in northern terrane. Contour interval at 2, 4, 6, and 8 percent per 1-percent area.

SOUTHERN TERRANE

In the southern terrane only a single period of folding and metamorphism has affected the rocks (fig. 15). Scattered fold axes have a gently dipping southwest trend (fig. 16). Cleavage orientation in rocks of the southern terrane (fig. 17) is similar to the S_1 foliation orientation in the northern terrane (fig. 10) and is different from S_2 cleavage in the northern terrane (fig. 14), possibly indicating that an early strong regional metamorphic event produced structures in both terranes. The absence of evidence for a second episode of folding and metamorphism in the southern terrane suggests that the two terranes were separated far enough so that only the northern terrane was affected by the second, weaker metamorphic event.

CENOZOIC STRUCTURES

Early Cenozoic folding and late Cenozoic block faulting affected both metamorphic terranes and the overlying Paleocene Cantwell Formation (pl. 1) (Gilbert, 1975; Gilbert and Redman, 1975). Fold axes shown in plate 1 reflect early Cenozoic folding. The vague girdle suggested by S surfaces in both terranes (figs. 10, 14, and 17) most likely reflects northeast-

Figure 11. Folded Birch Creek Schist, showing prominent F_2 folds.

trending open to closed folds formed at this time (Gilbert, 1975).

HINES CREEK FAULT

Although the Hines Creek fault projects from the east into the Wyoming Hills fault in the study area, the Hines Creek fault in this report is considered to be the tectonic contact between the two dissimilar metamorphic basement terranes. The fault probably merges with the Wyoming Hills fault near the Teklanika River in the northeast part of the map area (pl. 1).

West of the East Fork Toklat River, the Hines Creek fault dips about 45° north and consists of a zone about 150 m wide that contains slivers from both the northern and southern terranes (fig. 18). This portion of the fault shows no evidence of Cenozoic movement. East of the East Fork Toklat River, the Hines Creek fault has apparently been rejuvenated as a high-angle fault during Cenozoic block faulting (Gilbert, 1975).

Figure 12. Photomicrograph of sericite-quartz phyllite of Wyoming Hills sequence showing S_1 foliation and crosscutting S_2 cleavage. Plane light.

CONCLUSION

In the area of the Toklat and Teklanika rivers, the Hines Creek fault juxtaposes two distinct metamorphic terranes. The northern terrane was formed by multiple

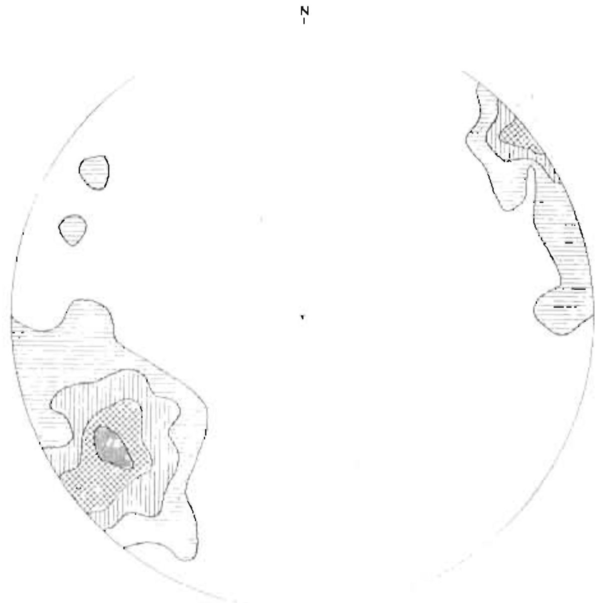

Figure 13. Lower hemisphere equal-area plot of 155 F_2 fold axes in northern terrane. Contour interval at 2, 4, 6, and 8 percent per 1-percent area.

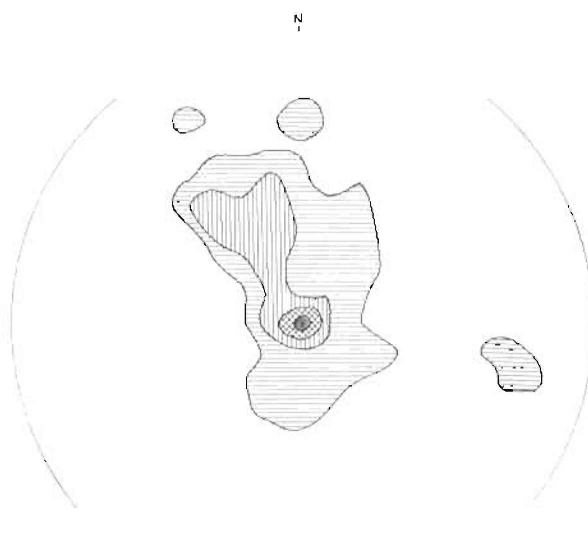

Figure 14. Lower hemisphere equal-area plot of 111 poles to S_2 cleavage in northern terrane. Contour interval at 2, 4, 6, and 8 percent per 1-percent area.

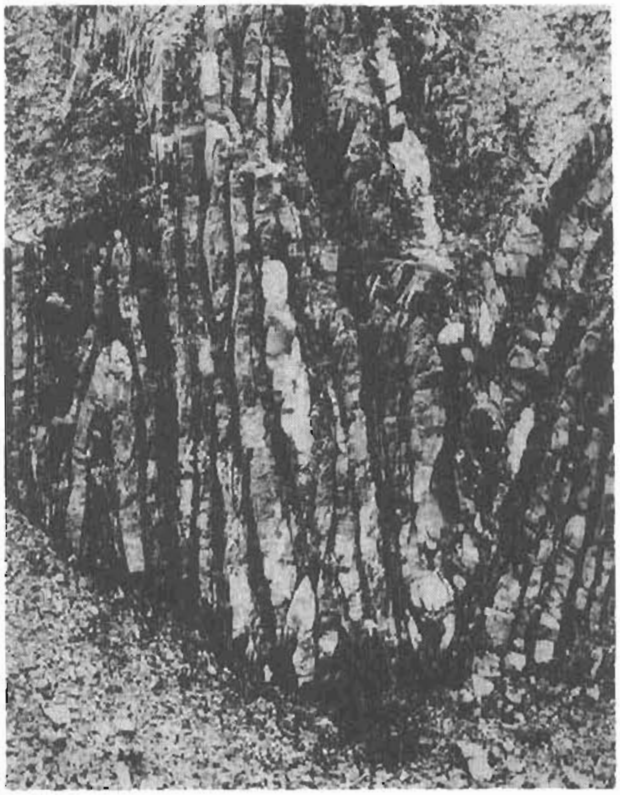

Figure 15. Folds in siliceous marble unit on east side of Wyoming Hills.

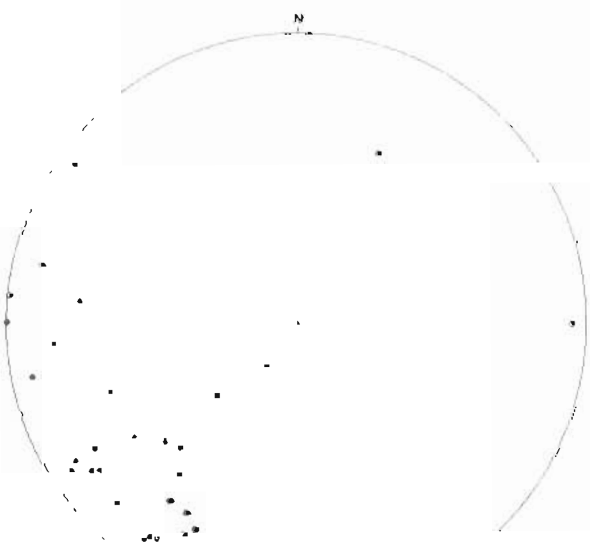

Figure 16. Lower hemisphere equal-area plot of 30 fold axes in southern terrane.

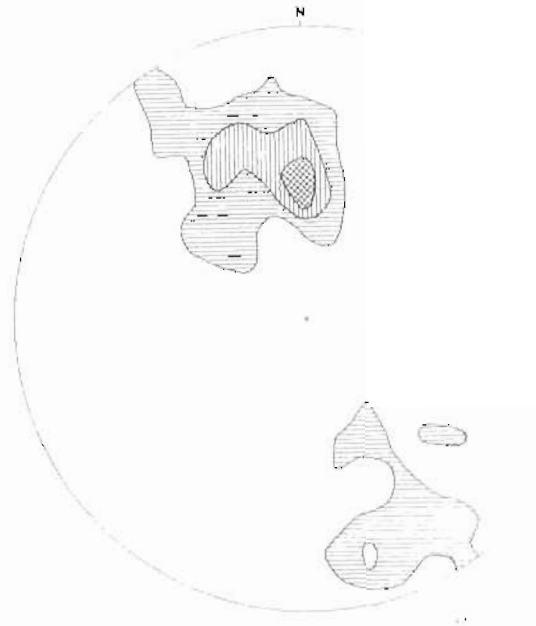

Figure 17. Lower hemisphere equal-area plot of 181 poles to cleavage in southern terrane. Contour interval at 2, 4, and 6 percent per 1-percent area.

deformation of quartz-rich predominantly clastic sedimentary rocks. Moreover, correlation of metavolcanic parts of the Wyoming Hills sequence with nearby coeval metavolcanic sequences suggests that mid-Paleozoic andesitic volcanism affected at least 5,000 km^2 in central Alaska.

The weakly metamorphosed Mesozoic rocks of the southern terrane probably represent land-derived, marine clastic and pelagic sediments. Gabbro intrusions, which are characteristic of this terrane, together with equivalent mafic extrusive rocks, suggest tectonic instability in latest Mesozoic time. By Cenozoic time, however, both terranes were juxtaposed along the Hines Creek strand of the Denali fault system.

ACKNOWLEDGMENTS

The authors wish to thank the National Park Service, in particular Daniel Kuehn and Vernon Ruesch, superintendents of Mt. McKinley National Park, for their cooperation during our field studies.

The paleontological information given by W.A. Oliver, J.T. Dutro, and D.L. Jones of the U.S. Geological Survey is greatly appreciated.

In addition, special thanks are due to John E. Decker, Florence R. Weber, Thomas K. Bundtzen, Thomas E. Smith, and Richard D. Reger for their helpful criticism and review of the manuscript, and to Richard Jirik and John W. Buza for their assistance in the field.

Figure 18. Looking west at trace of Hines Creek Fault (black line) in Wyoming Hills.

REFERENCES CITED

Brooks, A.H., 1911, The Mount McKinley region, Alaska: U.S. Geol. Survey Prof. Paper 70, 243 p.

Bundtzen, T.K., 1976, Progress report, geology and mineral deposits of the Kantishna Hills: Alaska Div. Geol. and Geophys. Surveys Open-File Rept. 98, 80 p.

Capps, S.R., 1919, The Kantishna region, Alaska: U.S. Geol. Survey Bull. 687, 118 p.

____, 1932, The eastern portion of Mount McKinley National Park: U.S. Geol. Survey Bull. 836-D, p. 219-300.

____, 1940, Geology of the Alaska Railroad region: U.S. Geol Survey Bull. 907, 201 p.

Folk, R.L., 1974, Petrology of sedimentary rocks: Hemphill Publishing Company, Austin, Texas, 182 p.

Gilbert, W.G., 1975, Outline of tectonic history of west-central Alaska Range: Geol. Soc. America Abs. with Programs, Cordilleran Section, p. 320.

____, 1977, General geology and geochemistry of the Healy D-1 and southern Fairbanks A-1 quadrangles and vicinity: Alaska Div. Geol. and Geophys. Surveys Open-File Rept. 105, 12 p., 2 maps.

Gilbert, W.G., and Redman, Earl, 1975, Geologic map and structure sections of Healy C-6 quadrangle, Alaska: Alaska Div. Geol. and Geophys. Surveys Open-File Rept. 80, 1 p., map.

Gilbert, W.G., Ferrell, V.M., and Turner, D.L., 1976, The Teklanika Formation—A new Paleocene volcanic formation in the central Alaska Range: Alaska Div. Geol. and Geophys. Surveys Geol. Rept. 47, 16 p.

Hickman, R.G., 1974, Structural geology and stratigraphy along a segment of the Denali fault system, central Alaska Range, Alaska: Unpub. Ph.D. thesis, Madison, University of Wisconsin, 276 p.

Hickman, R.G., and Craddock, Campbell, 1976, Alaska Div. Geol. and Geophys. Surveys Open-File Rept 95, 3 maps.

King, P.B. (compiler), 1968, Tectonic map of North America, U.S. Geol. Survey map.

Morrison, D.A., 1964, Geology and ore deposits of Kantishna and vicinity, Kantishna district, Alaska: Unpub. M.S. thesis, Fairbanks, University of Alaska, 109 p.

Redman, Earl, 1974, Geology of the Wyoming Hills, Mount McKinley National Park, Alaska: Unpub. M.S. thesis, Fairbanks, University of Alaska, 61 p.

Reed, J.C., Jr., 1961, Geology of the Mount McKinley quadrangle, Alaska: U.S. Geol. Survey Bull. 1108-A, 36 p.

Wahrhaftig, Clyde, 1968, Schists of the central Alaska Range: U.S. Geol. Survey Bull. 1254-E, 22 p.

Wegner, W.W., 1972, The Denali fault (Hines Creek strand) in the northeastern Mount McKinley National Park, Alaska: Unpub. M.S. thesis, Madison, University of Wisconsin, 74 p.