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GEOLOGY AND GEOCHRONOLOGY OF THE HEALY QUADRANGLE, ALASKA

By

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Pamphlet comprising Abstract, Introductory remarks, Description of map units, Structure, Tectonics, Table of potassium-argon age determinations, Table of fossil data, and Reference list to accompany the four map sheets of

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GEOLOGY AND GEOCHRONOLOGY OF THE HEALY QUADRANGLE, ALASKA

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ABSTRACT

The Healy quadrangle is underlain by a wide variety of sedimentary, volcanic, and plutonic rocks, ranging in age from Precambrian and (or) early Paleozoic to Recent. There are fifty five map units on the geologic map. All the pre-Cenozoic rocks are intensely deformed, mainly by overthrusting and folding, and most of them underwent at least one period of low- to medium-grade regional metamorphism. This deformation is the result of the middle Cretaceous collision and subsequent obduction of the northward-moving Talkeetna superterrane with and onto the Yukon-Tanana and Nixon Fork terranes of the ancient North American continent. Late Cenozoic deformation, the result of continued northward plate motions, has modified but not substantially altered the geology of the quadrangle.

INTRODUCTORY REMARKS

Geologic mapping of the Healy quadrangle was undertaken between 1978 and 1982 by the U.S. Geological Survey as part of a multidisciplinary effort to assess the mineral resource potential of the quadrangle. The multidisciplinary effort included geological, geochemical, and geophysical investigations, all carried out under the auspices of the Survey's Alaska Mineral Resource Assessment Program (AMRAP). The geologic map and accompanying discussions of this report constitute the first of a series of planned publications presenting the results of these investigations.

To a large extent, the geologic map of this report is a compilation and reinterpretation of the work of a number of geologists who within the last twenty years, in association with a number of geologic research organizations, conducted geologic mapping in the Healy quadrangle. Most of these geologists who were principal investigators are listed as authors in this report. As in the case of any geologically complex area investigated by a number of geologists, a unanimity of opinion among them could not be reached on either all details of the geologic map or larger interpretations. Thus, the geologic map and interpretations of this report primarily reflect the views and opinions of the first three authors, and not necessarily those of the others. Geologists with differing opinions and views on the geology of the Healy quadrangle and adjacent regions are encouraged to publish those views in the geologic literature in the hope that a full exposition of the diversity of views on this challenging region of Alaska will contribute to further resolutions of the geologic problems.

DESCRIPTION OF MAP UNITS
Sedimentary and volcanic rocks

Qs SURFICIAL DEPOSITS, UNDIFFERENTIATED (Quaternary)—Glacial drift of several ages, including moraines, outwash, and lake deposits; alluvium and colluvium including several landslides, especially along the Alaska Railroad in the Nenana River canyon (Wahrhaftig and Black, 1958). All mainly consist of unconsolidated gravel, sand, silt, clay; and the landslides include blocks of bedrock.

Thd HORNBLENDE DACITE (Pliocene)—Subvolcanic intrusive of Jumbo Dome, in north-central part of quadrangle. An age determination on basaltic hornblende by the K-Ar method (M.A. Lanphere in Wahrhaftig, 1970d) yielded a Pliocene age (2.79 ±0.25 m.y.; map no. 1 on Table 1).

Tng NENANA GRAVEL (Miocene(?) and Pliocene)—Poorly consolidated, buff to reddish-brown-colored, fluvial sequence of pebble- to boulder-conglomerate and coarse-grained sandstone with interbedded mudflow deposits, thin claystone layers, and local thin lignite beds. Sequence is moderately deformed, is over 1,300 m thick, and occurs mostly along the northern flank of the Alaska Range. Near the mouth of Honolulu Creek, in the southwestern part of the quadrangle, an isolated patch of buff-weathering, unfossiliferous and unconsolidated pebble- to boulder-conglomerate and coarse-grained sandstone appears to be lithologically very similar to rocks of the Nenana Gravel to the north (Inyo Ellersieck, oral commun., 1984), and thus is shown on the map as "Tng?". The Nenana Gravel rests unconformably on rocks as old as the Precambrian and(or) early Paleozoic pelitic and quartzose schist sequence (unit Pqs). Locally, however, the contact is conformable with the underlying Tertiary coal-bearing rocks (unit Tcbu; Capps, 1940; Wahrhaftig, 1958). Because of the lack of diagnostic fossils, the age of the Nenana Gravel is uncertain, but it appears to be older, on the basis of regional geological and geomorphological considerations, than the Pliocene (about 2.79 m.y. old) hornblende dacite intrusive of Jumbo Dome (Wahrhaftig, 1970a, 1975, oral commun., 1984). The lower age bracket is provided by the late Miocene age of the underlying Grubstake Formation of the undivided coal-bearing rocks (unit Tcbu; Wahrhaftig and others, 1969). Thus, the bulk of the Nenana Gravel is most probably of Pliocene age, but its basal portion may be as old as late Miocene (Capps, 1940; Wahrhaftig, 1970a, 1970d, 1970e, 1975). The deposition of the Nenana Gravel is interpreted to mark a still ongoing Late Cenozoic orogenic activity of uplift and relatively minor deformation in south-central Alaska. The present topographic relief of south-central Alaska, including the Alaska Range, is the result of this orogenic activity (Capps, 1940; Wahrhaftig, 1970a, 1975).

Tcbu COAL-BEARING ROCKS, UNDIVIDED (Eocene to Miocene)—This map unit mostly comprises, in ascending order, the Healy Creek, Sanctuary, Suntrana, Lignite Creek, and Grubstake Formations of the Nenana coal field in the northern part of the quadrangle, consisting of terrestrial rocks of Eocene and early to late Miocene in age (Capps, 1940; Wahrhaftig and others, 1969; Wahrhaftig, 1970b, 1970c, 1970d, 1970e; Inyo Ellersieck, oral commun., 1983; present age assignments as revised by J.A. Wolfe, oral commun., 1984). The map unit also includes the Oligocene or Miocene coal-bearing rocks between Sable Pass and Polychrome Pass (Gilbert and Redman, 1975), and the coal-bearing deposits of Oligocene age (J.A. Wolfe, oral commun., 1984) at the Dunkle mine along Costello Creek in the southwest part of the quadrangle (Wahrhaftig, 1944). Provisionally correlated with unit Tcbu are the scattered exposures of unfossiliferous, lignite-bearing, poorly consolidated sedimentary rocks near Broad Pass Station on the Alaska Railroad (Hopkins, 1951). According to A.J. Wolfe (oral commun., 1984), the lower part of the Healy Creek Formation, of areally limited extent and containing the so-called Rex Creek flora, is not of late Oligocene age, as previously reported in Wahrhaftig and others (1969), but is Eocene in age.

The coal-bearing rocks comprise terrestrial cyclic sequences, in varying proportions, of siltstone, claystone, mudstone, shale, generally cross-bedded and pebbly sandstone, both arkosic and quartz-rich, subbituminous coal and lignite, and minor amounts of dominantly quartz- and chert-pebble conglomerate. All of these rocks are characteristically poorly consolidated. More detailed lithologic descriptions of the coal-bearing rocks can be found in Wahrhaftig (1944), Wahrhaftig and others (1969), and Hopkins (1951). Available plant fossil data for the coal-bearing rocks in the quadrangle are summarized under map nos. 1 to 3 on Table 2.

The thickness of the coal-bearing rocks varies greatly as a result of their deposition on an irregular surface of moderate relief, lateral facies changes, and of pre-Nenana Gravel erosion. In the Nenana coal field, some of the individual formations comprising the coal-bearing rocks may reach maximum thicknesses of over 600 m. However, at any one locality within the Nenana coal field the total maximum thickness of the coal-bearing rocks does not exceed about 900 m. Some of the coal seams are as much as 20 m thick, but most have a maximum thickness of only a few meters. Outside the Nenana coal field the thickness of the coal-bearing rocks is imperfectly known as a result of poor exposures. At the Dunkle mine more than 150 m of coal-bearing rocks are known to be present, and individual coal beds are as much as 2 m thick.

Current directions measured on the coal-bearing rocks within the Nenana coal field by Wahrhaftig and others (1969) show a generally southward stream-flow pattern, indicating that the site of the present central Alaska Range at that time was a lowland (Wahrhaftig, 1970a, 1975).

The coals within the coal-bearing rocks range in rank from subbituminous to lignite. Heating values determined on coal samples from the Nenana coal field and from the Dunkle mine generally are between 7,000 and 12,000 Btu's (British thermal units; Wahrhaftig, 1951; Wahrhaftig and others, 1951; Barnes, 1967). The Nenana coal field has been and still is a major coal-producer in Alaska. Current mining is by stripping along Healy Creek and Lignite Creek (Sanders, 1975; Parks, 1983). At present, the bulk of the mined coal is used in power plants generating electricity for the city of Fairbanks. In addition to production from the Nenana coal field, some coal was produced in the past from the coal-bearing rocks along and near the Alaska Railroad, for example at the Dunkle mine until 1954, primarily for heating in communities along the railroad. A more exhaustive discussion on the economic potential of the coal reserves of the quadrangle will be given in a subsequent publication as part of the folio on the geology and economic resources of the Healy quadrangle.

Tfv FLUVIATILE AND SUBORDINATE VOLCANIC ROCKS (Eocene?)—These rocks comprise an intercalated, fluviatile, only slightly deformed sequence of conglomerate, sandstone, siltstone, and mudstone, and a few interlayered, thin flows of basaltic andesite. They rest unconformably on intensely and penetratively deformed Late Jurassic to early Late Cretaceous flysch deposits (unit KJfa), and are exposed in a narrow band of erosional remnants along ridge tops near the headwaters of the West Fork of the Chulitna River, in the southwestern part of the quadrangle, south of the McKinley fault of the Denali fault system. Although the top of this fluviatile and volcanic sequence is nowhere exposed, a maximum thickness of about 100 to 150 m still remains.

At the exposures adjacent to the headwaters of Colorado Creek, the conglomerates form massive, apparently lenticular layers a few to several tens of meters thick. They are whitish gray and poorly to moderately well cemented, with a chalky sand and clay matrix. The clasts are clay coated, subangular to well rounded, and commonly between 1 and 3 cm in diameter, although some are as much as 10 cm across. Most of the clasts consist of white quartz and gray and black chert, but a subordinate amount is composed of gray quartzite, massive as well as laminated limestone, fine-grained pink sandstone, light-green and medium-brown chert, and fine-grained chert conglomerate. The intercalated sandstone, siltstone and shale occur in beds as much as a few meters thick, are gray and brown, and contain carbonized plant fragments.

Hoping to establish a source area or correlation with similar rock types elsewhere in the quadrangle or in Alaska, the limestone clasts were examined by M.W. Mullen for lithology and for microfossil content. Five different rock types were determined and named, using the carbonate classification scheme of Dunham (1962). These rocks are: (1) brown, finely crystalline limestone with no recognizable sedimentary structures, (2) dark brownish-gray, thinly laminated mudstone, (3) dark bluish-gray, thinly laminated mudstone, (4) dark bluish-gray, sandy wackestone containing about 17 percent detrital quartz, and (5) dark bluish-gray, thinly bedded (up to 2 cm) silty mudstone alternating with dark gray calcareous shale. The latter two clast types contain distinctive Upper Devonian conodont faunas. (For more detailed paleontology, see map nos. 5 and 8 on Table 2). The source of these limestone clasts is still unknown, but they possibly may be from the belt of Paleozoic rocks (unit DOs) which crops out about 10 km to the north, across the McKinley fault, where rocks of Devonian age have been found (Capps, 1932, 1940; Jones and others, 1983; and Reed, 1961).

One of the carbonized plant fragments from a shale interbed near the headwaters of Colorado Creek (map no. 6 on Table 2) has been identified by J.A. Wolfe (oral commun., 1982, 1984) as Metasequoia occidentalis (Newberry) Chaney, which ranges in age through the Paleocene to early Eocene. This plant fossil is also part of the flora of the Paleocene and fluviatile rocks of the Cantwell Formation to the north of and across the McKinley fault of the Denali fault system (Wolfe and Wahrhaftig, 1970; Wolfe and Tanai, 1980). Based on the occurrence of Metasequoia occidentalis, and on lithologic and stratigraphic similarities, the fluviatile and volcanic rocks (unit Tfv) south of the McKinley fault have been tentatively correlated in the past with the sedimentary rocks unit of the Cantwell Formation (unit Tc) across the fault (Csejtey and others, 1984). However, subsequent reexamination of poorly preserved broad-leafed plant fossils from the fluviatile rocks (unit Tfv) south of the fault (map nos. 6 and 7 on Table 2) by J.A. Wolfe (oral commun., 1984) provisionally suggests that these rocks are early Eocene in age, that is, slightly younger than the Paleocene Cantwell Formation, and thus the two rock sequences are not correlatable.

In view of the lithologic and stratigraphic similarities, the uncertainty of the age determination on the broad-leafed plant fossils, and(or) the possibility of the Cantwell Formation extending in age into the early Eocene, the first author of this report believes that correlation between the two sequences still is a possibility. Reliably proving or disproving the correlation between the two rock sequences would have decisive importance on deciphering the Cenozoic movement history of the Denali fault system, a still controversial problem for interpreting the tectonic evolution of Alaska.

CANTWELL FORMATION (Paleocene)—The Cantwell Formation (Eldridge, 1900; Capps, 1940; Wolfe and Wahrhaftig, 1970) consists of an upper volcanic unit (map unit Tcv) and a lower sedimentary rocks unit (map unit Tc). The Formation occurs in a large, east-west trending synclinorium north of the McKinley fault of the Denali fault system.

Tcv

Volcanic rocks unit of Cantwell Formation—These rocks comprise an intercalated, moderately deformed sequence of andesite, generally zeolitized basalt, rhyolite and dacite flows, dominantly felsic pyroclastic rocks, a few interbeds of sandstone and carbonaceous mudstone, and a few small bodies of related subvolcanic intrusive rocks. The Cantwell volcanic rocks occur in fairly large but discontinuous patches overlying the Cantwell sedimentary rocks, mostly at or in the vicinity of Polychrome Pass, Mt. Fellows, and Dick Creek. At many localities, the contact with the underlying Cantwell sedimentary rocks seems to be conformable, but at some localities it appears to be a slight angular disconformity. The individual flows are from a few meters to several tens of meters thick, many of them are vesicular or amygdaloidal, and the basalts and andesites frequently exhibit columnar jointing. The maximum preserved thickness of the Cantwell volcanic rocks is over 3,700 m (Gilbert and others, 1976). Their stratigraphic position, resting on Paleocene sedimentary rocks of the Cantwell Formation, and potassium-argon age determinations (map nos. 15, 18, 19, 21, 22, 23, 24, and 25 on Table 1) indicate that the Cantwell volcanic rocks are themselves of Paleocene age. Their lithology and age further indicate that they are an integral part of an early Tertiary volcanic activity, of a great variety of rock types, involving not only the Healy quadrangle but large areas of south-central Alaska as well. Where similar early Tertiary volcanic rocks are not spatially associated with the Cantwell sedimentary rocks, they are shown on the geologic map as units Tv, Tif, and Tim. More detailed lithologic descriptions of the Cantwell volcanic rocks can be found in Hickman (1974), and in Gilbert and others (1976), who have referred to these rocks as the Teklanika Formation.

Tc Sedimentary rocks unit of Cantwell Formation—These rocks consist of a fluviatile, intercalated sequence, in varying proportions, of dominantly polymictic conglomerate, sandstone (including arkose), siltstone, argillite, shale, and a few thin coal beds. Locally, the rocks contain thin flows and related tuff layers of mafic to intermediate composition. The Cantwell sedimentary rocks are also intruded by numerous dikes and sills ranging in composition from diabase to rhyolite. Bedding usually is massive and regionally lenticular. The rocks are generally moderately well to locally very well indurated and their color commonly ranges from dark to medium gray to dark brown. The maximum preserved thickness of the Cantwell sedimentary rocks is about 3,000 m, and these moderately deformed rocks rest everywhere with a pronounced angular unconformity on intensely deformed and(or) metamorphosed older rocks of Precambrian(?) to Early Cretaceous age.

The lithology of the conglomerate clasts varies greatly within the outcrop area of the Cantwell Formation, indicating that the clasts were derived from a number of geologically different source areas, and were deposited by a number of river systems. A good example of deposition by different river systems and accompanying difference in clast composition can be seen around the headwaters area of the Teklanika River. East of the river, the Cantwell sedimentary rocks comprise a thick sequence of quartz-rich, fairly well sorted, medium- to dark gray and dark brown sandstone which changes eastward into pebbly sandstone and conglomerate of well-rounded clasts. The clasts consist of white quartz, black to gray chert, white to gray quartzite, dark-gray fine-grained sandstone, black argillite, and subordinate red chert and green chert. Due west and southwest of the river, the Cantwell sedimentary rocks dominantly consist of poorly sorted pebble and cobble conglomerates with well-rounded to subrounded clasts of medium-gray to black, fine-grained sandstone; gray to black argillite; massive or laminated, medium to dark bluish gray limestone (locally constituting as much as 25 percent of the clasts); black chert; medium to dark greenish gray, finely crystalline, altered volcanic rock of mafic to intermediate composition; white quartz; red chert; medium-gray quartzite; and minor green chert. The clasts are contained in a medium- to coarse-grained sandstone matrix of similar composition. The overall color of these conglomerates is dark to medium gray, locally with a greenish hue. The two areas of dissimilar, apparently river channel conglomerates and sandstones are separated by an about 2 to 3 km wide zone of an intercalated, thinly to thickly bedded sequence of shale, siltstone, and fine-grained sandstone, interpreted to be flood plain deposits.

The limestone clasts in the Cantwell Formation west and southwest of the Teklanika River were derived mainly from units DOs and Dls. The limestone clasts from unit DOs comprise the following rock types: laminated, dark-gray to black, radiolarian-bearing lime mudstone; medium-gray, bioclastic, lime mudstone and wackestone; medium-gray, intraclastic lime packstone; and cross-laminated, medium-gray, lime bioclastic grainstone (carbonate nomenclature according to Dunham, 1962; also see map nos. 9, 10, and 11 on Table 2). The limestone clasts from unit Dls consist of light-gray recrystallized limestone and dolomitic limestone. Also, there are a few clasts of calcareous sandstone and sandy to silty limestone which probably were derived from the sedimentary interbeds of unit TRbd.

As mentioned previously, the clast composition of the Cantwell conglomerates varies greatly between exposure areas of the Formation. In the area just south and east of the Wood River, pebbles of white quartz, black chert, and dark-gray sandstone and argillite predominate, but numerous well-rounded clasts of mica schist and phyllite, which are identical to and thus most probably were derived from the Precambrian(?) and Paleozoic metamorphic rocks north and west of the Wood River, also occur. In the region between Sable and Polychrome Mountains, the Cantwell conglomerates generally contain pebbles, locally as much as 10 percent, of impure limestone which lithologically and in age (determined by conodont studies, see map no. 13 on Table 2) are identical to limestones in the Upper Triassic calcareous sedimentary rocks (unit TRcs) cropping out about 10 km to the north. Many of the dark gray to black argillite and sandstone clasts, ubiquitous to most Cantwell outcrops, probably were derived from the Upper Jurassic to Lower and(or) Upper Cretaceous flysch-like rocks (units KJf, KJfk, KJfa) which occur in large areas of the quadrangle. It appears that although a considerable portion of the clasts in the Cantwell sedimentary rocks came from nearby source areas, a large, perhaps the dominating portion of the clasts, such as most of the white quartz and black chert, must have originated from still unknown and possibly distant provenances.

Additional lithologic description of the Cantwell Formation can be found in Eldridge (1900), Capps (1940), Wolfe and Wahrhaftig (1970), Decker (1975), and Csejtey and others (1984).

The age of the Cantwell Formation has been determined, on the basis of plant fossils, by Wolfe and Wahrhaftig (1970), and by J.A. Wolfe in Hickman (1974), and in Sherwood and Craddock (1979) to be Paleocene (map nos. 12, 14 to 20, 22, and 23 on Table 2). However, two small granitic stocks (unit TKgr) apparently intruding the Cantwell sedimentary rocks, one in Riley Creek and the other along the Nenana River, yielded Late Cretaceous potassium-argon ages (78.7 and 71.9 m.y., map nos. 17 and 26, respectively, in Table 1; Hickman, 1974; Hickman and Craddock, 1976; Sherwood and Craddock, 1979). Trying to resolve the conflicting paleobotanical and potassium-argon ages, two possibilities are herein considered to be most likely: (1) perhaps due to excess argon, the potassium-argon age determinations yielded somewhat older than crystallization ages, and (2) the basal portion of the Cantwell sedimentary rocks may be as old as Late Cretaceous, and thus the Cantwell Formation has a range in age from Late Cretaceous through the Paleocene.

The moderately deformed Cantwell Formation overlies all older rock units, all intensely and penetratively deformed and ranging in age from Precambrian(?) to Early Cretaceous (also see map no. 21 on Table 2), with a pronounced angular unconformity. Thus, the age and stratigraphic position of the Cantwell Formation provide an upper age limit for the main phase of the late Mesozoic orogenic deformation of south-central Alaska, at least for the region north of the Denali fault system.

The lithologic and stratigraphic characteristics, and the distribution pattern of the Cantwell sedimentary rocks, being preserved in a late Cenozoic synclinorium, strongly suggest that the present exposures of the Cantwell rocks are only the erosional remnants of formerly much more extensive deposits. These features further suggest deposition in a basin of considerable relief, occupying at least a part of the area of the present central Alaska Range, by a complex network of braided rivers with multiple flow directions.

Tsu TERTIARY SEDIMENTARY ROCKS, UNDIVIDED (Paleocene(?) to Miocene(?)—Poorly consolidated, fluviatile sequence of dark-gray shale, yellowish-gray sandstone, siltstone, and pebble conglomerate of dominantly gray quartz and black chert. These rocks occur in poorly exposed outcrops containing indeterminate plant fossil fragments (map no. 4 on Table 2) along the Jack River. Although their age is unknown, their lithologic characteristics suggest that they are part of the Paleocene to Miocene continental rocks of the quadrangle, possibly correlative with the Eocene to Miocene coal-bearing rocks (unit Tcbu).

TERTIARY VOLCANIC ROCKS (Paleocene to Oligocene)—These rocks are shown in three separate units on the geologic map: unit Tv is mostly subaerial flows and associated pyroclastic rocks ranging in composition from rhyolite to basalt; unit Tif is subvolcanic dikes, sills, and small plugs of felsic composition; and unit Tim is small subvolcanic bodies and dikes of mafic composition. All three rock units, along with the Cantwell volcanic rocks (unit Tcv), are considered to be genetically related, and to be part of the same early Tertiary igneous activity, both plutonic and volcanic, prevalent over large regions of south-central Alaska. Paleomagnetic investigations by Hillhouse and Grommé (1982) and by Hillhouse and others (1984, 1985) on early Tertiary volcanic rocks (units Tcv and Tv), which straddle the Hines Creek and McKinley faults and the Talkeetna thrust in the Healy and Talkeetna Mountains quadrangles, indicate that all these volcanic rocks were formed essentially in their present positions relative to the North American continent.

Tv <u>Volcanic flows, pyroclastic rocks, and subordinate subvolcanic intrusives</u>—Rocks mapped as part of this unit occur in several varying-sized outcrop patches, mostly in the south-central part of the quadrangle where they appear to be part of perhaps several but closely spaced volcanic centers. The bulk of these rocks are moderately altered rhyolites and basalts, but rocks of intermediate compositions, namely andesite, dacite and latite, also occur. The rhyolites are generally cryptocrystalline to very fine grained with quartz and sanidine phenocrysts. The basalts are generally fine grained, with ophitic to subophitic textures, and their major rock forming minerals are sodic labradorite and augite. The rhyolite flows, from a few to several tens of meters thick, commonly display columnar jointing. A potassium-argon age determination on sanidine from a rhyolite flow near the East Fork of the Chulitna River yielded an Eocene age of 53 m.y. (map no. 53 on Table 1).

Tim — Mafic subvolcanic intrusive rocks—Dikes and small hypabyssal intrusive bodies of dark gray basalt, diabase, and subordinate andesite. These rocks occur with varying frequency in the western half of the quadrangle, but only the larger bodies in the northern part of the quadrangle are shown on the geologic map. A potassium-argon age determination from a basalt dike near Sugarloaf Mountain yielded an Eocene age of 54.7 m.y. (map no. 20 on Table 1; Bultman, 1972; Sherwood and Craddock, 1979).

Tif — Felsic subvolcanic intrusive rocks—Dikes and small hypabyssal intrusive bodies with subordinate associated pyroclastic rocks, of dominantly tan-colored, aphanitic to very fine-grained, locally porphyritic rhyolite, quartz latite, latite, and dacite. These rocks are fairly common throughout the quadrangle, especially in the western half. Four potassium-argon age determinations on felsic rocks near Sugarloaf Mountain yielded early Oligocene ages (map nos. 2, 3, 4, and 5 on Table 1; Albanese, 1980). The association of felsic dikes with Eocene, and possibly Paleocene volcanic rocks in the south-central part of the quadrangle strongly suggests that all the rocks mapped as unit Tif in the quadrangle range in age from Eocene, perhaps Paleocene, to Oligocene.

Plutonic rocks

Tgr — GRANITIC ROCKS (Paleocene to early Oligocene)—A wide variety of epizonal (Buddington, 1959) granitic rocks, occurring in numerous small- to medium-sized plutons throughout most of the quadrangle. The most common rock types are granite and granodiorite, but tonalite and quartz monzodiorite also occur (granitic rock nomenclature according to IUGS, 1973). The bulk of the granites have alkali feldspar and plagioclase ratios between 65 and 35, and thus could be called adamellites. Quartz content for most of these rocks is between 30 to 40 modal percent. The color index ranges from 1.4 to 13.7, but commonly it is between 6 and 10. Grain sizes range from coarse- to fine-grained, and textures from granitic to porphyritic and seriate. Some of the granitic rocks were emplaced at very shallow depths, and thus could be called hypabyssal intrusives. Where exposed, contacts with the country rocks are always sharp and discordant. The larger plutonic bodies generally have aplitic dikes associated with them, have a fine-grained border phase and a narrow contact aureole. None of the Tertiary granitic rocks display any flow foliation. Potassium-argon age determinations (map nos. 13, 16, 27 to 32, 48, 50, and 54 on Table 1) indicate that these rocks range in age from Paleocene to early Oligocene (from about 59.8 to 36.7 m.y.).

The similar age, composition, and the spatial association of the early Tertiary granitic rocks of the quadrangle with the Tertiary volcanic rocks (units Tv, Tcv, Tim, and Tif) strongly suggest that the granites essentially are the deeper-seated equivalents of the felsic volcanic rocks, and that both suites of rocks are the products of the same early Tertiary igneous activity that was prevalent in south-central Alaska.

Tgrv GRANITIC AND VOLCANIC ROCKS, UNDIVIDED (Paleocene to early Oligocene)—Extensive border zone between a large Tertiary granitic pluton (granite and granodiorite of unit Tgr) and slightly younger, numerous felsic dikes and small subvolcanic intrusives of unit Tv cutting the granitic rocks, as well as small erosional remnants of rhyolite flows capping the pluton, in the south-central part of the quadrangle.

TKgr GRANITIC AND HYPABYSSAL INTRUSIVE ROCKS (Late Cretaceous and Paleocene(?))—This unit includes two small plutons of medium-grained granodiorite, one along Riley Creek and another along the Nena River, and numerous small hypabyssal intrusive bodies of heterogeneous rock types in the area roughly between Lookout Mountain and the Bull River, in the southwest part of the quadrangle.

The two small granodiorite plutons appear to intrude the Paleocene Cantwell Formation. However, as already discussed under the Cantwell Formation, potassium-argon age determinations yielded Late Cretaceous ages for them (map nos. 17 and 26 on Table 1; Hickman, 1974; Hickman and Craddock, 1976; Sherwood and Craddock, 1979). Two possible explanations seem to be most likely: either the two plutons are both of Paleocene age, but due to perhaps excess argon the potassium-argon age determinations yielded older than crystallization ages, or the basal portion of the Cantwell Formation may be as old as Late Cretaceous.

The hypabyssal intrusive rocks in the Lookout Mountain and Bull River area form small stocks, volcanic plugs, intrusive breccia pipes, and dikes. They comprise a wide variety of rock types, namely diorite, andesite, quartz diorite porphyry, phaneritic granite, rhyolite, granite porphyry, rhyolite porphyry, quartz porphyry, coarse grained quartz monzonite porphyry, aplite, and basalt (Swainbank and others, 1977). Many of the breccia pipes are mineralized (epigenetic vein or vein-disseminate type), and metals commonly present include arsenic, silver, copper, and gold (Hawley and Clark, 1973). Lead, zinc, bismuth, tungsten, and tin are also fairly common, and molybdenum occurs at one locality at Long Creek. The most important of the mineralized breccia pipes is at the Golden Zone mine which during 1941 and 1942 produced 1,581 oz of gold, 8,617 oz of silver, 21 tons of copper, and about 3,000 pounds of lead (Hawley and Clark, 1974).

Potassium-argon age determinations on mineralized rocks from the Lookout Mountain-Bull River area (Swainbank and others, 1977) yielded Late Cretaceous and possibly Paleocene ages (minimum 58.8 to 70.6 m.y., map nos. 55 to 58 on Table 1).

Northern, eastern, and south-central parts of quadrangle

Sedimentary and volcanic rocks

Yukon-Tanana terrane

Kvb BASALTIC VOLCANIC ROCKS (Late Cretaceous)—Dark gray to black, porphyritic basalt, occurring in a swarm of dikes of limited areal extent just northwest of the headwater area of Dean Creek, in the north-central part of the quadrangle. Only the area of their general extent is shown on the geologic map. The dikes are entirely within the Paleozoic and Precambrian(?) rocks of the Yukon-Tanana terrane (units pqs and Pzmb). A potassium-argon age determination (Sherwood, 1973; Sherwood and Craddock, 1979) yielded a Late Cretaceous age of 79.1 m.y. (map no. 6 on Table 1).

TRcs CALCAREOUS SEDIMENTARY ROCKS (Late Triassic, late Karnian and middle(?) Norian stages)—The rocks of this unit occur in a discontinuous, east-west trending outcrop belt between the Hines Creek and McKinley faults, and in discontinuous exposures south of the McKinley fault, in the eastern and central parts of the quadrangle. The map unit comprises a generally thin-bedded, commonly cross-bedded, carbonaceous, dark- to medium-gray, marine, intensely deformed thick sequence of intercalated calcareous shale, argillite, sandstone, siltstone, and sandy to silty and argillaceous limestone. The sequence is interpreted to be continental slope-type turbidite and capping shelf-type deposits. Not shown separately on the map, the sequence also contains numerous large dikes, sills as much as several tens of meters thick, and small plugs of altered diabase and gabbro. In the eastern and southern parts of the quadrangle, the rocks of the sequence have been regionally metamorphosed into greenschist and amphibolite facies mineral assemblages (Csejtey and others, 1982, 1984). The metamorphosed rocks are part of a northeast-trending, apparently late-tectonic, in situ metamorphic belt, the Maclaren metamorphic belt of Smith (1974), of middle Cretaceous age (map nos. 35, 38, and 40 on Table 1; map sheet no. 4).

As indicated in a good ridge-top exposure just south of the Wood River, the Triassic calcareous sedimentary rocks (unit TRcs) rest with a slight angular unconformity on rocks of unit Pzy which are herein correlated with rock sequences of the Yukon-Tanana terrane north of the Hines Creek fault (to be discussed later). The top of the Triassic calcareous sequence is nowhere exposed.

The rocks of unit TRcs are intensely and penetratively deformed, and as mentioned earlier, locally metamorphosed. Isoclinal folding, high-angle reverse and normal faults are common. At several localities the Triassic calcareous rocks and the underlying rocks of unit Pzy have been imbricated by thrust faults of unknown amounts of horizontal displacement. The deformation is the result of at least two periods of deformation which affected south-central Alaska: a very severe orogenic deformation in about middle Cretaceous time, and a comparatively minor one in the Cenozoic (Csejtey and others, 1982). As a result of the intense deformation, the maximum preserved thickness of the Triassic calcareous sequence is uncertain but it is estimated to be several hundreds of meters.

The age range of the Triassic calcareous sequence (unit TRcs) is from the late Karnian to the middle(?) Norian stages of the Late Triassic. These ages are based mainly on the occurrences of the conodont species Neogondolella polygnathiformis and Epigondolella primitia, found in samples collected by the U.S. Geological Survey (this report) as well as in samples collected by workers from the University of Wisconsin (Sherwood and Craddock, 1979; Umhoefer, 1984; also see map nos. 72 to 75, 82 to 84, and 87 to 96A in Table 2). The same Upper Triassic conodont faunas occur in samples both from north and south of the McKinley fault of the Denali fault system, and in both areas from rocks of similar depositional environments. The conodont faunas from the Healy quadrangle are the same as the faunas reported by Jones and others (1981b) from correlative strata to the southwest. Only one megafossil locality was discovered in the Healy quadrangle (map no. 93 on Table 2), and it contained fragments of the pelecypod Monotis cf. M. subcircularis (N.J. Silberling, written commun., 1982), the age of which correlates with the age range of the conodonts. At several localities, the Triassic calcareous rocks also yielded trace fossils, namely Chondrites sp. (map nos. 76 to 81, 85, and 86 on Table 2).

The Triassic calcareous rocks (unit TRcs) are interpreted to represent a marine regressive sequence, with deep continental slope-type deposits at the base, overlain by progressively shallower slope deposits, then by outer shelf, and finally by inner shelf deposits. The slope deposits make up the majority of the sequence, whereas the shelf-type deposits constitute only about the uppermost one-fifth of the known section. The regressive episode may have been caused by a relative sea-level change coupled with a large sediment supply which allowed the progradation of shallow water sediments over outer shelf and slope deposits. The deeper continental slope deposits consist of turbidites and intercalated hemipelagic sediments, both of which are commonly bioturbated. The turbidites are thin-bedded, generally base-cut-out turbidites which progress upward from cross-laminated, fine- grained calcareous sandstone and siltstone to parallel-laminated calcareous siltstone, and finally to carbonaceous shale and argillaceous limestone (Tc-Te layers of Bouma, 1962, 1964). In places complete Bouma Ta-Te turbidites are also present, but they are thin (up to 25 cm) with parallel-bedded (Tb) and normal-graded basal sandstone (Ta) layers. Channel conglomerates were not found. The hemipelagic rocks comprise intercalated argillaceous lime-mudstone, carbonaceous shale, and calcareous siltstone with a few, thin turbidite interbeds (usually Bouma Tc-Te layers). At several localities the slope-type deposits also contain intercalations, up to a few meters thick, of non-bioturbated, alternatingly light- and dark-colored laminae of carbonaceous and argillaceous lime-mudstone (nomenclature after Dunham, 1962). These lime-mudstone intercalations probably were deposited either in an interslope oxygen-starved basin, or within the oxygen minimum zone of an open slope where infaunal invertebrates are uncommon. The upper slope and outer shelf deposits are represented by medium- to thick-bedded, calcareous, fine- to medium-grained sandstones, siltstones, and shales, generally without small-scale sedimentary structures, such as parallel-laminations and cross-bedding. These were probably destroyed by bioturbation (some trace fossils are present). The inner shelf deposits are fine- to coarse-grained, calcareous sandstones; and quartz-grain, skeletal packstones and grainstones (nomenclature after Dunham, 1962) with medium- to small-scale planar crossbedding. The carbonate grains consist of fragments of molluscs, brachiopods, echinoderms, and encrusting foraminifers, as well as peloids and limestone clasts. Many of the quartz and carbonate grains have relict coats of rim cement, indicating vadoze-zone cementation prior to neomorphism. These deposits probably were produced by a series of migrating barrier bars in a wave dominated environment.

The diabase and gabbro intrusives are generally massive, medium to dark greenish gray, fine to coarse grained, and strongly altered. Locally, the gabbros are pegmatitic. These intrusive rocks underwent the same degree of deformation, and locally metamorphism, as the sedimentary country rocks. In addition to occurring within rocks of unit TRcs, both north and south of the McKinley fault, these mafic intrusives are also present in rocks of unit Pzy unconformably underlying the Triassic calcareous rocks. Numerous attempts to date these intrusive rocks by the potassium-argon method have been unsuccessful so far (Sherwood and Craddock, 1979). The diabases and gabbros intrude rocks as young as Norian in age, and in turn are intruded by middle Cretaceous granitic rocks (unit Kgr). Most probably they are Jurassic or Early Cretaceous in age.

As already discussed, the Triassic calcareous rocks occur both north and south of the McKinley fault of the Denali fault system. In the past, the rocks north of the McKinley fault have been assigned to the so-called Pingston terrane, whereas the rocks south of the fault to the so-called Nenana tectonostratigraphic terrane (for instance, Jones and others, 1981a). In this report, on the basis of the overwhelming lithologic and stratigraphic similarities between the two suites of rocks, and their identical conodont faunas and age spans, the Triassic calcareous rocks north and south of the McKinley fault are considered to be tectonically telescoped portions of the same sequence of continental slope and shelf-type deposits, and most probably to be part of the Yukon-Tanana terrane

Pzy YANERT FORK SEQUENCE (Late Devonian)—Informal name used in this report for an intensely deformed, thick marine sequence of dominantly metasedimentary and metavolcanic rocks cropping out primarily in the headwater region of Yanert Fork, in the eastern part of the quadrangle. The bulk of the sequence comprises dark-gray to black carboneous shale with intercalations of thin-bedded, commonly bioturbated, medium- to dark-gray, normally graded, both cross- and parallel-laminated, fine- to medium-grained lithic sandstone, and siltstone (turbidites). Most of these rocks have been regionally metamorphosed into siliceous mudstone, argillite, slate, phyllite, semischist, and impure quartzite. The sequence also contains thin interbeds of dark- to medium-gray, locally greenish-gray, banded chert or metachert, commonly with radiolarians; several-meters-thick interbeds of pale greenish-gray and medium gray, very fine-grained siliceous phyllite, most probably felsic meta-tuff; a few several-meters-thick interbeds of dark brownish- or greenish-gray phyllitic metabasalt, locally with still recognizable pillow structures and vesicles; subordinate stretched-pebble, schistose conglomerate interbeds a few meters thick; and a very few, thin interbeds, as much as 30 cm thick, of medium-gray, fine- to medium-grained impure marble. The Yanert Fork sequence also contains the same, probably Jurassic or Early Cretaceous diabase and gabbro intrusions, locally making up more than half of the exposed section, as the Triassic calcareous rocks of unit TRcs.

The Yanert Fork sequence is overlain with a slight angular unconformity by the Triassic calcareous rocks (unit TRcs), but the base of the sequence is nowhere exposed. Because of the intense deformation, including isoclinal folding and repetitions of section by several, laterally untraceable thrust faults of unknown horizontal displacements, the thickness of the Yanert Fork rocks is not known, but the maximum preserved thickness is estimated to be at least 1,000 m.

The metamorphic grade of the Yanert Fork rocks is generally low. Field observations, and thin section and x-ray diffraction studies for a number of samples indicate that the bulk of the Yanert Fork rocks is in the low temperature and low pressure field of the greenschist metamorphic facies (definition of metamorphic facies after Turner, 1968). Only along the eastern edge of the quadrangle have the Yanert Fork rocks been metamorphosed into mineral assemblages of the low-grade amphibolite facies (Csejtey and others, 1982; and this report). The age of metamorphism probably is middle Cretaceous (map no. 14 on Table 1). No evidence of regional polymetamorphism was detected but the evidence for it might not be apparent because of the fine grain-size and generally low metamorphic grade of the rocks.

The age span of the rather thick Yanert Fork sequence is imperfectly known. A marble interbed just west of Louis Creek yielded several specimens of the conodont fossil Palmatolepis sp. of Late Devonian age (middle Famennian; map no. 157 on Table 2). No other identifiable fossils were found in the Yanert Fork rocks. Chert samples from a number of localities were examined for radiolarians, but none could be identified due to the effects of metamorphism (N. R. D. Albert, written and oral commun., 1982; C.D. Blome, written commun., 1982; map nos. 158 to 164 on Table 2). Thus, on the basis of the conodont evidence, the Yanert Fork sequence is herein considered to be of Late Devonian age. However, because of the thickness of the

Yanert Fork sequence, it is possible that rocks of other than Late Devonian age are also present.

The lithologies of the Yanert Fork sequence indicate that its rock components are a mixture of continentally derived and pelagic sediments (for example, the turbidites and the conglomerates versus the banded radiolarian cherts). Thus, the sequence is interpreted to be continental margin-type rocks which were deposited along the base of a continental slope.

The lithologies, the depositional environment, the general metamorphic grade, the known age, and the structural style of intense, penetrative deformation, especially that of imbricate thrusting, of the Yanert Fork sequence are identical, or at least very similar, to those of several of the Paleozoic units of the Yukon-Tanana terrane north of the Hines Creek fault. Thus, in this report the Yanert Fork sequence is considered to be part of the Yukon-Tanana terrane. Accordingly, the overlying Triassic calcareous rocks of unit TRcs are also part of the Yukon-Tanana terrane. If the correlation is valid, then neither the Hines Creek fault nor the McKinley fault are major tectonostratigraphic terrane boundary faults, as the Yukon-Tanana terrane extends to the south of both of these faults.

Pzmf FELSIC METAVOLCANIC ROCKS (Late Devonian)—These rocks occur in discontinuous outcrops just north of the Hines Creek fault, along the southern flank of an east-west trending regional antiform cored by the pelitic and quartzose schists of unit pqs, in the northern part of the quadrangle. The unit comprises a massive, thick section of generally dark- to medium-gray, fine- to medium-grained schists and locally phyllites, with relict phenocrysts of quartz, orthoclase, and plagioclase. The phenocrysts are about 0.5 to 2.0 mm in maximum dimension, and make up about 10 to 25 percent of the rocks by volume. The groundmass consists of quartz, white mica (mostly sericite), K-feldspar, plagioclase, chlorite, biotite, with opaques and zircon as accessory minerals. The metamorphic grade of these rocks appears to be within the greenschist metamorphic facies of Turner (1968). Schistosity is moderately- or well-developed, and commonly bends around the relict phenocrysts. Kink-bending and strain-slip cleavage at high angles to the primary schistosity are common. The overall composition of these rocks, and the generally well-preserved forms of the relict phenocrysts, including resorption embayments in quartz phenocrysts with beta-quartz pseudomorphs (Wahrhaftig, 1968; Gilbert and Redman, 1977) indicate that the protoliths of the schists and phyllites of unit Pzmf were felsic volcanic rocks, ranging from rhyolite to dacite. The original emplacement method of these rocks, whether submarine or subaerial flows or tuffs, or shallow subvolcanic intrusions, is imperfectly known. Their spatial association with marine sedimentary and volcanic rocks (units Pzmb and Pzms) suggest that at least the bulk of them originated as submarine flows and(or) pyroclastic rocks. As a result of structural complexities, the total thickness of these rocks is also imperfectly known, but it must reach at least several hundreds of meters.

The nature of the contacts of the felsic metavolcanic rocks with adjacent metamorphosed rock units has been obscured by the metamorphism, and hence is poorly known. The irregular outcrop pattern of the felsic metavolcanic rocks, their occasional repetitions and intercalations with rock units which stratigraphically appear to lie below them, strongly suggest that most of the lithologic contacts in fact are thrust faults (Wahrhaftig, 1968). Thus, the structure of these rocks may be much more complex than what can be detected in the field. This appears to be true not only for the felsic metavolcanic rocks but for other units of the Yukon-Tanana terrane north of the Hines Creek fault as well (Wahrhaftig, 1968). Most of these presumed and unmapped thrusts appear to have predated or have been contemporaneous with the metamorphism, which is definitely older than the unconformably overlying Paleocene Cantwell Formation.

The age of the felsic metavolcanic rocks is not known for certain, as no fossils of any kind were found in these rocks. At three localities, marble interbeds in the spatially closely associated unit Pzmb yielded conodont specimens of Late Devonian and Devonian to Mississippian ages (Sherwood and Craddock, 1979; map nos. 149, 151, and 152 on Table 2). The Mystic Creek Member of the Totatlanika Schist (unit Pzts), which tentatively has been correlated with the felsic metavolcanic rocks (Wahrhaftig, 1968), yielded fossiliferous float from a marble interbed with conodonts and coral fragments of Middle Devonian to Early Mississippian age (map no. 148 on Table 2). On the basis of the above evidence, the felsic metavolcanic rocks (unit Pzmf) are provisionally considered to be of Late Devonian age.

Pzmb METABASALT AND SUBORDINATE METASEDIMENTARY ROCKS (Late Devonian)—These rocks, like the felsic metavolcanic rocks of unit Pzmf, occur in discontinuous exposures on the southern flank of a regional antiform north of the Hines Creek fault, in the northern part of the quadrangle. They comprise an over 600 m thick, intercalated sequence of schistose and phyllitic, generally medium to dark greenish-gray, fine-grained and massive metabasalt; dark-gray to black, generally fine-grained carbonaceous pelitic schist and phyllite and associated metasiltstone; and a few thin interbeds of black metachert, and fine- to medium-grained, dark-gray marble.

The metabasalts have been metamorphosed into mineral assemblages of chlorite, sericite, calcite, plagioclase—probably albite, opaque minerals, including leucoxene, and locally biotite. In some places original igneous minerals such as hornblende and plagioclase are still partly preserved (Wahrhaftig, 1968). In the north-central part of the quadrangle, agglomerate textures are moderately well preserved, and at one locality relict pillow structures were observed (Wahrhaftig, 1968).

The intercalated pelitic black schists and phyllites, as well as the associated metasiltstones, occur in interbeds several meters thick, and they essentially consist of quartz, sericite and(or) muscovite, and carbonaceous material.

Schistosity appears to parallel bedding. The metamorphic mineral assemblages suggest low-grade greenschist facies regional metamorphism (nomenclature after Turner, 1968). The age of the metamorphism, or even whether it is single or polymetamorphism, is uncertain. A potassium-argon age determination on metamorphic muscovite from one of the black phyllite interbeds (map no. 8 on Table 1; Anderson, 1973; Sherwood and Craddock, 1979; Wilson and others, 1985b) yielded a late Early Cretaceous age of 114.6 million years.

The Late Devonian age of unit Pzmb is rather well established by fossil evidence. One of the marble interbeds in the north-central part of the quadrangle yielded numerous conodont fragments of Palmatolepis sp. and Icriodus sp., some of which provisionally were identified to the species level, and specimens of Polygnathus sp. (no. 149 on Table 2; Sherwood and Craddock, 1979). This fauna indicates a Late Devonian age. In the northeast part of the quadrangle, two adjacent marble interbeds yielded conodont fragments, one identifiable as Polygnathus sp. (map nos. 151 and 152 on Table 2; Sherwood and Craddock, 1979; this report), which ranges in age through the Devonian and Mississippian. Another marble interbed turned out to be barren of microfossils (map no. 150 on Table 2).

Just as in the case of unit Pzmf, the irregular outcrop patterns of unit Pzmb, and its intercalation with rock units which stratigraphically appear to lie below or above it, strongly suggest that most, if not all, of its contacts with adjacent rock units are actually thrust faults (Wahrhaftig, 1968). Consequently, the structure and the tectonics of these rocks may be much more complex than what can be discerned in the field.

Not enough is known of the protoliths of unit Pzmb to determine adequately their depositional environment. The rocks of unit Pzmb definitely are a marine sequence, and most probably were deposited along a continental slope and(or) in a deep basin.

According to Wahrhaftig (1968), the rocks of unit Pzmb probably correlate with the Chute Creek Member of the Totatlanika Schist, unit Pzts and undivided in this report, near the northern edge of the quadrangle.

Pzms METASEDIMENTARY ROCKS (Late Devonian)—Rocks of this unit occur in discontinuous outcrops just north of the Hines Creek fault, and appear to be closely associated with units Pzmf and Pzmb. These rocks comprise an intercalated, generally thinly bedded, locally laminated, thick, marine sequence of dark-gray to black, carbonaceous, fine-grained pelitic schist or phyllite; dark-gray, fine-grained, carbonaceous metasiltstone (quartzose phyllite); fine grained, medium gray quartzite; thin interbeds of dark-gray to black metachert; and a few interbeds, as much as 5 m thick, of dark gray, fine-grained fossiliferous marble in the outcrops of this unit near the western edge of the quadrangle (Gilbert and Redman, 1977). Metamorphic foliation is well developed, and appears to parallel the bedding. Metamorphism has obliterated most of the primary sedimentary features, but the bedding in some of the metasiltstones appears to be graded.

The pelitic schists or phyllites and metasiltstones essentially consist of quartz, sericite and(or) muscovite, carbonaceous material, minor dolomite, and scattered idioblastic crystals of pyrite. The fine-grained quartzites have the same metamorphic mineralogy, except that quartz makes up more than 90 percent of the rock.

The metamorphic mineral assemblages suggest that the metamorphic grade of these rocks is within the low-pressure and low temperature field of the greenschist facies of Turner (1968). The age of metamorphism is unknown but it appears to be the same middle Cretaceous event as that of the surrounding metamorphic rocks.

Some of the marble interbeds near the western edge of the quadrangle yielded poorly preserved megafossils, still identifiable to the genus level, indicating a Late Devonian, possibly Middle Devonian age (Gilbert and Redman, 1977; map nos. 153 to 156 on Table 2).

As in the case of the already discussed units Pzmf and Pzmb, lithologic contacts between rocks of unit Pzms and those of adjacent units may in fact be thrust faults, suggesting a complex structural and tectonic history. This is also suggested by some field observations and thin section studies, as the primary foliation is commonly deformed by kink folding, slip cleavage, as well as large folds several meters in amplitude (Gilbert and Redman, 1977; this report).

The depositional environment of unit Pzms appears to range from shallow and(or) moderately deep marine, such as the rocks with the marble interbeds in the western part of the quadrangle, to deep marine along the Wood River. Most likely, this is the result of facies changes, but it is also possible that the rocks in the above two areas belong to two separate tectonic units, and thus do not correlate.

Rocks of unit Pzms had been correlated tentatively with the pelitic and quartzose schists of unit pqs in the past (Wahrhaftig, 1968). However, the age of the marble interbeds near the western edge of the quadrangle, as well as the generally higher level of metamorphic recrystallization of the pelitic and quartzose schists of unit pqs make this correlation unlikely. Although there are rocks within the Totatlanika Schist which are very similar to rocks of unit Pzms, no obvious correlation seems to exist between any Member of the Totatlanika Schist and rocks of unit Pzms. On the other hand, the metasedimentary rocks of unit Pzms which occur along the Wood River are very similar, if not identical, to the Yanert Fork sequence (unit Pzy) in their lithologies, metamorphic grade and level of recrystallization, deformational style, and in their apparent age and depositional environment.

Pzts TOTATLANIKA SCHIST, UNDIVIDED (Middle Devonian to Early Mississippian)—The Totatlanika Schist crops out in an east-west-trending belt along the northern edge of the quadrangle, along the northern flank of a large, regional antiform. The formation predominantly consists of metavolcanic and metavolcaniclastic rocks, both felsic and mafic in composition, and subordinate amounts of intercalated metasedimentary rocks such as black pelitic schist and, at one locality, a thin interbed of fossiliferous marble (Wahrhaftig, 1968; Gilbert and Bundtzen, 1979). The Totatlanika Schist was first mapped and named by Capps (1912). Subsequently, the boundaries of the Totatlanika Schist were revised, and the formation itself was divided into five members by Wahrhaftig (1968). In ascending order, which is either stratigraphic or tectonic, the five members are: Moose Creek Member, California Creek Member, Chute Creek Member, Mystic Creek Member, and Sheep Creek Member. The five members are not shown separately on the geologic map of this report, but their distribution and possible correlative rock types within the Healy quadrangle can be found in Wahrhaftig (1968, 1970a, 1970c, 1970d, 1970e), Gilbert and Bundtzen (1976, 1979), and Gilbert (1977). The correlation of the Totatlanika Schist into the northwest part of the quadrangle is still somewhat tentative, thus in that region the unit is shown as Pzts? on the accompanying geologic map.

The distribution of the major rock types within the Totatlanika Schist is as follows: The Moose Creek, California Creek, and Mystic Creek Members dominantly consist of metamorphosed felsic volcanic rocks, the Chute Creek Member of basic metavolcanic rocks, and the Sheep Creek Member essentially comprises felsic metavolcaniclastic rocks. Black, fine-grained carbonaceous pelitic schists and phyllites occur intercalated with the above rock types, in varying proportions, throughout the entire known section of the Totatlanika Schist. At one locality in the Healy D-2 quadrangle (Wahrhaftig, 1968, 1970b), a thin interbed of fossiliferous marble occurs within the Mystic Creek Member (map no. 148 on Table 2).

The felsic metavolcanic rocks comprise varicolored schists, gneisses, and some phyllites consisting of quartz, orthoclase, plagioclase, sericite and(or) muscovite, chlorite, and opaque minerals. Many of these rocks contain blastoporphyritic crystals of quartz, orthoclase, and plagioclase in a fine- to medium-grained matrix. The basic metavolcanic rocks are dark greenish-gray, fine- to medium-grained schists, and phyllites of chlorite, epidote, albite, actinolite, sericite and(or) muscovite, biotite, and opaques. Relict pyroxene and plagioclase are locally present. The volcaniclastic rocks comprise schistose or phyllitic, intercalated fine- to medium-grained metasandstones, siltstones, and purple or pale green, fine-grained metatuffs. The dominant metamorphic minerals are, in varying proportions, quartz, feldspar, sericite, and chlorite. At numerous localities, graded bedding and cross bedding are still preserved in the metasandstones. Detailed lithologic descriptions of the Totatlanika Schist are given in Wahrhaftig (1968), and chemical data in Gilbert and Bundtzen (1979).

The metamorphic mineral assemblages suggest that the Totatlanika Schist has been recrystallized in the low pressure, low temperature field of the greenschist metamorphic facies of Turner (1968). The number of metamorphic events affecting these rocks is not known for certain, but probably it is more than one event. Regional considerations suggest that the latest event is about middle Cretaceous in age (Csejtey and others, 1982).

The structure of the Totatlanika Schist appears to be complex. As in the case of the already discussed neighboring units of the Yukon-Tanana terrane, the repetitions and the frequent occurrence of rocks of the Totatlanika Schist outside their assumed stratigraphic position strongly suggest that most of the lithologic contacts are thrust faults. This seems to be valid not only for the Totatlanika Schist as a whole unit, but for the various members within the formation as well. Thus, the Totatlanika Schist itself may consist of a number of imbricated thrust sheets (Wahrhaftig, 1968). These supposed thrust fault contacts are parallel to the mineral foliation of the Totatlanika Schist. Because of these structural complexities, the thickness of the Totatlanika Schist can not be reliably determined. The maximum preserved cumulative thickness is over 5,700 m, but at any one area the thickness of the rocks present is considerably less.

The depositional age or rather the depositional age span of the Totatlanika Schist is inadequately known because fossils were found only at one locality in this thick and structurally complex unit. A thin marble interbed within the Mystic Creek Member yielded unindentifiable crinoid columnals and gastropod shell fragments, poorly preserved fragments of the coral Syringopora sp., and more diagnostically, specimens of the conodont Polygnathus sp., and ramiform elements (map no. 148 on Table 2). The coral Syringopora implies a probably Mississippian, possibly Devonian age (Helen Duncan in Wahrhaftig, 1968), and the conodonts indicate a Middle Devonian to Early Mississippian age (A.G. Harris, written commun., 1985). On the basis of this evidence, and because of the Late Devonian age of unit Pzmb, tentatively correlated with the Chute Creek Member, the Totatlanika Schist is considered to be Middle Devonian to Early Mississippian in age.

As a result of the metamorphism, very few of the original depositional features of the Totatlanika Schist are still preserved. Hence, little can be speculated on the depositional environment of this formation. The mineralogies and chemical data suggest that the bulk of the Totatlanika Schist originated as felsic volcanic rocks. The intercalated carbonaceous black schists, the graded and cross bedded nature of the clastic rocks, and the fossiliferous marble interbed indicate deposition in a marine environment. According to Wahrhaftig (1968), the felsic metavolcanic rocks, that is, the bulk of the Totatlanika Schist, were most probably deposited as a result of a series of submarine pyroclastic eruptions or ash flows. On the basis of this evidence, and on the basis of tentative correlation of the Chute Creek and Mystic Creek Members with units Pzmb and Pzmf, respectively, the rocks of the Totatlanika Schist are interpreted to be continental margin-type deposits.

kp KEEVY PEAK FORMATION (Precambrian and(or) early Paleozoic)—The Keevy Peak Formation was first defined by Wahrhaftig (1968). It occurs along the northern flank of a regional antiform, in a stratigraphic position between the overlying Totatlanika Schist and the underlying pelitic and quartzose schists of unit pqs. The formation comprises an intercalated sequence of fine- to medium-grained quartz-sericite or muscovite schist, fine-grained black quartzite, black carbonaceous pelitic schist and phyllite, stretched-pebble conglomerate, greenish-gray or purple schist and slate, and a few thin marble interbeds. The bulk of the formation appears to be composed of metamorphosed clastic rocks. According to Gilbert and Bundtzen (1979), many of the black quartzites are metacherts, and the varicolored slates are metatuffs. Many of the quartz-sericite or muscovite schists contain numerous porphyroblastic crystals, as much as 1 mm in maximum dimension, of bluish quartz and feldspar in the finer-grained matrix, giving the rock a "grit"-like appearance (Wahrhaftig, 1968). Relict graded-bedding and cross-bedding are locally preserved within the Keevy Peak Formation in spite of multiple deformation and metamorphism. Detailed lithologic descriptions of the Keevy Peak Formation can be found in Wahrhaftig (1968).

The Keevy Peak Formation underwent multiple deformation. The primary metamorphic foliation, which appears to parallel original bedding, is commonly transsected by kink-folding and axial-plane slip cleavage of tight or isoclinal folds as much as several tens of meters of amplitude. The occurrence of lenses of rocks characteristic of the Totatlanika Schist within the Keevy Peak Formation strongly suggests that these lenses are thrust slices (Wahrhaftig, 1968). Thus, lithologic contacts with the Totatlanika Schist are probably thrust faults, but the contact with the underlying pelitic and quartzose schists of unit pqs is thought to be a depositional unconformity (Wahrhaftig, 1968).

Because of the structural complexities, the thickness of the Keevy Peak Formation is not known for certain, but between 700 and 1,200 m of section appear to be present.

In addition to the ubiquitous metamorphic minerals of quartz and sericite and(or) muscovite (present in varying proportions depending on the composition of the protolith), most Keevy Peak rocks contain carbonaceous material, and subordinate amounts of metamorphic chlorite, calcite, feldspar, and rarely stilpnomelane. The metamorphic mineral assemblages indicate metamorphism of the greenschist facies (nomenclature after Turner, 1968). According to Gilbert and Bundtzen (1979), the Keevy Peak Formation underwent more than one period of regional metamorphism, the latest of which took place in the Cretaceous.

The age of the Keevy Peak Formation is not known. No fossils have been found so far in the Keevy Peak Formation or in rocks which might correlate with the Keevy Peak Formation. On the basis of regional geologic considerations, Wahrhaftig (1968) assigned the formation a Precambrian and(or) early Paleozoic age.

The scarcity of original sedimentary features and lack of fossil data make it nearly impossible to speculate on the depositional environment of the Keevy Peak Formation. Gilbert and Bundtzen (1979) considered the formation to have been deposited in a relatively deep-marine, low-energy environment.

pqs PELITIC AND QUARTZOSE SCHIST SEQUENCE (Precambrian and(or) early Paleozoic)—These rocks occur in a broad, east-west-trending belt, forming the core of a large regional antiform, in the northern part of the quadrangle. The metamorphic rocks of this unit, both within the Healy quadrangle and in adjacent regions, were previously mapped and designated by earlier workers as the "Birch Creek Schist" (for example, Brooks and Prindle, 1911; Capps, 1912, 1940; Péwé and others, 1966; Wahrhaftig, 1968, 1970b, 1970c, 1970d, 1970e; Gilbert, 1977; Gilbert and Bundtzen, 1976, 1979; Gilbert and Redman, 1977; Sherwood and Craddock, 1979). However, systematic reconnaissance geologic mapping in the type area of the "Birch Creek Schist," in the Yukon-Tanana Upland, has revealed uncertainties as to what really constitutes the "Birch Creek Schist" as a rock stratigraphic unit (Foster and others, 1973). Foster and her coworkers have recommended that the term "Birch Creek Schist" be abandoned. On the recent geologic map of the Circle quadrangle (Foster and others, 1983), which includes the original type area of the "Birch Creek Schist" of Spurr (1898), the term "Birch Creek Schist" is not used. Accordingly, the term "Birch Creek Schist" is not used in this report and on the accompanying geologic map.

The pelitic and quartzose schist sequence (unit pqs) consists of the following rock types, intercalated in varying proportions: medium- to fine-grained, generally medium gray quartz-sericite and(or) muscovite pelitic schist; fine- to medium-grained, medium-gray quartzite; quartz-sericite and(or) muscovite-calcite pelitic schist; fine-grained, dark gray to black carbonaceous schist or phyllite; a few interbeds, as much as several tens of meters thick, of medium gray, fine- to medium-grained massive marble; and a few small bodies and layers of chloritic schist which originally probably were sills or interbedded flows or tuffs. The typical quartz-sericite and(or) muscovite pelitic schist, making up the bulk of the rocks of unit pqs, has the following composition: 60-80 percent quartz, 10-25 percent sericite and(or) muscovite, 5-10 percent calcite, 5-15 percent albite and microcline, and frequently small amounts of chlorite, epidote, biotite, and carbonaceous material. More detailed lithologic descriptions of the rocks of unit pqs can be found in Wahrhaftig (1968), and in Gilbert and Redman (1977), under the term "Birch Creek Schist."

The rocks of unit pqs appear to have undergone several periods of metamorphism and intense deformation (Wahrhaftig, 1968; Gilbert and Redman, 1977). Metamorphic compositional layering defines a prominent foliation, which displays pervasive minor folding, and is cut by well-developed axial-plane slip cleavage. The metamorphic mineral assemblages suggest that the rocks of unit pqs, at least the bulk of them, belong to the low-pressure and low-temperature field of the greenschist metamorphic facies of Turner (1968). The primary metamorphic foliation roughly parallels the contacts between unit pqs and the other adjacent units of metamorphic rocks. The contact with the overlying Keevy Peak Formation (unit kp) is thought to be a depositional unconformity, but all other contacts with metamorphic rock units are suspected to be thrust faults (Wahrhaftig, 1968). The base of unit pqs is not exposed.

As the result of the structural complexities, and the fact that original depositional features, including bedding, have been obscured by metamorphism, the thickness of unit pqs is not known. According to Wahrhaftig (1968), the thickness of this unit..."measured perpendicular to the axial plane cleavage of minor folds (not a true stratigraphic thickness) is at least 10,000 feet" (about 3,050 m).

The age of the rocks of unit pqs is imperfectly known. Only at one locality were indeterminate fossils found (Gilbert and Bundtzen, 1979; map no. 171 on Table 2). No reliable age determinations by isotopic methods of any kind are so far available. On the basis of regional geologic considerations, correlative rocks (under the term "Birch Creek Schist") in the adjacent Fairbanks quadrangle were assigned by Péwé and others (1966) to the Precambrian and(or) early Paleozoic.

The lack of original depositional features as well as any determinate fossils preclude reliable speculations as to the depositional environment of the metamorphosed rocks of unit pqs. Wahrhaftig (1968) considered these rocks to be of sedimentary origin, probably as marine shales and sandstones, and Gilbert and Bundtzen (1979) interpreted the rocks of unit pqs (under the term "Birch Creek Schist") to be continental margin-type deposits.

Rocks of unit pqs are the oldest and(or) structurally lowest rocks of the Yukon-Tanana terrane in the Healy quadrangle.

Not shown separately on the geologic map, there is a small exposure of serpentinite within the rocks of unit pqs, just north of Montana Creek in the north-central part of the quadrangle (Sherwood and Craddock, 1979). Its age is unknown, and it appears to have been derived from harzburgitic peridotite. The method and time of its emplacement are also unknown, but perhaps it is related to the thrusting assumed to separate most, if not all, of the rock stratigraphic units of the Yukon-Tanana terrane in the quadrangle.

Kva ANDESITIC VOLCANIC INTRUSIVES (Late Cretaceous)—This unit consists of two large sills or dikes intruding the metamorphosed flysch-like rocks of unit KJf, in the southeast part of the quadrangle. The rock constituting the sills is an altered, medium greenish gray, porphyritic hornblende andesite, with subhedral to euhedral phenocrysts, as much as 5 mm in maximum dimension, of prismatic hornblende and altered plagioclase in an aphanitic matrix. The matrix, originally microcrystalline or very finely crystalline, now consists of a very fine-grained aggregate of sericite, chlorite, clay minerals, opaques, very minor quartz, and some relict plagioclase. The hornblende phenocrysts are still quite fresh, but the plagioclase phenocrysts have been altered to sericite, clay minerals, and some quartz. A potassium-argon age determination on hornblende yielded an early Late Cretaceous age of 97.3 m.y. (map no. 43 on Table 1). The intrusion of the two andesite sills appears to post-date the greenschist facies regional metamorphism of the flysch-like country rocks of unit KJf.

KJf FLYSCH SEQUENCE (Late Jurassic and Early Cretaceous)—The rocks included in this unit comprise a monotonous, intensely deformed and locally highly metamorphosed, probably several thousands of meters thick, flysch-like turbidite sequence which underlies large areas in the western, central, eastern, and southern parts of the quadrangle. The sequence consists of a variety of rock types, intercalated in varying proportions. These are: dark-gray to black argillite; fine- to coarse-grained, generally dark-gray lithic graywacke; dark-gray polymict pebble conglomerate; subordinate black chert-pebble conglomerate; a few thin interbeds of dark gray to black radiolarian chert; and a few thin beds of dark-gray, impure limestone.

In the southeastern part of the quadrangle, rocks of the flysch sequence have been intensely metamorphosed, and are part of an in situ, northeast-trending metamorphic belt, first described and named by Smith (1970, 1974) the Maclaren metamorphic belt, of about middle Cretaceous age. The axis of the belt in the quadrangle runs from about Deadman Mountain northeasterly toward an area south of Butte Lake, then toward Rusty Hill and on through the area of the Susitna Glacier (Csejtey and others, 1982, 1984; sheet no. 4 of this report). Along the core of the metamorphic belt the metamorphic grade is that of the amphibolite facies (nomenclature after Turner, 1968), which rapidly decreases toward both flanks to the greenschist, and to the prehnite-pumpellyite metamorphic facies. Within the belt the metamorphosed flysch-like rocks consist of fine- to medium-grained paragneisses, fine- to medium-grained pelitic schists, and phyllites.

The whole flysch sequence has been compressed into tight or isoclinal folds, and has been complexly faulted, including thrust faults. Even outside the Maclaren metamorphic belt, the flysch-like rocks are highly indurated, and many are sheared and pervasively cleaved. Most of this cleavage is probably axial plane cleavage. Because of the lithologically monotonous nature of the flysch sequence, thrust faults are especially hard to detect in the field. The notable exception is a large klippe in the south-central and southwestern parts of the quadrangle. There, in a formerly very large thrust sheet, rocks of the flysch sequence were thrust upon the same flysch sequence and on the Upper Triassic rocks of unit TRvs, and then were compressed into a tight, giant megafold with a calculated amplitude of at least 10 km (Csejtey and others, 1982). The present surface dimensions of the klippe are about 30 km by 60 km. In order to show the areal extent of this klippe on the geologic map, the flysch-like rocks of the klippe are labeled as KJf_k. However, lithologically they are identical to the flysch-like rocks of unit KJf.

The typical argillite of the flysch sequence is dark-gray to black, and it commonly contains small grains of detrital mica as much as 1 mm in diameter. Because of the intense deformation and accompanying dynamometamorphism, in large areas the argillite is actually a slate or fine-grained phyllite. Thin sections show that some of the argillites are very fine-grained siltstone, and that they all contain considerable carbonaceous material.

The typical lithic graywacke is dark- to medium-gray, fine- to medium-grained, and occurs intercalated with the argillite in graded beds ranging in thickness from laminae to about 1.5 m. The individual graywacke beds are not uniformly distributed throughout the whole sequence, of which they comprise about 30 to 40 percent by volume, but tend to be clustered in zones 1 to 5 m thick. Thin sections of graywacke samples show them to be composed of angular or subrounded detrital grains of lithic fragments, quartz, moderately fresh plagioclase, and some generally altered mica in a very fine-grained matrix; euhedral opaque grains, probably authigenic pyrite, are present in most thin sections. The lithic fragments consist, in varying proportions, of little altered, fine-grained to aphanitic volcanic rocks of mafic to intermediate composition; fine-grained, weakly foliated low-grade metamorphic rocks; chert; and some fine-grained unmetamorphosed sedimentary rocks possibly of intraformational origin. No carbonate grains were seen. The matrix constitutes about 20 to 30 percent of the rock by volume, generally contains some secondary sericite and chlorite, and, in some of the more dynamometamorphosed rocks, biotite.

The polymict pebble conglomerate is generally dark- to medium-gray, well indurated, with poorly to well-sorted layers as much as several meters thick. Clasts are well-rounded to subrounded, and range in size from about 2 mm to about 15 cm, but most clasts are less than 5 cm in diameter. In varying proportions, the clasts consist of black and dark gray chert; dark- to medium-gray argillite and sandstone or graywacke, some of which may be of intraformational origin; gray quartzite; and subordinate amounts of pebbly sandstone and conglomerate, white quartz, and gray-green chert. Some of the sandstone or graywacke clasts may actually be altered volcanic rocks.

Within the Maclaren metamorphic belt the rocks of the flysch sequence have been recrystallized, depending on the metamorphic grade, into compositionally layered gneisses and schists, primarily consisting of quartz, muscovite, biotite, and feldspar, and into phyllites of quartz, sericite and(or) muscovite. The highest grade of metamorphism occurs in the area around Rusty Hill, where the metamorphic mineral assemblages include kyanite, staurolite, and sillimanite, indicating an intermediate pressure field of the amphibolite metamorphic facies. A thorough discussion of the metamorphic rocks and the developmental history of the Barrovian-type Maclaren metamorphic belt in the Healy A-1 quadrangle is given by Smith (1981).

The age of the Maclaren belt metamorphism, at least its main phase, is about middle Cretaceous, but it is possible that the age span of this apparently complex metamorphic episode may range from Late Jurassic to early Tertiary. Several potassium-argon age determinations on mineral separates from these metamorphic rocks of unit KJf (map nos. 44, 45, 46, and 49 on Table 1) yielded latest Late Cretaceous and early Tertiary ages. However, these ages are herein considered to be minimum reset ages because potassium-argon age determinations on metamorphosed rocks of unit TRcs to the north (map nos. 35 and 38 on Table 1), produced by the same metamorphism, yielded somewhat older Late Cretaceous ages. But these ages may also be reset ages because still older granitic rocks (unit Kgr) seem to intrude the already metamorphosed rocks.

The depositional age span of the flysch sequence is fairly well established by fossil evidence, both from within and outside the quadrangle (for example, Reed and Nelson, 1977; Csejtey and others, 1978; Jones and Silberling, 1979), although fossils are very sparse in the sequence. A number of localities within the quadrangle yielded micro- and(or) megafossils which range in age from Late Jurassic to Early Cretaceous (map nos. 24 to 26, and 39 to 42 on Table 2). Included in this fossil list are the fossils from unit KJf_k in the south-central part of the quadrangle. Unit KJf_k is considered to be part of the flysch sequence, and it is designated separately on the geologic map only to show the extent of a large klippe formed by rocks of the flysch sequence. The rocks mapped as JKf_a are also considered to be part of the flysch sequence because of identical lithologies, but in addition to Late Jurassic and Early Cretaceous fossils, these rocks also yielded fossils of earliest Late Cretaceous (Cenomanian) age, thus they are shown separately on the geologic map. It is quite likely that the deposition of all of the flysch-like rocks, including unit KJf, extended into the earliest Late Cretaceous, but as a result of subsequent deformation and erosion, only in a few areas are rocks of this young age preserved.

The flysch-like rocks of the quadrangle are part of a thick, dominantly turbidite sequence which underlies large areas of southern Alaska. The flysch sequence is interpreted to have been deposited more or less in situ, in a narrowing oceanic basin between, and lapping onto, the late Mesozoic North American continent which the Yukon-Tanana terrane was already a part of, and the converging Talkeetna superterrane (Csejtey and others, 1982). Thus, the flysch-like rocks of the quadrangle, as well as those of southern Alaska, are the intensely deformed remnants of turbidite deposits of a once large but narrowing and subsequently collapsed oceanic basin between converging continents.

KJf_k OVERTHRUST FLYSCH-LIKE ROCKS (Late Jurassic and Early Cretaceous)—These rocks are identical lithologically and in age to the flysch-like rocks of unit KJf. They are designated separately on the geologic map only to show the extent of a large, folded klippe, about 30 km by 60 km in maximum areal dimensions, in the southwestern and south-central parts of the quadrangle. The klippe is the remnant of a once much larger thrust sheet which imbricated the rocks of the flysch sequence, and also brought the flysch-like rocks on top of Triassic basalts and volcaniclastic rocks of unit TRvs. Three localities within the klippe yielded mega- and microfossils of Late Jurassic and Early Cretaceous age (map nos. 24, 25, and 26 on Table 2).

KJcg CONGLOMERATE, SANDSTONE, SILTSTONE, SHALE, AND VOLCANIC ROCKS, UNDIVIDED (Late Jurassic and Early Cretaceous)—These rocks occur in two thrust slivers along the Talkeetna thrust fault in the southeastern part of the quadrangle. They comprise an intercalated sequence of polymictic pebble and cobble conglomerate, sandstone, siltstone, shale, and flows and dikes of andesitic to latitic feldspar porphyry. Some of these rocks appear to have undergone very low-grade regional metamorphism. Locally, the rocks are strongly sheared with shear planes cutting across conglomerate clasts. The best exposed section, south of Butte Creek, is over 400 m thick, and it contains many fining- and thinning-upward sequences (sequences in which the clastic component grain-size and thickness of individual beds decrease stratigraphically upward).

The conglomerates are massive to thick-bedded with common non-stratified grading and clast imbrication (organized conglomerate). The well-rounded to subrounded clasts range from about 1 cm to 20 cm in maximum dimension, and chiefly consist of unmetamorphosed andesite, latite, dacite, feldspar porphyry, and altered basalt and diabase which resemble the nearby Nikolai Greenstone (unit TRn). Sedimentary rock types comprise about 40 to 45 percent of the clasts and consist of greenish gray tuffaceous sandstone and siltstone; dark to medium gray, fine- to medium-grained sandstone; dark gray siltstone; dark gray argillite; and some white quartz. The clasts generally are grain-supported with small amounts of polymictic sandy matrix which is locally altered to a clay-mica-quartz or a sericite-quartz-prehnite aggregate.

The sandstone, siltstone and shale are thinly to moderately thickly bedded, and are intercalated sequences of graded- and cross-bedded sandstone and siltstone, and parallel-laminated siltstone and shale (turbidites). These rocks generally are medium to dark gray with common feldspar grains, but dark greenish-gray varities are also present which contain abundant tuffaceous material.

The dark gray andesitic to latitic feldspar porphyry, occurring as dikes and flows, contains flow aligned phenocrysts of zoned andesine and oligoclase up to one centimeter in length, along with varying amounts of hornblende and biotite, in an aphanitic matrix.

The age of this unit is based on the occurrence of specimens of Buchia spp. of Late Jurassic to Early Cretaceous age (Silberling and others, 1981a; map no. 27 on Table 2) in a shale bed at the top of the 5,053-ft peak near the southern edge of the quadrangle.

The rocks of unit KJcg probably were deposited at the base of a continental slope as part of a submarine fan complex. The organized conglomerates are the channel facies of the complex and are equivalent to facies A2 of Walker and Mutti (1973). The fining- and thinning-upward sequences in the section south of Butte Creek grade from channel facies conglomerate to interchannel facies siltstone and shale. These repeated sequences probably were formed by channel migration across this fan complex.

The lithologies and age range of the rocks of unit KJcg provisionally suggest that they might constitute a submarine fan facies of the Upper Jurassic and Lower Cretaceous flysch sequence (unit KJf) of the quadrangle, or that they may correlate with, and thus be the westernmost occurrence of the Gravina-Nutzotin sequence of Berg and others (1972) in eastern Alaska.

Talkeetna superterrane

TRvs METAVOLCANIC, METAVOLCANICLASTIC, AND SUBORDINATE METASEDIMENTARY ROCKS (Late Triassic, late Norian)—Rocks of this unit form intercalated sequences several hundreds of meters thick, and occur as thrust slices in the southeastern and southwestern regions of the quadrangle. Two of these slices occur along the Talkeetna thrust fault, and the others, including the largest one, are sandwiched between the East Fork and Honolulu thrusts near the southwestern corner of the quadrangle. Although there are some variations in the rock types and in the proportions of rock types between the discontinuous slivers, the overall lithologic similarities and the same fossils, hence the same age of these rocks, make correlation reasonably certain. Previously, the rocks in the various slivers have been assigned to different tectonostratigraphic terranes, namely the Susitna, Wrangellia, and Clearwater terranes (Jones and others, 1981a; Silberling and others, 1981a, 1981b).

The most common rock type in these slivers is a dark greenish-gray, aphanitic metabasalt with numerous amygdules. Most of the metabasalts occur in thick, commonly pillowed, massive flows. Thin sections show the primary minerals to be twinned labradorite, augite, and opaque minerals which probably are mostly ilmenite. Secondary minerals are chlorite (much of it after glass), epidote, clinozoisite, minor zoisite, calcite, leucoxene, very minor sericite, very fine-grained felty amphibole (probably seralite after augite), and possibly very subordinate albite. The original texture was intersertal and subophitic. The amygdules consist of chlorite, zeolites (primarily prehnite), quartz, and some feldspar. Some of the metabasalts are pyroclastic in origin, forming thick layers of agglomerate comprising chaotic assemblages of coarse, angular to subangular basalt fragments with subordinate exotic rock fragments such as argillite or marble; all the fragments are densely packed in a fine-grained, greenish-gray or reddish gray matrix.

The metavolcaniclastic rocks comprise dark gray or dark greenish-gray, generally fine-grained, tuffaceous metasandstones and metasiltstones, occurring either as several-meters-thick interbeds within the metabasalts, or forming thick, monotonous sections a few hundreds of meters thick.

The metasedimentary rocks comprise dark gray, locally greenish gray slate and argillite, and subordinate dark gray, finely crystalline, thinly bedded marble. Thin sections of the slates show that some of them are fine-grained metasiltstones. All of the slates and argillites contain considerable carbonaceous material and some amounts of fine-grained, secondary sericite. Secondary biotite is present in some of the slates. The subordinate, thinly bedded marbles occur in uncommon layers several meters thick.

The secondary mineral assemblages in rocks of unit TRvs suggest that, in addition to the deuteric alteration of the volcanic rocks, all rocks of the unit underwent very low grade regional metamorphism which locally may reach the low pressure and low temperature field of the greenschist metamorphic facies (nomenclature after Turner, 1968).

At several localities the slates, argillites, metasandstones, and marbles yielded the megafossils Monotis subcircularis and(or) Heterastridium sp. of late Norian (Late Triassic) ages (map nos. 97 to 99, 101, and 102 on Table 2).

At a locality in the Talkeetna Mountains D-2 quadrangle, about a mile south of the southern boundary of the Healy quadrangle, limestone fragments from an agglomerate layer of unit TRvs yielded conodont species of Late Triassic (late Karnian-early Norian) age (map no. 100 on Table 2). This age is equivalent to that of the Chitistone and Nizina Limestones of the Wrangellia terrane (Jones and others, 1977), a component terrane of the Talkeetna superterrane (Csejtey and others, 1982). These limestone fragments, up to 12 cm in maximum diameter, lithologically resemble the Chitistone and Nizina Limestones (unit TRcl) found elsewhere in the quadrangle. If these limestone fragments indeed come from unit TRcl, that is, from the Wrangellia terrane, then this would indicate that basalts do occur in the stratigraphic section of Wrangellia above the Chitistone and Nizina Limestones. No basalts have been recognized previously in this stratigraphic interval of Wrangellia (for instance, Jones and others, 1977, 1981a; Jones and Silberling, 1979).

The rocks of unit TRvs represent a series of submarine volcanic flows and pyroclastic deposits, as well as interfingering volcaniclastic and pelagic (open-ocean) sediments which were deposited contemporaneously with and between eruptive events.

TRcl CHITISTONE AND NIZINA LIMESTONES, UNDIVIDED (Late Triassic, early Norian and late Karnian)—This unit occurs in three separate, small thrust slivers in the southeastern part of the quadrangle. The unit comprises several varieties of limestones, the compositions of which vary between the slivers. These lithologic variations apparently are the result of facies changes and subsequent telescoping by thrust faults. The ages and lithologies of these limestones are very similar to the type Chitistone Limestone of eastern Alaska, but parts of these limestones also correlate with the type Nizina Limestone, stratigraphically overlying the Chitistone, of the same area (MacKevett, 1976, 1978). On the basis of this correlation, the rocks of unit TRcl are the youngest rocks in the Healy quadrangle which are certain to be part of the Wrangellia tectonostratigraphic terrane of Jones and others (1977).

The thrust sliver near Butte Creek (map no. 104 on Table 2) is composed of a medium- to thick-bedded, medium-gray weathering, brownish-gray lime mudstone (nomenclature after Dunham, 1962) with chert nodules and streamers. The sliver to the south (map no. 103 on

Table 2) consists of a medium- to thin-bedded, commonly thinly laminated, dark-gray to dark brownish-gray lime mudstone which releases a fetid (possibly petroleum) odor when broken. The sliver in the Clearwater Mountains (map no. 105 on Table 2), near the eastern edge of the quadrangle, is made up of thin- to medium-bedded, dark-gray lime mudstone and wackestone (Silberling and others, 1981a, 1981b). All of the above exposures show evidence for at least incipient recrystallization, possibly as the result of very low-grade regional metamorphism.

Two of the fault slivers are fossiliferous, and yielded the megafossil Halobia sp., as well as several conodont specimens (map nos. 103 and 105 on Table 2), all of which indicate a late Karnian and early Norian (Late Triassic) age range.

Because all the Chitistone and Nizina Limestone exposures in the quadrangle are fault bounded, their stratigraphic thickness and position are somewhat conjectural. At least several tens of meters of section are present. On the basis of correlation with the Chitistone Limestone in the Nabesna and McCarthy quadrangles of eastern Alaska (Richter, 1976; MacKevett, 1976, 1978), it is fairly certain that in the Healy quadrangle the unit called Chitistone and Nizina Limestones, undivided, stratigraphically was overlying the Nikolai Greenstone (unit TRn) prior to thrusting.

On the basis of similar lithologies and fossil contents, and thus age range, the rocks of unit TRcl in the Healy quadrangle correlate well with the Chitistone Limestone and the lower part of the Nizina Limestone at their type section in the McCarthy quadrangle (MacKevett, 1976, 1978).

The depositional environment of the cherty limestone in the sliver near Butte Creek (map no. 104 on Table 2) is interpreted to be supratidal. This is suggested by the irregular form of the chert nodules, characteristic of post-depositional origin, and by the lack of fossils. The limestone in the sliver to the south (map no. 103 on Table 2) probably was deposited in deeper water, possibly at bathyal water depths (more than 200 m). This is suggested by the fine grain size, thin laminations, common pelagic megafossils, and the small, delicate conodont fauna. The lime mudstone and bioclastic wackestone in the sliver near the eastern edge of the quadrangle (map no. 105 on Table 2) probably was deposited in a subtidal inner-shelf or shallow-platform environment.

TRn NIKOLAI GREENSTONE (Late and(or) Middle Triassic)—The formation occurs near the southeast corner of the quadrangle, south of the Talkeetna thrust fault. The Nikolai is one of the most prominent and widespread rock units of the Wrangellia tectonostratigraphic terrane in southern and eastern Alaska. In the Healy quadrangle, the Nikolai Greenstone comprises an over 3,000 m thick, slightly metamorphosed sequence of massive basalt flows with subordinate amounts of intercalated basaltic tuffs and breccias, some bedded volcaniclastic rocks such as pebble conglomerate, sandstone, and siltstone, and possibly a few thin limestone interbeds. The entire sequence has been telescoped and offset by numerous faults.

The Nikolai Greenstone can be roughly subdivided into two parts in the quadrangle (Silberling and others, 1981a, 1981b). The upper part is an over 1,000 m thick pile of dominantly subaerial, massive flows of dark greenish-gray, amygdaloidal basalt. The individual basalt flows are as much as a few tens of meters thick. These amygdaloidal basalts closely resemble the type section of the Nikolai Greenstone in the Wrangell Mountains (MacKevett, 1976, 1978). The lower part of the Nikolai is over 2,000 m thick, and it comprises a number of laterally variable and interfingering rock types, probably all of submarine origin. These rock types are: massive flows of dark greenish-gray, non-amygdaloidal basalt; massive flows of light to medium greenish-gray pillow basalt interlayered with tuff; and massive, layered breccia of dark greenish-gray basalt clasts. The clasts range from subangular to rounded, and are as much as 20 cm in maximum dimension. According to Silberling and others (1981a), this lower part of the Nikolai may equate with the Paxson Mountain Basalt of Stout (1976). At several localities within the quadrangle, the Nikolai Greenstone is cut by diabasic and gabbroic dikes which are interpreted to be feeder dikes for the basalt flows higher up in the section. For more detailed lithologic descriptions of the Nikolai, and for the distribution of its various rock types in the Healy A-1 quadrangle, the reader is referred to Silberling and others (1981a, 1981b), and to Smith (1981).

The rocks of the Nikolai Greenstone in the quadrangle underwent an apparently single event of low grade regional metamorphism. Secondary mineral assemblages in the basalts (Silberling and others, 1981b; Smith, 1981) suggest the metamorphic grade to be that of the prehnite-pumpellyite metamorphic facies (nomenclature after Turner, 1968). The age of this metamorphism is not known for certain, but in this report the metamorphism is considered to be part of the approximately middle Cretaceous regional metamorphic event affecting large parts of the Healy quadrangle.

The age of the Nikolai Greenstone has been determined in the Wrangell Mountains of eastern Alaska by the ages of the bracketing sedimentary rocks, as no fossils had been found in this largely subaerial formation (MacKevett, 1976, 1978; Jones and others, 1977). In the Wrangells, the Nikolai is underlain by the "Daonella beds" of middle Ladinian (Middle Triassic) age, and is overlain by upper Karnian (Upper Triassic) beds of the Chitistone Limestone. Thus, the Nikolai has been designated to be Middle and(or) Late Triassic in age. In the Healy A-1 quadrangle, a poorly exposed limestone bed apparently within the Nikolai Greenstone yielded the fossil *Halobia superba* of late Karnian-early Norian age (map no. 106 on Table 2). Unfortunately, it could not be determined for certain in the field that this limestone is an interbedded lens in the youngest part of the Nikolai. So far, such a young age for the upper part of the Nikolai has not been demonstrated in Alaska. However, thin interbeds of limestone within the Nikolai in the Healy A-1 quadrangle have been reported by Seraphim (1975). On the other hand, it is also possible that these limestones are thrust slivers of the Chitistone and Nizina Limestones (unit TRcl) within the Nikolai Greenstone.

In the Healy quadrangle and adjacent areas, the dominantly marine character of the Nikolai Greenstone makes it markedly different from the largely subaerial Nikolai at its type area in the Wrangell Mountains (MacKevett, 1976, 1978). The Nikolai rocks in the Healy quadrangle and adjacent areas appear to indicate, and to be part of a large-scale lateral facies change from a non-marine to a marine environment in the Alaskan parts of Wrangellia during Nikolai time.

Paleomagnetic studies on the Nikolai Greenstone in various parts of Alaska (Hillhouse, 1977; Stone, 1982), including the Healy quadrangle (Hillhouse and Grommé, 1984), indicate that Wrangellia, the host terrane of the Nikolai Greenstone, is allochthonous in its present position in Alaska, and that it has moved thousands of kilometers northward, relative to the North American craton, since Triassic time. The accretion of Wrangellia as part of the Talkeetna superterrane, to the ancient North American continent is interpreted to have taken place in about middle Cretaceous time (Csejtey and others, 1978, 1982; Csejtey and St. Aubin, 1981).

TRPs METASEDIMENTARY SEQUENCE (Early Permian, or possibly Late Pennsylvanian, to Middle Triassic)—These metasedimentary rocks are part of the Wrangellia terrane, and they occur near the southeastern corner of the quadrangle, south of the Talkeetna thrust fault. This sequence underlies the Nikolai Greenstone with an apparent unconformity, but it rests conformably on the andesitic volcanic rocks of unit PPv. The maximum thickness of this marine sequence is about 800 m. The lower and principal part of the sequence, about 700 m thick, consists of black argillite with laminae and thin interbeds of volcanic sandstone; and lesser amounts of thin-bedded crinoidal limestone, apparently turbidite deposits, forming discontinuous interbeds as much as 10 m thick; and a few interbeds, several tens of meters thick, of mafic volcanic breccia. The upper part of the sequence, approximately 100 m thick, comprises gray-green, red, or black, thin-bedded radiolarian chert (Silberling and others, 1981a, 1981b). Numerous large dikes and sills, diabasic and gabbroic in composition, occur throughout the sequence (unit TRPs). These dikes and sills appear to be feeders and the intrusive equivalents of the overlying Nikolai Greenstone. Further descriptions of the metasedimentary rocks (unit TRPs) can be found in Silberling and others (1981a, 1981b), and in Smith (1981).

Thin section studies indicate that the rocks of unit TRPs underwent an apparently single event of very low grade regional metamorphism, the intensity of which does not exceed the prehnite-pumpellyite metamorphic facies of Turner (1968).

In addition to the unidentifiable crinoid columnals, as much as 1.5 cm in maximum diameter, at several localities within and just outside the quadrangle the limestones and cherts yielded conodont and radiolarian fossils, respectively, which range in age from Early Permian, possibly Late Pennsylvanian, to Middle Triassic (Silberling and others, 1981a, 1981b; map nos. 142 to 147 in Table 2).

Not enough is known of the rocks of unit TRPs to reliably speculate on their depositional environment. Probably they were deposited at moderate and(or) deep oceanic depths, perhaps along the flank of a Pennsylvanian volcanic arc, represented by the andesitic volcanic rocks of unit PPv, which became essentially inactive by Permian time (Richter and Dutro, 1975).

According to Silberling and others (1981a), the lower part of unit TRPs probably is equivalent to part of the Slana Spur Formation of the Mankomen Group in eastern Alaska (Richter and Dutro, 1975), and the upper part is equivalent to the Eagle Creek Formation of the Mankomen Group of the same area.

PPv ANDESITIC VOLCANIC ROCKS (Early Permian(?) and Pennsylvanian)—These rocks occur near the southeastern corner of the quadrangle, and are part of the oldest known rocks of the Wrangellia terrane in southern Alaska (Richter and Jones, 1973; Richter and Dutro, 1975; Jones and others, 1977). The rocks of the unit comprise an over 2,000 m thick sequence of gray-green massive volcanic flows, breccias, and subordinate volcaniclastic rocks, all of largely andesitic composition (Silberling and others, 1981a, 1981b).

No fossils were found in these volcanic rocks, thus their age assignment is based primarily on correlating them (Silberling and others, 1981a) with the Tetelna Volcanics, named and described in the eastern Alaska Range by Richter and Jones (1973), and by Richter and Dutro (1975). According to these workers, the Tetelna Volcanics represent a late Paleozoic volcanic arc of dominantly andesitic composition, which had become virtually inactive by Early Permian time.

Plutonic rocks

Kgr GRANITIC ROCKS (Late and latest Early Cretaceous)—These granitic rocks occur in a number of dominantly medium-sized and generally discordant plutons which appear to be restricted to the eastern half of the quadrangle, but to the north of the Talkeetna thrust. The most common rock type is tonalite, but granodiorite, quartz diorite, diorite, and quartz monzodiorite also occur (granitic rock nomenclature according to IUGS, 1973). The more felsic rock types in most cases appear to be the result of differentiation. The typical tonalite, forming the bulk of the Cretaceous plutons, especially the larger ones, contains very small amounts of K-feldspar, generally between 0 to 7 modal percent, and the modal quartz content ranges from about 20 to 40 percent. The major mafic minerals are biotite and hornblende, generally in about equal proportions. The color index ranges from about 10 to 38, but commonly it is between 19 and 34. Grain size ranges from medium to coarse, but fine-grained varieties, probably border facies, also occur. Texture is generally granitic. Most of the Cretaceous granitic rocks have a fairly to moderately well-developed flow foliation. This flow foliation appears to be the most reliable criterion in the field to differentiate between the Cretaceous granitic rocks and the Tertiary ones. Some of the

Cretaceous plutons south and southwest of the Susitna Glacier are migmatitic, displaying alternating bands rich in felsic or mafic minerals. As some of the potassium-argon age determinations suggest, to be discussed later, some of these felsic rich bands may actually be lit-par-lit type intrusions of felsic magmas in Tertiary time.

The Cretaceous plutons of the quadrangle appear to have been emplaced at deeper levels of the earth's crust than the Tertiary granitic rocks which display all the characteristics of epizonal plutons (nomenclature of zones of granite emplacement according to Buddington, 1959). The Cretaceous plutons are interpreted to have been emplaced in a transitional zone between the epizone and mesozone. The main reasons for this interpretation are as follows: the prevalence of primary foliation, the scarcity of border facies, the partly concordant contacts with the regionally metamorphosed country rocks, and the lack of myarolitic cavities, associated volcanic rocks, and aplitic dikes.

Potassium-argon age determinations on the Cretaceous granitic rocks (map nos. 7, 9, 10, 11, 12, 33, 34, 36, 37, 39, 41, 47, 51, and 52 on Table 1) yielded a disparate range of latest Early Cretaceous to early Tertiary ages (about 105 to 49 million years). Some of these early Tertiary ages are suspected to be the result of lit-par-lit, that is intricate intrusions of granitic magma into the Cretaceous plutons in early Tertiary time. This is especially suspected for the pluton just south of the Susitna Glacier (map no. 39 on Table 1). However, the majority of the ages falling between roughly 50 to 70 million years appear to have been reset by a regional thermal event or events, perhaps caused by the widespread plutonic and volcanic activity in the Healy quadrangle in early Tertiary time. This is suspected even where the biotite and hornblende ages are nearly concordant (for instance, map nos. 37 and 41 on Table 1). The cause for resetting is especially convincing in areas near and just to the south of the southern edge of the quadrangle, where foliated and deep-seated, assumedly Cretaceous granitic rocks are intruded by shallow, that is epizonal Tertiary granitic rocks, or are in close spatial proximity to subaerial volcanic flows and tuffs of early Tertiary age. All of these three rock types of disparate geologic environments yielded the same or nearly the same potassium-argon ages (map nos. 47, 48, 51, and 52 on Table 1 of this report; and map nos. 2 and 3 on Table 1 of Csejtey and others, 1978. On the geologic map of Csejtey and others, 1978, the map unit Tsmg at and around the location of the dated sample no. 3 of Table 1 of Csejtey and others (1978) correlates with the unit Kgr on the geologic map of this report, as has been determined by subsequent field checking). Reheating of some of the Cretaceous granitic rocks in Tertiary time, that is resetting their potassium-argon ages, is further indicated by the significantly discordant ages on a biotite-hornblende mineral pair from the Cretaceous pluton just west of the Susitna Glacier (map no. 36 on Table 1). On the basis of the above considerations, the Cretaceous plutons are interpreted to have been emplaced, probably by a series of intrusions, during a period about 106 to 70 million years ago.

As mentioned previously, the Cretaceous plutons occur only in the eastern half of the Healy quadrangle, on both sides of the Hines Creek and McKinley faults, and are intruding a variety of regionally metamorphosed rock units which were juxtaposed during an accretionary orogenic period (Csejtey and others, 1982) in about middle Cretaceous time. Thus, the Cretaceous plutons provide an upper age bracket for the main phase of this orogeny. One of the plutons, about 95 to 102 million years old (map nos. 10, 11, and 12 on Table 1), intrudes the Hines Creek fault, and thus restricts the timing of significant movement vertical and(or) horizontal, along the fault (Wahrhaftig and others, 1975). The roughly symmetrical distribution of the Cretaceous plutons across the Denali fault is supportive of the interpretation that only limited horizontal displacements took place along the fault since about middle Cretaceous time (Csejtey and others, 1982).

Kgrt TOURMALINE-BEARING GRANITE (Late or latest Early Cretaceous)—Occurs in a small, irregular-shaped, discordant pluton with associated small satellitic bodies, of a total surface area of about 2.5 square kilometers, along Virginia Creek in the northeastern part of the quadrangle (Wahrhaftig, 1970b). The rock is a medium- to fine-grained, tourmaline-bearing granite with a granitic to seriate texture. The age of this rock is not known for certain, but it is assumed to be the same as that of the nearby Cretaceous granitic rocks which do not contain tourmaline.

KJum ULTRAMAFIC ROCK (Early Cretaceous(?) or Jurassic(?))—This unit consists of a dark greenish- or brownish-gray, coarse- to medium-grained, plagioclase-bearing ultramafic rock which occurs in a small, sill-like intrusive body within amphibolite-grade metamorphic rocks of unit TRcs, near the eastern edge of the quadrangle, just north of the McKinley fault. Thin-section studies indicate that the rock-forming minerals are olivine, phlogopite, pale brown amphibole, subordinate clinopyroxene (possibly diopside), some orthopyroxene, opaque minerals, and a few interstitial grains of plagioclase. The olivine forms small, rounded crystals which are poikilitically enclosed in phlogopite, amphibole, and less frequently, in clinopyroxene. The plagioclase has the approximate composition of andesine, and occurs in very small amounts as small, interstitial grains. The overall texture of the rock appears to be transitional between igneous and metamorphic.

The origin of this rock is poorly understood. Its unusual mineral assemblage, especially the high volume of phlogopite, makes it hard to place in any rock classification scheme. Undoubtedly, it is a plagioclase-bearing ultramafic rock of igneous origin, most probably the differentiation product of a more felsic magma. The intrusion of this rock appears to have preceded the regional metamorphism of the Late Triassic country rocks.

The age of this ultramafic rock is imperfectly known. It is younger than the Late Triassic country rocks, but appears to be older than the approximately middle Cretaceous regional metamorphism of these same country rocks.

Jgb ALKALI GABBROS (Late Jurassic)—These rocks occur in a small, discordant pluton, about 5.2 square kilometers in surface area, in the Clearwater Mountains near the southeast corner of the quadrangle. The rocks comprise an extremely heterogeneous subsilicic fractionation series of alkali gabbros, ranging from mafic theralites through essexites and monzogabbros into monzodiorites and monzonites (Smith, 1981; plutonic rock nomenclature according to IUGS, 1973). The most common rock type is a coarse- to medium-grained, dark greenish-gray hornblendic monzogabbro. The emplacement of the pluton predates the prehnite-pumpellyite facies regional metamorphism of the flysch-like country rocks of unit KJf. Hence, the metamorphism has obscured to some extent the original igneous textures.

Potassium-argon age determinations on biotite and hornblende mineral pairs from a sample of alkali gabbro yielded discordant ages (132 and 146 million years, respectively), indicating that the pluton is latest Late Jurassic in age (Smith, 1981; map no. 42 on Table 1).

A detailed description of the alkali gabbros, including their petrochemistry, can be found in Smith (1981, p. 37-39).

Pzmg METAGABBRO (Late Devonian(?))—This is a dark greenish-gray, fine- to medium-grained, well foliated rock which underwent the same greenschist facies regional metamorphism (metamorphic nomenclature after Turner, 1968) as the surrounding country rocks of unit pqs. Field relationships suggest the rock is a metamorphosed igneous rock, and has been interpreted to be a metagabbro (Wahrhaftig, 1968). The metagabbro occurs in two small, irregular-shaped intrusive bodies within the Precambrian and(or) early Paleozoic metamorphic rocks of unit pqs. One of the plutons is located in the north-central part of the quadrangle, the other in the northeastern part.

Thin sections indicate the metagabbro to consist of epidote, chlorite, quartz, sericite, calcite, albite(?), and opaque minerals (Wahrhaftig, 1968). The greenschist facies regional metamorphism has obliterated the original mineralogy and igneous texture.

The age of the metagabbro is uncertain. The metagabbro may be the intrusive equivalent of the metabasalts of unit Pzmb, and thus be of Late Devonian age. But it is also possible that the metagabbro correlates with the Jurassic to Early Cretaceous gabbroic intrusives within the Yanert Fork sequence (unit Pzy) and within the Upper Triassic calcareous rocks of unit TRcs, all these rocks occurring south of the Hines Creek fault.

Southwestern and west-central parts of quadrangle

Sedimentary and volcanic rocks

Ohio Creek area (Chulitna district)

JTRrs RED AND BROWN SEDIMENTARY ROCKS AND BASALT, UNDIVIDED (Early Jurassic and Late Triassic)—Rocks of this unit occur in thrust slivers near the southwest corner of the quadrangle. The maximum preserved thickness of these rocks is at least 2,000 m. The basal part of the unit consists of a red-colored sequence of sandstone, siltstone, argillite, and conglomerate, with a few thin interbeds of brown fossiliferous sandstone, pink to light-gray dense limestone, and intercalated basalt flows. This red bed sequence grades upward into highly fossiliferous brown sandstone, which in turn grades upward into brownish-gray siltstone with yellowish-brown limy concretions.

Clasts in the red beds are dominantly basalt grains and pebbles which probably were derived from basalt flows of unit TRlb that lies unconformably below the red beds and from the basalt flows within the red bed sequence. Subordinate amounts of the clasts consist of white, in part foliated, metaquartzite pebbles; flakes of white mica which, along with the metaquartzite, must have been derived from an unidentified siliceous metamorphic terrane; and red radiolarian chert pebbles and grains, which probably were derived from the ophiolitic rocks of unit Dsb. No other clasts that can be identified as coming from the ophiolitic rocks have been recognized.

Fossils from the limestone and the overlying brown sandstone are of Late Triassic age, and those from the yellowish-brown limy concretions are of Late Triassic and Early Jurassic age (map nos. 107 to 114 on Table 2).

Most of the rocks of this unit appear to have undergone very low-grade regional metamorphism. Judging by the metamorphic mineral assemblages in the underlying basalts of unit TRlb, the metamorphic grade of the red and brown sedimentary rocks (unit JTRrs) does not exceed the prehnite-pumpellyite facies of Turner (1968).

More detailed discussions of both the red and brown beds, and their detailed distribution in the Healy A-6 quadrangle, can be found in Jones and others (1980).

TRlb LIMESTONE AND BASALT SEQUENCE (Late Triassic, most probably Norian)—Interlayered sequence, at least several hundreds of meters thick, of limestone, partly recrystallized to marble, and flows of altered amygdaloidal basalt. Individual units are as much as several tens of meters thick. These rocks occur in a complexly thrust-faulted zone in the southwest corner of the quadrangle. The limestone and basalt sequence unconformably underlies the rocks of unit JTRrs. The base of the sequence is not exposed.

The limestone is medium-gray, massive to thick-bedded, but locally it has altered to fine- to medium-grained marble. Several of the limestones contain sparse fragments of poorly preserved corals and thick-shelled megalodontid bivalves up to 20 cm in length. A single specimen of Spondylospira(?) sp., in conjunction with the megalodontid bivalves, suggests a Norian age for the sequence (Jones and others, 1980; map nos. 115 to 117 on Table 2).

The amygdaloidal basalt is dark gray to greenish gray, aphanitic, with numerous amygdules. Locally, it displays well-developed pillow structures. Primary rock-forming minerals are fine-grained labradorite, titanium-rich augite, and opaques in an originally intersertal or subophitic texture. The original mineral assemblage has been more or less altered to an aggregate of chlorite (much of it after glass), epidote, calcite, sericite, and some zeolite, probably prehnite. The amygdules consist of chlorite, calcite, prehnite, and minor quartz. Most of the secondary minerals are probably the result of deuteric alteration, but some are the product of prehnite-pumpellyite facies regional metamorphism (metamorphic nomenclature after Turner, 1968). Fifteen chemical analyses of least altered basalt samples indicate that the basalts are somewhat low in silica (normalized SiO_2 contents average 46.7 percent by weight, ranging from 43.7 to 48.7 percent), high in alkalis (normalized Na_2O contents average 3.06 percent by weight, ranging from 1.3 to 5.2 percent; and normalized K_2O contents average 0.47 weight percent, ranging from 0.07 to 1.5 percent), and are high in titanium (normalized TiO_2 contents average 3.8 weight percent, ranging from 2.5 to 5.0 percent). The chemistry and mineralogy suggest that these basalts had alkali affinities prior to alteration.

The fossils and the lithologies of the limestones and the basalts indicate shallow water marine deposition. The probable alkali affinity of the basalts further suggests that they either were part of an ocean island shield volcano, perhaps associated with a barrier reef, or that they were formed on a continental margin.

TRr RED BEDS (Late Triassic)—These red beds occur in thrust slivers along Long Creek and around Lookout Mountain near the southwest corner of the quadrangle. The maximum preserved thickness of these rocks is estimated to be about 500 meters. The red beds of this unit consist of red sandstone, siltstone, argillite, and conglomerate similar to the red beds of unit JTRrs. Clasts of gabbro, serpentinite, and fossiliferous Permian(?) limestone are present in these rocks but have not been identified in rocks of unit JTRrs. Also, a thin conglomerate bed containing angular clasts of rhyolite is locally present at the base. These red beds lie with depositional unconformity on Lower Triassic to Upper Devonian strata of unit TRDs. The top of the red beds section is nowhere exposed. The red beds lack fossils and, therefore, have not been dated, but they are assumed to be equivalent in age to the Upper Triassic red beds of unit JTRrs (Jones and others, 1980). The metamorphic grade of the red beds of unit TRr is not known, but it is assumed to be that of the prehnite-pumpellyite facies of Turner (1968), the same as that of the surrounding rocks of the region.

TRDs VOLCANOGENIC AND SEDIMENTARY ROCKS, UNDIVIDED (Early Triassic to Late Devonian)—These rocks occur in several thrust slivers around Lookout Mountain in the southwestern portion of the quadrangle. They comprise an heterogeneous, intercalated sequence, over 500 m thick, of greenish-gray to black tuffaceous chert, volcanic conglomerate, lesser amounts of maroon volcanic mudstone, breccia composed largely of basaltic detritus, laminated flysch-like graywacke and shale, large lenses of light-gray, thick-bedded limestone, and poorly exposed thin beds of ammonite-bearing limestone. Ammonites and conodonts from the ammonite-bearing limestone are Early Triassic in age; fossils from the thick-bedded limestone are Permian in age; brachiopods from the conglomerate are also of Permian age; and fossils from the chert are Late Devonian and Carboniferous (Nichols and Silberling, 1979; Jones and others, 1980; map nos. 129 to 136 on Table 2). The stratigraphic and structural relations between these diverse rocks are obscured by numerous folds and faults, and by poor exposures.

The metamorphic grade of these rocks is not known, but it is probably that of the greenschist metamorphic facies of Turner (1968).

Detailed discussions of these rocks are given in Nichols and Silberling (1979), and in Jones and others (1980).

Dsb SERPENTINITE, BASALT, CHERT, AND GABBRO (Late Devonian)—These rocks comprise a tectonically intermixed assemblage, a few hundreds of meters thick, that forms a northeast-trending belt of thrust slivers in the southwestern corner area of the quadrangle. Sheared serpentinite is the most abundant rock type; the remaining component rocks occur in various proportions in lenticular and podiform tectonic blocks as much as several hundred meters in extent. Many chert lenses occur intercalated with basalt flows which locally show poorly preserved pillow structures. Rocks of this map unit have been previously described and interpreted as a dismembered ophiolite assemblage by Clark and others (1972) and by Jones and others (1980).

The serpentinite is dark gray to dark greenish gray, always sheared, and consists almost entirely of clinocrysotile and lizardite with subordinate brucite, talc, and chromite. Sparse relict olivine crystals and a bastite texture suggest that the serpentinite originally was a pyroxene-olivine ultramafic rock.

The basalt is dark gray, aphanitic to fine grained with a few phenocrysts, as much as 4 mm in maximum dimension, of altered plagioclase, pyroxene, and olivine. The rock is locally vesicular or amygdaloidal and generally is fragmental; many of the fragments are palagonite. Some of the vesicles and amygdules are concentrated along spherical surfaces which may be parts of pillow structures. Depositionally intercalated marine chert beds further indicate that the basalts were formed as submarine flows.

The chert is generally red, but reddish-brown and greenish-gray varieties also occur. It is commonly in beds a few millimeters to a few centimeters in thickness, and contains abundant radiolaria.

The gabbro is medium to dark greenish gray, fine to coarse grained, and is composed of altered plagioclase, pyroxene, olivine, and opaques. Compositional layering, interpreted to be cumulate textures, is common, and the layers range in thickness from a few millimeters to a few centimeters. The best exposed gabbro occurs in a lens about 100 m thick and about 1 km long on the ridge north of the unnamed northern branch of Shotgun Creek.

Age determinations of radiolarians and conodonts in chert samples from five separate localities reliably indicate a Late Devonian (Fammennian) age for the ophiolitic rocks (Jones and others, 1980; map nos. 137 to 141 on Table 2).

KJs ARGILLITE, CHERT, SANDSTONE, AND LIMESTONE (Early Cretaceous and Late Jurassic)—These rocks occur in thrust slivers, sandwiched between Triassic and Jurassic strata of units TRlb and JTRrs, in the southwestern part of the quadrangle. The unit consists of dark-gray argillite, dark-gray to greenish-gray bedded chert, thick-bedded sandstone, thin-bedded gray sandstone, and rare thin beds of shelly limestone. Both Late Jurassic and Early Cretaceous radiolarians were obtained from the chert. The thick-bedded sandstone contains abundant fragments of Inoceramus sp. of Hauterivian to Barremian age, and some of the limestone beds contain Buchia sublaevis of Valanginian age (for fossil descriptions, see map nos. 28 to 31 on Table 2). Some of the thin-bedded sandstone contains abundant detrital white mica and may be as young as Albian (mid-Cretaceous). Thicknesses and the stratigraphic relations within these rocks and with adjacent rocks are unknown because of complex folding and faulting, and poor exposures. The age range and lithologies of the rocks of unit KJs tentatively suggest that these rocks might be tectonically emplaced distal facies of the flysch-like rocks of unit KJf.

The metamorphic grade of these rocks is unknown, but it appears to be no higher than the prehnite-pumpellyite metamorphic facies of Turner (1968).

More detailed descriptions of these rocks are given in Jones and others (1980).

JTRta CRYSTAL TUFF, ARGILLITE, CHERT, GRAYWACKE, AND LIMESTONE (Late to Early Jurassic, possibly to Late Triassic)—Moderately deep to deep marine sequence, tightly folded and internally faulted, at least several thousand meters thick. These rocks are interpreted to occur in a large thrust block along the western slope of the Upper Chulitna Valley, in the southwest portion of the quadrangle. Four-fifths of the sequence is comprised of the massive, cliff-forming crystal tuff, while the remaining rocks form only a narrow outcrop belt along the western margin of the unit. The contact between these two groups of rocks may be tectonic.

The crystal tuff is light to dark gray, locally with a greenish tint, and weathers to various shades of brown. It is massive with obscure rhythmic laminations and thin bedding. The tuff is composed of abundant small feldspar crystals (albite?) set in a very fine grained matrix of devitrified volcanic glass in which some shards can be recognized. Sparse but unidentifiable fragments of radiolarians were also found. A thin interbed of volcaniclastic sandstone yielded the following fossils: Arctoasteroceras jeletskyi Frebold, Paltechioceras (Orthechioceras?) sp., and Weyla sp. (Jones and others, 1980). According to R. W. Imlay (written commun. to D.L. Jones, 1976), these fossils indicate a late Sinemurian age (Early Jurassic; map no. 70 on Table 2). As the Sinemurian fossils come from near the top of the several thousand meters thick crystal tuff section, the base of the section may be as old as Late Triassic.

The argillite, chert, graywacke, and limestone occur interbedded in various proportions in individual units as much as several tens of meters thick. The argillite and chert are dark gray to black; the graywacke is medium to dark gray, very fine to medium grained, locally with graded bedding. The limestone is medium gray, generally phosphatic, in part sandy, locally is associated with limy siltstone and conglomerate; forms blocks and lenticular beds as much as several kilometers in extent. Some of the chert beds yielded radiolarians of Callovian to early Tithonian age (Late Jurassic; map nos. 68 and 71 on Table 2), and at five different localities, the limy rocks yielded Early Jurassic ammonite faunas of early Sinemurian age (Jones and others, 1980; map nos. 64, 65, 66, 67, and 69 on Table 2).

The moderately deep to deep marine rocks of unit JTRta are dissimilar in lithologies, depositional environment, and partly in age to the surrounding rock units. Perhaps the rocks of unit JTRta are the tectonically emplaced remnants of deep oceanic sediments which were deposited in a large oceanic basin between the ancient North American continent and the northward drifting Talkeetna superterrane (Csejtey and others, 1982). Accordingly, the Upper Jurassic rocks of unit JTRta are the distal oceanic basin equivalents of the Jurassic portion of the flysch-like rocks of unit JKf. If this interpretation is valid, then it also implies that the Talkeetna superterrane must have accreted to the ancient North American continent in post-Jurassic time, because during the Jurassic the converging continents were still separated by a large oceanic basin.

KJfa FLYSCH SEQUENCE (Earliest Late Cretaceous to Late Jurassic)—These flysch-like rocks occur in the southwestern part of the quadrangle. Lithologically they are identical to the flysch-like rocks of unit JKf, and are considered to be part of the more or less autochthonous Jurassic and Cretaceous flysch sequence interpreted to have been deposited on and between the ancient North American continent and the converging Talkeetna superterrane (Csejtey and others, 1982). The rocks of this unit are shown separately on the geologic map because, in addition to Early Cretaceous fossils, they have also yielded fossils of earliest Late Cretaceous (Cenomanian) age (map nos. 32 to 36 on Table 2). None of the other flysch-like rocks of the quadrangle have yielded fossils of such a young age, but perhaps this is the result of intense, post-depositional deformation and subsequent erosion. Conglomerates of unit KJfa also contain limestone pebbles of early Paleozoic age (map nos. 37 and 38 on Table 2).

TRcg CONGLOMERATE AND VOLCANIC SANDSTONE (Late Triassic, late Norian)—These rocks occur in small cutbank exposures along the Jack River in the central-western part of the quadrangle. They are interpreted to be part of a small thrust sliver. According to rock types, the conglomerate and volcanic sandstone unit (TRcg) can be subdivided into three parts (Jones and others, 1980). The lower part of the section, about 40 to 50 m thick, comprises cobble to boulder conglomerate composed of green volcanic rocks and red radiolarian chert. The chert clasts are well-rounded; some are as much as 30 cm in diameter. Radiolarians from the red chert clasts were determined to be Permian in age (unpub. data by D.L. Jones and B.K. Holdsworth in Jones and others, 1980). Thus, the red chert clasts of this unit could not have derived from the Devonian red cherts of unit Dsb. Their source area is unknown. The middle part of the section, about 40 to 50 m thick, comprises finer-grained volcanigenic (andesitic?) conglomerate with locally abundant fossils of Heterastridium sp., indicating a Late Triassic (late Norian) age (map no. 118 on Table 2). The upper part of the section consists of about 50 m of massive volcanic sandstone.

The lithologic characteristics of the rocks of unit TRcg are markedly different from those of any other rocks occurring in the quadrangle. However, the fossil Heterastridium sp., of late Norian age, has also been found in the rocks of unit TRvs. On this basis, and on the basis that volcanogenic rocks and cobble conglomerates also occur in unit TRvs, a possible correlation between these units is herein suggested. Perhaps the difference in the clast compositions of the conglomerates is the result of facies changes and(or) different source areas. Accordingly, the rocks of unit TRcg might be part of the Wrangellia terrane of the Talkeetna superterrane.

Nixon Fork terrane

DOs and Dls SEDIMENTARY SEQUENCE (Middle Devonian to Ordovician)—The rocks of this sequence occur in the west-central part of the quadrangle, north of the McKinley fault. Previously, these rocks have been referred to by Jones and Silberling (1979) and by Jones and others (1981a, 1982, 1983, and 1984) as the "Dillinger" tectonostratigraphic terrane. As will be discussed later in this report, the rocks of this sequence are provisionally correlated with the deep-water facies "shale out" beds of the Nixon Fork terrane (Churkin and others, 1980; Dutro and Patton, 1982).

The rocks of these units (DOs and Dls) comprise a complexly folded and faulted, regionally metamorphosed, intercalated, and a stratigraphically upward shallowing marine sequence of dominantly slope and basinal turbidites and hemipelagic deposits with lesser amounts of shelf-type deposits. The sequence consists of medium- to dark-gray, thinly graded-bedded to laminated, medium- to fine-grained sandstone; dark-gray to black argillite; intercalated layers, a few tens of meters thick, of dark gray, generally thinly bedded, locally thick-bedded limestone and dark-gray argillite; and near the top of the section about a 200 m thick interbed of medium- to light-gray, a massive, finely to medium-crystalline, partly dolomitic limestone. The massive limestone interbed near the top of the section is shown separately on the geologic map as Dls, while all the other rocks constituting the bulk of the sequence are shown as DOs.

The sandstones contain grains of mica and feldspar, in addition to abundant quartz and quartzitic grains, suggesting a continental source (Jones and others, 1982). The thinly bedded limestone and argillite interlayers also appear to be turbidites (Jones and others, 1982) deposited in a continental slope and deep-marine basin environment. The massive limestone (Dls) appears to have been deposited in a shallow carbonate shelf and shoreline environment. This is indicated by the presence of dolomitic limestones with algal laminations, mud cracks, intraformational breccias, and birdseye structures which typically form in tidal flat environments of restricted platforms.

At one locality (map no. 170 on Table 2), one of the thinly bedded limestones yielded gastropod fossils of Ordovician to Devonian ages (E.L. Yochelson and J. Pojeta in Jones and others, 1983). From the headwater area of the Sanctuary River, Capps (1932, p. 255; map no. 169 in Table 2) reported Middle Devonian fossils from the massive limestone interbed (Dls). Samples from two localities in the massive limestone interbed (map nos. 165 and 168 on Table 2) and two from thinly bedded limestones (map no. 166 and 167 on Table 2), were processed for conodonts, but none were found. However, a more extensive sampling of both the massive and the thinly bedded limestones most probably would yield identifiable conodonts, because specimens were found in limestone pebbles from the nearby, stratigraphically overlying clastic rocks of the Cantwell Formation (unit Tc). These Cantwell pebbles consist of both massive and thinly bedded limestones, which lithologically are identical to the massive limestone and the thinly bedded limestones of units Dls and DOs, respectively. The Cantwell conodont-bearing limestone pebbles almost certainly were derived from less recrystallized limestones of units Dls and DOs. The conodonts from the Cantwell limestone pebbles (map nos. 9, 10, and 11 on Table 2) range in age from Ordovician to Early Devonian. On the basis of the above fossil data, unit DOs is considered to range in age from Ordovician to Middle Devonian and the massive limestone interbed (Dls) is considered to be of Middle Devonian age.

The metamorphic grade of the rocks of units DOs and Dls is not known. On the basis of field observations it is estimated to be probably not higher than the prehnite-pumpellyite metamorphic facies of Turner (1968).

The lithologic characteristics of units DOs and Dls suggest that they are continental margin-type deposits representing a stratigraphically upward shallowing marine sequence which was deposited at water depths ranging from deep to very shallow.

The age range and the lithologies of units DOs and Dls are dissimilar to any other map units in the Healy quadrangle. Jones and others (1981a, 1982) correlated the rocks of unit DOs and Dls, and their westward extension in the McKinley quadrangle, with similar rocks about 100 km to the southwest, underlying large areas south of the Denali fault system. They designated both of these rock sequences as the "Dillinger" terrane. However, Dutro and Patton (1982) provisionally considered the "Dillinger" terrane rocks south of the Denali fault system to be at least partly correlative with deep-water facies strata of the Nixon Fork terrane. The rocks of units DOs and Dls in the Healy quadrangle are very similar in their age range and lithologies to the deep-water facies rocks and some of the shallow-water facies rocks of the Nixon Fork terrane described by Dutro and Patton (1982), and by Churkin and others (1980). On this evidence, the rocks of units DOs and Dls of the Healy quadrangle are provisionally considered to be a tectonically displaced fragment of the deep-water and part of the shallow-water portions of the Nixon Fork terrane. This terrane appears to have been part of the ancient North American continent in Cretaceous time, and possibly much earlier (Patton, 1978; Foster and Keith, 1974; H.L. Foster, unpub. data, 1980). The postulated subsurface extent of the Nixon Fork terrane, and the postulated tectonic processes which emplaced fragments of the Nixon Fork terrane in the Healy quadrangle, will be discussed in more detail in the "Tectonics" section of this paper.

KJf FLYSCH SEQUENCE (Early Cretaceous and Late Jurassic)—These rocks are the same as the flysch-like rocks of unit KJf in the eastern and southern parts of the quadrangle. The reason that the flysch-like rocks are shown again in the correlation chart of map units (under the heading "Southwestern and west-central parts of quadrangle") is to indicate that the flysch-like rocks of unit KJf in the central part of the quadrangle and north of the McKinley fault rest unconformably on the Upper Triassic to Devonian(?) rocks of unit TRbd. Everywhere else in the quadrangle, the contact between the flysch-like rocks of unit KJf and all older rocks is either tectonic or is covered by surficial deposits. Fossil data for unit KJf in the western part of the quadrangle are given under map nos. 39 to 42 in Table 2.

TRbd BASALT, DIABASE, AND SUBORDINATE SEDIMENTARY INTERBEDS (Late Triassic, Karnian-Norian)—The rocks of this unit and the depositionally underlying, and locally interfingering flysch-like rocks of unit TRPzs occur in a narrow and discontinuous, fault-bounded, east-west trending belt in the west-central part of the quadrangle. Both units have been previously described and designated as part of the "McKinley" tectonostratigraphic terrane by Jones and others (1981a, 1982).

Rocks of this unit comprise a several-hundred-, perhaps several-thousand-meters thick submarine sequence of basalt flows, mostly pillowed, with associated sills and dikes of diabase and gabbro which also cut the underlying rocks of unit TRPzs. According to Jones and others (1982), most of the basalts are porphyritic, with phenocrysts of clinopyroxene, olivine, and magnetite. The subordinate interbedded sedimentary rocks are dark-gray to dark-grayish-green, fine-grained sandstone, siltstone, and argillite. Some of these rocks contain abundant angular tuffaceous material which produces a greenish hue. Fossils from this unit are rare, but an halobid bivalve of Late Triassic (Karnian-Norian) age was found at one locality, and radiolarians of Late Triassic (late Norian) age were recovered from a sample at another (Gilbert and others, 1984; map nos. 119 and 120 on Table 2).

The metamorphic grade of these rocks is imperfectly known, but probably is no higher than the prehnite-pumpellyite, possibly the lower greenschist facies of Turner (1968). This unit probably represents a series of subaqueous basalt flows with minor intercalated clastic and pelagic sediments which were deposited in a deep marine environment. Some of the sediments were laid down synchronous with eruptions, as indicated by the abundance of angular tuffaceous material. All the sediments are fine-grained, mainly thin-bedded turbidites and pelagic mudstones, and they contain little or no continentally derived sand-sized grains, but they contain pelagic fossils. All these features indicate deposition in a deep marine environment away from a continental mass.

The stratigraphic position of the basalts, and the lithologies of the underlying flysch-like rocks of unit TRPzs are different from any rock units within the quadrangle. The rocks of both units undoubtedly comprise a tectonically emplaced block of unknown origin. However, the lithologies and the age of the basalts of unit TRbd are very similar to the basalts of unit TRvs in the southern parts of the quadrangle. The age span of the flysch-like rocks of unit TRpzs are somewhat similar to the Triassic and late Paleozoic sedimentary rocks (unit TRPs) of Wrangellia. As a remote possibility, perhaps units TRbd and TRPzs represent a tectonically emplaced fragment of so far unrecognized distal-facies-rocks of Wrangellia, where the Chitistone and Nizina Limestones, and the Nikolai Greenstone are absent. It is also possible that the Nikolai Greenstone, dominantly marine and pillowed in the southeastern part of the quadrangle, is also present but could not be differentiated from the lithologically similar Norian (Upper Triassic) basalts in the field.

TRPzs FLYSCH-LIKE SEDIMENTARY ROCKS (Late Triassic to Pennsylvanian)— This unit and the depositionally overlying and locally interfingering rocks of unit TRbd, as previously mentioned, occur in the west-central part of the quadrangle. Both units have been described and designated as part of the McKinley terrane by Jones and others (1981a, 1982).

Unit TRPzs comprises an intensely folded marine sequence, estimated to be at least several hundreds of meters thick, of dark-gray to black, massive to thin-bedded, flysch-like rocks, namely, conglomerate, sandstone, siltstone, argillite, a few thin interbeds of impure limestone, and near the top of the sequence, thin interbeds of chert intercalated with argillite. These rocks contain abundant trace fossils, and some of the conglomeratic layers contain displaced fossiliferous detritus such as bryozoans, echinoderm fragments, rare brachiopods of Permian to Carboniferous ages, and some corals of Devonian and probable Mississippian ages (Jones and others, 1982;

Sherwood and Craddock, 1979; map nos. 123, 124, and 125 on Table 2). Slump blocks of crinoidal limestone, as much as 1 m in diameter, occur locally in the upper part of the sequence. The source of these blocks is not known, but a sample from one block yielded conodonts of late Early to early Middle Devonian age (map no. 126 on Table 2).

The age of this unit is considered to range from Late Triassic to Pennsylvanian. Conodonts and radiolarians extracted from chert samples from near the top of the sequence indicate a Late Triassic (Karnian) age (map nos. 121 and 127 on Table 2), and conodonts from a calcareous layer in a sandstone and argillite section indicate a Middle Triassic (Anisian) age (map no. 122 on Table 2). The Pennsylvanian age determination is based on a collection of brachiopods reported on by L.R. Laudon in Sherwood and Craddock (1979) (map no. 128 on Table 2).

The metamorphic grade of these rocks is imperfectly known, but is most likely of the prehnite-pumpellyite facies, possibly of the low green schist facies of Turner (1968).

The depositional environment of this unit appears to have been at slope to base of slope water depths, and the rocks of the unit appear to represent a deepening-upward sequence (decrease in grain-size stratigraphically upward). This is indicated by the conglomerates and thick-bedded turbidites (sandstone, siltstone, and argillite) near the base of the sequence which grades upward into interbedded chert and argillite near the top of the sequence. The displaced fossiliferous blocks and clasts were undoubtedly derived from pre-existing basement rocks and possibly from a contemporaneous carbonate platform at shallower depths. A massive conglomerate layer which contains Devonian, Mississippian, and Permian fossil clasts (map nos. 123, 124, on Table 2), also contains large basalt clasts, implying an original depositional relationship with the associated basalts of unit TRbd (Jones and others, 1982). This may indicate the presence of an older basalt, possibly a Nikolai Greenstone equivalent (see discussion under unit TRbd), because rocks associated with the massive conglomerate contain Middle Triassic conodonts. Another possibility is that the section containing the massive conglomerate is a fault sliver of a younger flysch-like unit (KJf) as suggested by Jones and others (1982).

The possible regional correlation of this unit has already been discussed under the description of unit TRbd.

Tectonic melange(?) units

m_1 and ls_1 - MELANGE(?) ROCKS (Late and(or) Early Cretaceous)—The rocks of this unit occur in a southeast-trending, discontinuous, fault-bounded outcrop belt in the southwestern part of the quadrangle. Previously, the unit has been described by Jones and others (1980, 1981a, 1982) as the "Broad Pass" tectonostratigraphic terrane composed of Paleozoic rocks. In this report, the unit is provisionally reinterpreted as a tectonic, and probably sedimentary melange, comprising Paleozoic and late Mesozoic rocks. This melange probably formed during, and as a result of, the accretion of the Talkeetna superterrane to the ancient North American continent in middle Cretaceous time (Csejtey and others, 1982). The unit includes three distinct rock suites which are intensely deformed, sheared, and have been intricately intermixed by tectonic, and perhaps also by sedimentary processes. These rock suites are:

(1) Medium- to thin-bedded, greenish-gray to tan-colored, locally black, cherty tuff, chert, argillite, and fine-grained volcanic sandstone. Commonly, the bedding shows slight grading from fine sand-sized grains at the bottom to argillite at the top. Locally, vitroclastic textures in the tuffs are well developed (Jones and others, 1980).

(2) Dark-gray to black, flysch-like rocks of argillite, slate, shale, fine- to medium-grained graywacke, subordinate bedded chert, and both chert-pebble and polymictic conglomerates. Lithologically, these rocks are identical to the flysch-like rocks of units KJf, KJfa, and KJf_k.

(3) Lenses and elongate blocks, some as much as several kilometers in length, of medium-gray, generally medium-bedded and rarely massive, fine- to medium-grained fossiliferous limestone.

Rocks of the first two suites are shown as m_1 on the geologic map, and the limestone lenses as ls_1.

Radiolarians and conodont fragments from the cherty tuffs and associated rocks range in age from Late(?) Devonian to Mississippian (map nos. 44, 48, 49, 50, and 51 on Table 2). Megafossils and conodonts from the limestones indicate Silurian to about Middle Devonian ages (map nos. 43, 46, 47, 52, 53, and 54 on Table 2). The flysch-like rocks did not yield any fossils, with one possible exception of a chert sample that yielded a single Parasaturnalidae fragment of Mesozoic age (map no. 45 on Table 2). However, according to N.R.D. Albert (written commun., 1982), this single radiolarian fragment could be the result of contamination during sample processing.

A probable melange origin for this unit is supported by the following evidence: all contacts of the limestone lenses and blocks with their enveloping rocks are faults; the enveloping rocks are known, or interpreted, to be younger than the limestones; the limestones appear to be shallow-water bioherm (patch-reef) and related carbonate deposits, whereas many of the enveloping rocks are deeper water turbidites; the occurrence of flysch-like rocks whose probable Jurassic and Cretaceous age is based primarily on lithologic correlation; and the intricately intermixed occurrence of the three disparate rock suites. The fact that the age of the flysch-like rocks is based primarily on lithologic correlation with units KJf, KJf_a, and KJf_k, without reliable fossil evidence, makes the melange interpretation somewhat uncertain. However, fossils are scarce in the flysch units everywhere in the quadrangle. The best exposure showing the relationship of a limestone lens to the enveloping flysch-like rocks of probable Jurassic and Cretaceous age is in a road cut on the north side of the Denali Highway, about 1.8 km east of the new part of the town of Cantwell (map no. 47 on Table 2). On the basis of the above evidence, the melange interpretation is strongly favored in this report.

The source and mode of origin of the Paleozoic components of the melange, and the actual developmental process of the melange, are poorly understood. It is herein postulated that the Paleozoic rocks were intermixed with the parautochthonous flysch-like rocks primarily by complex thrusting in middle Cretaceous time, during the accretion of the Talkeetna superterrane to the ancient North American continent (Csejtey and others, 1982). According to this concept, the flysch-like rocks were deposited in the narrowing oceanic basin between, and lapping onto, the approaching continents. As a result of the continental collision, the flysch basin collapsed, and the Talkeetna superterrane was thrust upon, that is obducted upon, the margin of the ancient North American continent, which by that time included the Nixon Fork and Yukon-Tanana terranes. The collision was accompanied by complex thrusting and folding not only of the rocks of the Talkeetna superterrane and the flysch basin, but also of the ancient North American continent. It also is postulated that prior to the continental collision the rocks of the Nixon Fork terrane extended under the onlapping flysch-like rocks, and south of the Yukon-Tanana terrane, much further northeast than shown by Jones and others (1981a). During deposition of the flysch, submarine slump blocks of Paleozoic rocks from the Nixon Fork terrane, especially its eastward "shale-out" beds (Churkin and others, 1980), could have been incorporated into the flysch. During the process of continental accretion and accompanying orogenic deformation, these depositional melanges may have been further deformed, intermixed, and transported northwestward as a unit by complex thrusting and folding. One problem in this concept is the tenuous correlation of the Paleozoic rocks in the melange with rocks of the Nixon Fork terrane. Whatever the origin of the Paleozoic rocks, the concept of the rocks of this unit (m_1 and ls_1) as a late Mesozoic melange appears to be viable.

m_2, ls_2, and um - MELANGE ROCKS (Late and(or) Early Cretaceous)—This unit occurs in a few-kilometers-wide but elongated fault sliver just north of the McKinley fault, in the west-central part of the quadrangle. Previously, the unit has been described by Jones and others (1981a, 1982) as the "Windy" tectonostratigraphic terrane, comprising Paleozoic and Mesozoic rocks. In this report, the unit is interpreted as a tectonic, and possibly, sedimentary melange of middle Cretaceous age. The unit comprises four disparate, intricately intermixed and pervasively sheared rock suites:

(1) blocks of medium-gray, medium-grained, massive limestone of Silurian(?) and Devonian age; (2) blocks of medium-gray, medium-grained, massive limestone of Late Triassic age; (3) dark-gray to black flysch-like rocks, namely sandstone, argillite, and subordinate chert pebble and polymictic conglomerate, all of which correlate with the Jurassic and Cretaceous rocks of units KJf, KJf_a, and KJf_k; and

(4) a poorly exposed small fault sliver of serpentinized ultramafic rocks, altered basalt, green and maroon tuff, and recrystallized chert, all of unknown age, possibly comprising an ophiolitic assemblage (Jones and others, 1982).

The two kinds of limestones are shown on the geologic map as ls_2, the flysch-like rocks as m_2, and the possibly ophiolitic rocks as um.

Available fossil data for this unit are summarized under map nos. 55 to 63 on Table 2.

The intricate intermixing of the limestone blocks of two different ages, and of the possibly ophiolitic rocks, with the Jurassic and Cretaceous flysch-like rocks strongly indicates that this unit (m_2, ls_2, and um) is a tectonic, and possibly sedimentary melange. This is further indicated by the pervasively sheared nature of the rocks of this unit, and by the fault contacts of the limestone blocks with the enveloping rocks.

The time, method, and the tectonic setting of the development of this melange unit, although imperfectly known, is considered to be the same or very similar to that of the melange unit m_1 and ls_1, and for a discussion the reader is referred to the description of that unit. The Silurian(?) and Devonian limestone blocks may be tectonically displaced fragments of the Nixon Fork terrane, but the source of the Upper Triassic limestones is an enigma. Possibly, these limestones originated from the Upper Triassic section of the Yukon-Tanana terrane (unit TRcs), or they might be fragments from some of the Upper Triassic limestones of the Talkeetna superterrane (for example, units TRvs or TRcl). Because of the complete lack of any relevant information, no attempt is made here to speculate on the age and origin of the ophiolitic(?) rocks.

In spite of the uncertain origin of many of its rock components, available evidence strongly indicates that this unit (m_2, ls_2, and um) is a middle Cretaceous melange which primarily developed by tectonic, and possibly, by sedimentary processes.

STRUCTURE

The rocks of the Healy quadrangle and surrounding regions have undergone complex and intense thrusting, folding, high-angle reverse and normal faulting, shearing, and differential uplifting, with associated regional metamorphism and plutonism. At least two major periods of deformation are recognized: a middle to Late Cretaceous alpine-type orogeny with penetrative deformation, interpreted to be the result of accretion of the Talkeetna superterrane to the ancient North American continent (Csejtey and others, 1982); and a period of non-penetrative deformation of normal and high-angle reverse faulting, generally open folding, and uplifting of the already accreted continental margin in late Tertiary and Quaternary time.

Much of the geologic make up, and thus many of the major structural features of the quadrangle and adjacent areas are the result of the Cretaceous accretionary orogeny which produced a dominantly northeast-southwest- and east-west-trending structural grain of the region. The vergence of this structural grain is generally steep and is mostly toward the northwest and north, but in considerable parts of the quadrangle it is toward the southeast or the south. The reverses in the structural vergence generally occur abruptly. A good example of this is in the Chulitna River area, near the southwest corner of the quadrangle. East of the River a stacked thrust sequence, consisting of units KJf, TRvs, and KJfk, has been folded into giant westward overturned megafolds, with estimated minimum amplitudes of about 10 km, while west of the River a sequence of imbricate thrust sheets has been compressed into a southeastward overturned synform (figs. 5 and 6 in Csejtey and others, 1982). In the above case the abrupt reversal of the structural vergence is interpreted to be the result of local stress reversal during late orogenic folding, a fairly common phenomenon in alpine-type orogenic belts (for instance, Porada, 1979). In many other instances the southward vergence is probably the result of superposition of late Cenozoic deformation, namely folding, faulting, and tilting by differential uplifting, on the Cretaceous structures.

The dominant structural style of the Cretaceous orogeny is thrust faulting. The most important of the thrust faults in the quadrangle, and of south-central Alaska as well, is the steeply to moderately southeast-dipping Talkeetna thrust fault, which delineates, except for at least one small klippe in front of it, the northwestward extent of the largest and most significant allochthonous crustal fragment of south-central Alaska: the Talkeetna superterrane (Csejtey and others, 1982). The northwestward direction of tectonic transport along the Talkeetna thrust is indicated by a number of subsidiary, steeply southeastward-dipping, imbricate thrust faults structurally above the Talkeetna thrust, near the southern edge of the quadrangle. These subsidiary thrusts consistently bring, on the south, older rocks on top of younger strata to the north (fig. 7 in Csejtey and others, 1982).

The outlying klippe of the Talkeetna thrust is composed of rocks of unit TRvs in the southwestern part of the quadrangle east of the Chulitna River Valley. The Triassic rocks were thrust on Jurassic and Cretaceous flysch (unit KJf), and in turn the flysch (unit KJfk) was thrust upon the Triassic rocks. The rocks of unit KJfk outline a folded klippe approximately 60 km by 35 km in surface dimensions.

Another example of Cretaceous thrusting is in the Ohio Creek area, called the Chulitna district, at the southwest corner of the quadrangle. In this area numerous thrusts, the configurations of some of which are still poorly understood, superposed a number of disparate rock sequences ranging in age from Devonian to Cretaceous (map units Dsb, TRDs,TRr, TRlb, JTRrs, and KJs; fig. 5 in Csejtey and others, 1982). Gravity measurements across these thrust slivers, along Ohio Creek, confirm that they are rootless thrust sheets (R.L. Morin, oral commun., 1977).

Evidence that the Cretaceous thrusting not only juxtaposed disparate map units, but also imbricated map units that are parts of a continuous stratigraphic sequence, can be found in the east-central part of the quadrangle. At two localities within that general area, one near the headwaters of Dick Creek and another in an unnamed westerly side valley of the Gillam Glacier, rocks of unit Pzy have been thrust upon the Triassic rocks of unit TRcs. As already discussed in the unit descriptions, the Triassic rocks of unit TRcs unconformably overlie the Paleozic rocks of unit Pzy. The extents and the displacements of these thrusts are not known because the one near Dicks Creek is largely covered by the unconformably overlying Tertiary Cantwell Formation, and the one near the Gillam Glacier is only partially exposed next to a crosscutting Cenozoic high-angle reverse fault. Most probably there are more thrusts within unit Pzy, but they cannot be detected in the field because of poor exposures and the lithologically monotonous nature of unit Pzy.

North of the Hines Creek fault, most if not all the contacts between the various Precambrian (?) and Paleozoic units, as already discussed in the unit descriptions, are believed to be thrust faults (Wahrhaftig, 1968). The thrusts involving units Pzy and TRcs in the eastern part of the quadrangle lend further probability to this postulation. The concept of thrusting is also supported by the results of magnetotelluric measurements across the Hines Creek fault in the north-central part of the quadrangle, along the George Parks Highway (Dal Stanley, U.S. Geological Survey, unpub. data, 1985). These measurements suggest that the rocks of unit pqs north of the Hines Creek fault, that is rocks of the Yukon-Tanana terrane, are underlain at depth by a thick section of Jurassic and Cretaceous flysch-like rocks (unit KJf).

In addition to thrust faulting, the Cretaceous orogeny also produced some steeply dipping faults. The best example of these is the Hines Creek fault which is interpreted in this report to be a south-side down dip-slip fault within the Yukon-Tanana terrane.

The Cretaceous orogeny also caused widespread and intense folding which occured not only concurrently with the thrusting, but both before and after it. Most of the pre-Cenozoic rocks of the quadrangle are severely folded. The folds generally are tight or isoclinal, and range in size from small secondary folds to megafolds with amplitudes of several kilometers. The larger folds commonly have a well-developed axial plane slaty cleavage with fine-grained secondary sericite or biotite, and their limbs are frequently sheared or faulted out. The best examples of the megafolds are in the already discussed areas to the east and west of the Chulitna River. The antiform in the Precambrian (?) and Paleozoic rocks of the Yukon-Tanana terrane north of the Hines Creek fault, also mentioned under the descriptions of units Pzmf, Pzmb, Pzts, kp, and pqs, has a variable amplitude of several thousands of meters (Wahrhaftig, 1970 b, 1970 c, 1970 d).

Associated with the Cretaceous orogeny there is a Barrovian-type, late-tectonic metamorphic belt, the Maclaren metamorphic belt of Smith (1970, 1974, 1981), in the southeastern part of the quadrangle but in front of the Talkeetna thrust fault. The approximate extent of the amphibolite facies rocks and the approximate locations of the garnet and biotite isograds of this metamorphic belt are shown on sheet 4. The metamorphic features of this early Late Cretaceous metamorphic belt appear to trend across the McKinley fault of the Denali fault system without any significant horizontal offsets (Csejtey and others, 1982). Thus, the apparent continuation of the Maclaren metamorphic belt across the McKinley fault suggests that the previously proposed large-scale horizontal displacements along the fault (Smith, 1974; Forbes and others, 1974; Reed and Lanphere,1974; Turner and others,1974; Hickman and others, 1977; Jones and others, 1982; Stout and Chase, 1980; Nokleberg and others, 1985) do not exist.

The age of the middle to Late Cretaceous orogenic deformation, or at least its major phase, and that of the associated Maclaren matemorphic belt, is rather well bracketed by stratigraphic evidence. The youngest rocks clearly predating the middle to Late Cretaceous deformation are Early Cretaceous (Valanginian) in age (units KJf, KJfk, KJcg, and KJs). One of the strongly deformed Jurassic and Cretaceous flysch units (KJfa) yielded early Late Cretaceous (Cenomanian) fossils. However, Late and latest Early Cretaceous granitic rocks (unit Kgr) in the eastern part of the quadrangle appear to be emplaced at a late stage of this orogenic deformation. Thus, the Cenomanian rocks may be coeval with the main phase of the orogenic deformation, perhaps having been deposited in a tectonically quiet "pocket". One upper age bracket is provided by the Paleocene Cantwell Formation, which everywhere rests unconformably on intensely and penetratively deformed and regionally metamorphosed Cretaceous and older rocks. The Cantwell has not undergone regional metamorphism, and it is only moderately and non-penetratively deformed. Another age bracket is provided by the unmetamorphosed and only moderately deformed early Tertiary volcanic and plutonic rocks (units Tv and Tgr) which rest unconformably on or intrude all older intensely deformed and (or) metamorphosed rocks.

The late Tertiary and Quaternary non-penetrative deformation produced dominantly high- to moderate-angle reverse faults, generally open folds, differential uplift, and some normal faults. The present topography of south-central Alaska, including that of the Healy quadrangle, is the result of this deformation (for instance, Wahrhaftig, 1970a).

The most interesting of these late Cenozoic structures is in the east- central part of the Healy quadrangle, where at least two high-angle reverse faults, up on the south side, roughly delineate the northern extent of the high mountains around and including Mt. Deborah. Although these faults, located just south of the Hines Creek fault, do not show any detectable evidence of recent movement, they undoubtedly control the present topography. Displacements along these south-dipping high angle faults appear to increase eastward, but in a westerly direction they die out in the vicinity of Yanert Fork. Just about at the eastern edge of the quadrangle, the above two faults appear to merge with the Cretaceous Hines Creek fault (also see the geologic map on sheet 1). In the southwestern part of the Mt. Hayes quadrangle, just to the east of the Healy quadrangle, a number of moderately northward dipping thrust faults roughly delineate the southern edge of a high mountainous area to the north (Nokleberg and others, 1982). These high mountains are the eastward extension of the mountains around Mt. Deborah in the eastern Healy quadrangle. The two sets of faults delineating the northern and southern limits of the high mountains in the eastern Healy and western Mt. Hayes quadrangles are interpreted in this report to constitute a structural phenomenon described from the Italian Appenines by Migliorini (1948) as a "composite wedge" (also see the discussion of this structural feature in De Sitter, 1964, p.211-212). In cross section, a composite wedge comprises a number of centrally upthrust wedge-shaped blocks, bounded by upward diverging faults. Similar structural features are suspected to occur in other regions of the Alaska Range.

The age of the late Cenozoic deformation is based on stratigraphic evidence. All the pre-Nenana Gravel Tertiary and older rocks are intensely affected by this deformation. To a lesser degree, the Miocene (?) and Pliocene Nenana Gravel (unit Tng) is also affected. The lithologic characteristics of all the pre-Nenana Gravel Tertiary rocks, especially the "Coal-bearing rocks" of unit Tcbu, indicate that the area of the present central Alaska Range during that time was a depositional lowland (Wahrhaftig, 1970a, 1975). Thus, the generally coarse-grained rocks of the Nenana Gravel signal the onset of the still ongoing late Cenozoic regional tectonic deformation and accompanying uplift of the central Alaska Range.

A prominent and scientifically controversial structural feature in the quadrangle is the McKinley fault of the Denali fault system. The McKinley fault transects the middle of the quadrangle in a roughly east-west direction. In the quadrangle, the McKinley fault always occurs in topographically low areas, it appears to be vertical or nearly vertical, and in a right-lateral sense it clearly offsets for a distance of a few meters several geologically recent alluvial fans and lateral moraines.

In the past the Denali fault system, which has a northward convex surface trace over 1200 km long across the entire width of the State of Alaska, has been described by several workers as a major strike-slip feature with perhaps as much as several hundred kilometers of Cenozoic right lateral offset (for instance, Forbes and others, 1974; Nokleberg and others, 1985). A number of geologic phenomena in the Healy quadrangle suggest that such large displacement magnitudes along the Denali fault system do not exist. These phenomena are: 1) apparent continuity of amphibolite-grade rocks and garnet and biotite isograds across the McKinley fault in eastern part of quadrangle (Csejtey and others, 1982; sheet no. 4 of this report); 2) the occurence of the same Upper Triassic calcareous rocks (unit TRcs) containing lithologically identical diabase sills and dikes, on both sides of the McKinley fault; 3) occurence of the same Jurassic and Cretaceous flysch-like rocks (unit KJf) on both sides of the fault; 4) Cretaceous granitic plutons (unit Kgr), which are restricted to the eastern half of the quadrangle, occur opposite each other across the fault; 5) early Tertiary volcanic rocks (units Tv, Tcv, and Tif) occur on both sides of the fault but only in the western two-thirds of the quadrangle; 6) the occurence of early Tertiary sedimentary rocks with limestone pebbles (unit Tfv) south of the fault in the western part of the quadrangle. These rocks are lithologically identical to the rocks of the Cantwell Formation north of the fault, and might possibly be correlative with the Cantwell Formation; 7) the occurence of very similar melange-like rocks (units m1 and m2) on both sides of the McKinley fault; 8) lack of changes in the aeromagnetic values and anomaly patterns across both the Hines Creek and McKinley faults, in contrast with the marked changes across the Talkeetna thrust fault (Decker and Karl, 1977; Csejtey and Griscom, 1978; Csejtey, unpub. data, 1985); 9) lack of changes in the Bouguer gravity magnitudes and anomaly patterns across the Hines Creek and McKinley faults, again in contrast with the considerable changes across the Talkeetna thrust fault (Barnes, 1977; Csejtey, unpub. data, 1985); 10) the apparent continuation of a Late Cretaceous and(or) early Tertiary northeast-trending broad belt of tin anomalies, defined by stream sediment sample analyses, across the McKinley fault in the southwestern and central parts of the quadrangle (T.D. Light and R.B. Tripp, unpub. data, 1984; Light and Tripp, in press); and 11) the overall similarity of age and tectonic style of orogenic deformation of the pre-Cenozoic rocks on both sides of the McKinley fault.

Although none of the above phenomena, by themselves, are conclusive evidence, and some of them are admittedly not unequivocal, all of them together strongly suggest that Cenozoic horizontal displacements along the McKinley fault are minimal, probably not more than a few tens of kilometers at most.

As mentioned earlier, a number of workers in the past postulated large-scale horizontal displacements along the Denali fault in Cenozoic time (references summarized in Lanphere, 1978; and in Csejtey and others, 1982). While evaluating these previously proposed displacements from a regional point of view, it is important to note that none of the earlier workers have explained satisfactorily the problem of large-scale strike-slip motion along a fault with a sharply curving surface trace. Many of these workers ignore the problem altogether. The curvature between the western and eastern portions of the Denali fault system in Alaska is about 70 degrees, and it is of nonuniform radius. Other points worthy to consider concerning the various proposals of large-scale Cenozoic dextral movement along the Denali fault system are as follows: 1) each of these proposals is based on the tenuous correlation of a single geologic feature across the fault, such as a tectonostratigraphic terrane boundary, a pluton, or a metamorphic belt; 2) the various previously proposed Cenozoic movement magnitudes differ greatly and in fact are contradicting each other; and 3) the proposed correlation of the Maclaren metamorphic belt with metamorphic and plutonic rocks in the Kluane Lake-Ruby Range area in the southwestern Yukon Territory of Canada (for instance, Nokleberg and others, 1985) is quite tenuous because the rocks in the Kluane Lake-Ruby Range area have not been mapped and studied in sufficient detail to use as a foundation for regional correlations.

TECTONICS

A comprehensive concept of the tectonic evolution of south-central Alaska has been given in Csejtey and others (1982). Thus, only a brief summary of the subject will be given here, but the results of subsequent geologic investigations in the Healy quadrangle and the minor modifications of the concept required by these results will be discussed in more detail.

South-central Alaska, including the Healy quadrangle, is part of the accretionary continental margin of western North America which consists of a number of allochthonous and geologically disparate crustal fragments, called tectonostratigraphic terranes (for instance, Coney and others, 1980). In south-central Alaska these terranes, mostly of undetermined geographic origin, were accreted to the ancient North American continent by northward or northwestward plate motions in late Mesozoic time (for instance, Csejtey and others, 1982; Jones and others, 1984). The actual number of terranes present, and the mechanism, direction, and time of final emplacement of these terranes are imperfectly known, and thus are still open to question and conjecture.

According to Csejtey and others (1982), much of the geology of south-central Alaska has resulted from the collision and subsequent obduction of the Talkeetna superterrane with and onto the margin of the ancient North American continent, including the Yukon-Tanana and Nixon Fork terranes, in about middle Cretaceous time (nomenclature of individual terranes is after Jones and Silberling, 1979). The Talkeetna superterrane is comprised of the Wrangellia and Peninsular terranes which, as their stratigraphy indicates, were joined at least by Middle Jurassic time, prior to their emplacement in Alaska as a cohesive tectonic unit. According to Jones and others (1984), the Wrangellia and Peninsular terranes have been joined together and thus had a common geologic history only since about Middle Jurassic time. However, geologic mapping in the Alaska Peninsula by Detterman and Reed (1980), and by Wilson and others (1985a) indicates that in that area the Lower Jurassic Talkeetna Formation of the Peninsular terrane depositionally overlies Triassic and late Paleozoic volcanic and sedimentary rocks which may be part of Wrangellia. If their correlation is valid, Wrangellia and the Peninsular terrane always shared a common geologic history, and thus should not be considered separate terranes. In addition to Wrangellia and the Peninsular terrane of Jones and Silberling (1979), the Talkeetna superterrane probably included some other terranes as well prior to its accretion to ancient North America (for instance, Pavlis, 1982).

The tectonic concept of Csejtey and others (1982) is that the Talkeetna superterrane and possibly a few smaller geologically disparate continental fragments in front of it, were emplaced in their present positions by a north- or northwestward moving lithospheric plate. On the northeast this plate terminated against the ancient North American continent in a transform fault, but on the northwest it was subducted under the continent. The leading edges of the approaching continental fragments were separated from the ancient North American continent by an oceanic basin of dominantly flysch deposits. Upon reaching the trench, the Talkeetna superterrane and perhaps some other small continental fragments in front of it, because of their relatively lighter continental compositions, could not be subducted but were sheared off from their "undercarriage" and were subsequently thrust upon, that is obducted onto, the margin of the ancient North American continent by continuing northward plate motions. During this process the intervening flysch basin collapsed. The concept of northwestward obduction, for a distance of perhaps as much as 200 km, is supported by geophysical evidence, and by the absence of exposed volcanic arc and trench assemblage-type rocks which may have been masked by the overthrust Talkeetna superterrane. The structural features resulting from this collision and subsequent obduction are complex, gigantic, and truly alpine in style and character.

Recent geologic investigations in the Healy quadrangle strongly suggest that rocks of the Yukon-Tanana terrane extend south of the Hines Creek fault as well as south of the McKinley fault of the Denali fault system (also see sheet no. 4 and the descriptions of units Pzy and TRcs). This lends credence to the hypothesis that the Jurassic and Cretaceous flysch-like rocks (units KJF and KJfa) are underlain by continental crustal rocks of the Yukon-Tanana and Nixon Fork terranes (Csejtey and others, 1982). This is in good agreement with seismic investigations in southern Alaska by Davies and Berg (1973) which suggest that the exposure areas of the Jurassic and Cretaceous flysch-like rocks in the Healy quadrangle and adjacent regions are underlain by continental rocks to a depth of about 35 to 40 km, the depth of the Mohorovičić discontinuity. According to the above hypothesis, neither the Hines Creek fault nor the McKinley fault of the Denali fault system are terrane boundary faults. This is also supported by the lack of changes in the Bouguer gravity and aeromagnetic patterns and values across both of these faults (Barnes, 1977; and Decker and Karl, 1977, respectively).

Geologic investigations in the Healy quadrangle also strongly suggest that rocks of the Nixon Fork terrane do occur in the quadrangle (Mullen and Csejtey, 1986). Lithologic and paleontological studies on the carbonate-rich rocks of units DOs and Dls of the quadrangle, previously designated by Jones and Silberling (1979) to belong to the Dillinger terrane, have disclosed that these rocks have close lithologic, temporal, and spatial relationships with the deep-water or "shale-out" facies of the Nixon Fork carbonate platform of Churkin and others (1980). These "shale-out" beds occur about 300 km southwest of the quadrangle. Dutro and Patton (1982) also considered the "shale-out" beds, at least in part, to be the southeastward-deepening-water facies equivalents of the Nixon Fork and Minchumina terranes. Blodgett and Gilbert (1983), Blodgett and others (1984), and Blodgett and Clough (1985) have concluded that the Nixon Fork and Dillinger terranes were actually part of the same early Paleozoic continental margin with minor, if any, displacement with respect to the North American craton. If the above conclusions are valid, then the western area of the Yukon-Tanana terrane in Alaska, as shown by Jones and Silberling (1979), and by Jones and others (1981a), is flanked on the north, west, and south by carbonate-rich rocks of the Nixon Fork terrane. This also means that the late Mesozoic continental margin upon which the Talkeetna superterrane is interpreted to have been obducted, did include carbonate-rich rocks of the Nixon Fork terrane. Accordingly, the origin of the Paleozoic limestone blocks in melange units m_1 and m_2 of the Healy quadrangle could be explained as thrust slivers stripped off the continental margin and then intermixed with the parautochthonous Jurassic and Cretaceous flysch-like rocks by the obduction of the Talkeetna superterrane.

The obduction interpretation is further strengthened by the correlation of the Triassic basic volcanic and volcaniclastic rocks around the Honolulu Pass area with similar rock types which occur in small fault slivers along the Talkeetna thrust near the southeastern corner of the quadrangle. All of these rocks are shown as unit TRvs on the geologic map. If our correlation is valid, then the Triassic volcanic and volcaniclastic rocks around Honolulu Pass must constitute a klippe of the main Talkeetna thrust to the southeast, supporting the hypothesis that the Talkeetna thrust is indeed a southeastward-dipping feature, with regional tectonic transport toward the northwest.

A problem of vital importance for the obduction theory is the correlation of the highly metamorphosed marble-bearing metasedimentary rocks in the vicinity of Tsusena Creek (on some maps "River") near the south-central edge of the quadrangle. These rocks, shown as "TRcs?" on the geologic map, lithologically resemble metamorphosed rocks of unit TRcs further to the northeast, but the correlation is rather tenuous because of lack of any fossils or any other diagnostic features. The marble-bearing metasedimentary rocks near Tsusena Creek occur between the Talkeetna thrust and the klippe of unit TRvs (see the geologic map and sheet no. 4), and if they really are part of unit TRcs, interpreted in this report to belong to the Yukon-Tanana terrane, then the obduction concept is a certainty. Unfortunately, efforts in the field to find some diagnostic features in the marble-bearing metasedimentary rocks have been unsuccessful so far.

The role of the Cenozoic deformation including the Denali fault system, in the tectonic evolution of south-central Alaska has been discussed already in the "Structure" section, and it will not be repeated here.

In summary, geologic investigations in the Healy quadrangle, we believe, lend additional support to the previously exressed concept (Csejtey, and others, (1982) that much of the geology of south-central Alaska is the result of the accretion and subsequent obduction of the Talkeetna superterrane to and onto the ancient North American continent in about middle Cretaceous time. Cenozoic deformation has slightly modified but not substantially altered this already accreted continental margin. Geologic investigations in the Healy quadrangle also indicate that the number of tectonostratigraphic terranes previously postulated to be present in south-central Alaska (for instance, Jones and others, 1984) has been greatly exaggerated.

Table 1--Selected potassium-argon age determinations from the Healy quadrangle, Alaska

Asterisks denote footnotes at end of table. Map no. locations are shown on sheet 1.

[During the compilation of this table, all potassium-argon age determinations available for the Healy quadrangle, obtained by a number of workers, have been evaluated. However, only those age determinations which were deemed reliable or significant, either from a geologic or an analytical point of view, have been included in the table. For example, age determinations considered suspect or unreliable by the original authors were omitted, as were those where the age of an intrusive rock appeared to be older than the well-established age of the country rock. All the omitted age determinations can be found in Wegner, 1972; Hickman, 1974; Hickman and Craddock, 1976; Sherwood and Craddock, 1979; and Albanese, 1980.]

Map no.	Map unit	Location: Lat. (N)	Location: Long. (W)	Field no.	Rock type*	Mineral dated	K_2O** (weight percent)	$^{40}Ar_{rad}$ $\frac{moles}{gram} \times 10^{-10}$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Previously published age (millions of years)	Age calculated using the constants of Steiger and Jager, 1977 (millions of years)	References
1.	Thd	63°58'36"	148°42'06"	47Awg-142	Dacite	Hornblende	0.866	--	0.096	2.72 ± 0.25	2.79 ± 0.25***	M. A. Lanphere in Wahrhaftig, 1970d; Wilson and others, 1985b
2.	Tif	63°45'06"	148°47'24"	MR78-50	Rhyolite	Whole rock	3.277(4)	--	0.846	35.2 ± 1.0	35.2 ± 1.0***	Albanese, 1980; Wilson and others, 1985b
3.	Tif	63°47'36"	148°49'42"	MR78-2	Rhyolite	Whole rock	4.425(4)	--	0.964	34.2 ± 1.0	34.2 ± 1.0***	"
4.	Tif	63°47'24"	148°49'36"	MR78-39	Rhyolite	Whole rock	4.344(4)	--	0.019	32.5 ± 1.0	32.5 ± 1.0***	"
5.	Tif	63°46'48"	148°48'18"	MR78-58	Rhyolite	Whole rock	4.729(4)	--	0.891	32.8 ± 1.0	32.8 ± 1.0***	"
6.	Kvb	63°47'48"	148°15'10"	UW1583/30	Basalt	Hornblende	0.302	0.3517	--	77.0 ± 5.9****	79.1 ± 6.0	Sherwood, 1973; Sherwood and Craddock, 1979
7.	Kgr	63°46'04"	148°02'37"	UW1583/17	Monzonite (Quartz diorite)	Hornblende	0.561	0.8397	--	98.4 ± 5.5****	101.1 ± 5.6	"
8.	Pzmb	63°47'29"	147°59'50"	UW1580/16	Phyllite	Muscovite	2.818	4.803	--	112.0 ± 5****	114.6 ± 5.1	Anderson, 1973; Sherwood and Craddock, 1979; Wilson and others, 1985b
9.	Kgr	63°46'37"	147°50'17"	UW1580/42	Grano-diorite (Tona-lite)	Biotite	3.671	3.813	--	68.9 ± 2.8****	70.7 ± 2.9	"
10.	Kgr	63°44'24"	147°25'30"	UW1633/87	Quartz monzonite (Granodi-orite or tonalite)	Hornblende	1.093	1.648	--	99.1 ± 4.6****	101.8 ± 4.7	Sherwood, 1973; Sherwood and Craddock, 1979

Table 1--Selected potassium-argon age determinations from the Healy quadrangle, Alaska (Continued)

Map no.	Map unit	Location Lat. (N)	Long. (W)	Field no.	Rock type*	Mineral dated	K_2O** (weight percent)	$^{40}Ar_{rad}$ $\frac{moles}{gram} \times 10^{-10}$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Previously published age (millions of years)	Age calculated using the constants of Steiger and Jager, 1977 (millions of years)	References
11.	Kgr	63°44'59"	147°23'15"	DT72-43A	Quartz monzonite	Biotite	7.863(2)	11.18	0.855	93.8 ± 2.8	96.1 ± 2.9	Turner and Smith, 1974;
				DT72-43B	(Grano-	Biotite	7.536(2)	10.66	0.883	93.4 ± 2.8	95.7 ± 2.9	Wahrhaftig and
				DT72-43A	diorite	Hornblende	1.022(2)	1.476	0.838	95.3 ± 2.8	97.6 ± 2.9	others, 1975
				DT72-43B	or tona-lite)	Hornblende	0.974(2)	1.401	0.857	95.0 ± 2.8	97.2 ± 2.9	
12.	Kgr	63°45'35"	147°19'20"	DT72-44A	Quartz monzonite (Granodi-orite or tonalite)	Biotite Hornblende	7.785(2) 1.067(2)	10.92 1.507	0.903 0.823	92.6 ± 2.8 93.2 ± 2.8	94.9 ± 2.9 95.5 ± 2.9	Turner and Smith, 1974; Wahrhaftig and others, 1975; Wilson and others, 1985b
13.	Tgr	63°35'27"	147°22'10"	DT72-45A	Grano-diorite	Biotite Hornblende	8.840(2) 0.679(2)	4.878 0.3910	0.775 0.729	37.0 ± 1.1 38.5 ± 1.1	37.9 ± 1.1 39.6 ± 1.1	Turner and Smith, 1974
14.	Pzy	63°42'00"	147°47'04"	UW1633/43	Phyllite	Muscovite	4.081	6.485	--	104.0 ± 4.0****	107.1 ± 4.1	Sherwood, 1979; Sherwood and Craddock, 1979
15.	Tcv	63°42'25"	148°10'20"	UW1583/18	Dacite	Hornblende	0.882	0.8357	--	62.9 ± 3.3****	64.6 ± 3.4	Sherwood, 1973; Sherwood and Craddock, 1979
16.	Tgr	63°38'18"	148°29'50"	UW1574/17	Quartz diorite (Tona-lite)	Amphibole	0.421	0.2247	--	35.7 ± 2.8****	36.7 ± 2.9	Hickman, 1974; Sherwood and Craddock, 1979
17.	TKgr	63°38'22"	148°47'50"	UW1574/3	Grano-diorite	Biotite	1.435	1.661	--	76.6 ± 3.5****	78.7 ± 3.6	"
18.	Tcv	63°43'40"	148°42'00"	UW1563/2	Basalt	Whole rock	2.408	1.7882	--	49.5 ± 2.1****	50.9 ± 2.2	Bultman, 1972; Sherwood and Craddock, 1979
19.	Tcv	63°41'42"	148°47'10"	UW1563/4	Diabase	Whole rock	0.908	0.8025	--	58.8 ± 3.0****	60.4 ± 3.1	"
20.	Tim	63°45'20"	148°53'48"	UW1563/3	Diabase	Whole rock	2.324	1.8565	--	53.2 ± 2.3****	54.7 ± 2.4	Bultman, 1972; Sherwood and Craddock, 1979; Wilson and others, 1985b

Table 1--Selected potassium-argon age determinations from the Healy quadrangle, Alaska (Continued)

Map no.	Map unit	Location Lat. (N)	Location Long. (W)	Field no.	Rock type*	Mineral dated	K_2O** (weight percent)	$^{40}Ar_{rad}$ $\frac{moles}{gram} \times 10^{-10}$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Previously published age (millions of years)	Age calculated using the constants of Steiger and Jager, 1977 (millions of years)	References
21.	Tcv	63°36'43"	149°35'25"	UW1562/3	Basalt	Whole rock	2.549	2.1102	--	55.1 ± 2.3****	56.6 ± 2.4	Hickman, 1974; Hickman and Craddock, 1976
22.	Tcv	63°32'15"	149°49'00"	DT73-1	Quartz diorite	Plagioclase	0.319 ± 0.002(2)	0.274	0.661	57.2 ± 3.4	58.7 ± 3.5	Gilbert and others, 1976
23.	Tcv	63°30'24"	149°38'20"	74WG-14	Basalt	Whole rock	2.30(2)	1.436	0.480	41.8 Minimum age	42.9 Minimum age	"
24.	Tcv	63°34'20"	149°36'29"	DT73-9	Andesite	Plagioclase	0.605± 0.005(2)	*****	*****	60.6 Minimum age	62.2*** Minimum age	"
25.	Tcv	63°36'13"	149°28'11"	UW1562/4	Basalt	Whole rock	1.661	1.483	--	59.3 ± 2.7****	61.0 ± 2.8	Wegner, 1972; Hickman, 1974; Hickman and Craddock, 1976
26.	TKgr	63°34'24"	149°01'54"	UW1574/7	Grano-diorite	Biotite	6.776	7.1525	--	70.0 ± 2.6****	71.9 ± 2.7	Hickman, 1974; Hickman and Craddock, 1976
27.	Tgr	63°28'57"	148°36'45"	UW1553/4	Grano-diorite (Granite)	Biotite	6.396	3.650	--	38.1 ± 1.4****	39.2 ± 1.4	Hickman, 1971; Sherwood and Craddock, 1979
28.	Tgr	63°28'55"	148°29'20"	72ASt-332	Quartz monzonite (Granite)	Biotite	8.460(2)	4.665	0.693	36.9 ± 1.1	37.9 ± 1.1	Turner and Smith, 1974
29.	Tgr	63°27'02"	148°26'08"	UW1574/18	Granite	Biotite	5.560	4.650	--	55.7 ± 2.2****	57.2 ± 2.3	Hickman,1974; Sherwood and Craddock, 1979
30.	Tgr	63°24'55"	148°00'55"	72ASt-351	Granite	Biotite	6.996(2)	5.858	0.875	55.8 ± 1.7	57.2 ± 1.7	Turner and Smith, 1974
31.	Tgr	63°26'42"	147°54'37"	UW1596/26	Quartz monzonite (Granite)	Biotite	4.538	3.8325	--	56.2 ± 2.2****	57.7 ± 2.3	Rautman, 1974; Sherwood and Craddock, 1979
32.	Tgr	63°31'35"	147°40'10"	72ASt-331	Quartz monzonite (Granite or grano-diorite)	Biotite	8.863(2)	4.841	0.835	36.6 ± 1.1	37.5 ± 1.1	Turner and Smith, 1974

Table 1--Selected potassium-argon age determinations from the Healy quadrangle, Alaska (Continued)

Map no.	Map unit	Location Lat. (N)	Location Long. (W)	Field no.	Rock type*	Mineral dated	K_2O** (weight percent)	$^{40}Ar_{rad}$ $\frac{moles}{gram} \times 10^{-10}$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Previously published age (millions of years)	Age calculated using the constants of Steiger and Jager, 1977 (millions of years)	References
33.	Kgr	63°32'50"	147°26'30"	81ACy-66	Tonalite	Hornblende	By the $^{40}Ar/^{39}Ar$ method		0.147	--	105.7 ± 3.3	This report
34.	Kgr	63°35'23"	147°21'56"	82ACy-32	Tonalite	Age determination not available at publication time						This report
35.	TRcs	63°25'55"	147°26'45"	72ASt-329	Amphi-bolite gneiss	Amphibole	0.210	0.2223	0.272	70.3 ± 2.1	72.1 ± 2.2	Turner and Smith, 1974
36.	Kgr	63°28'10"	147°16'20"	72ASt-326	Quartz diorite	Biotite Hornblende	8.836(2) 0.597± 0.003(4)	7.062 0.7900	0.862 0.637	53.3 ± 1.6 87.4 ± 2.6	54.7 ± 1.6 89.6 ± 2.7	"
37.	Kgr	63°29'15"	147°10'10"	0T73-208	Diorite gneiss	Biotite Hornblende	8.438(2) 0.685(2)	6.383 0.6063	0.906 0.658	50.2 ± 1.5 59.9 ± 1.8	51.8 ± 1.5 60.5 ± 1.8	"
38.	TRcs	63°29'58"	147°08'55"	72ASt-323	Amphi-bolite gneiss	Hornblende	0.602 ± 0.006(4)	0.7026	0.743	77.3 ± 2.3	79.3 ± 2.4	"
39.	Kgr	63°28'57"	147°00'20"	0T73-207	Migmatite	Biotite Hornblende	8.993(2) 0.758(2)	6.746 0.5493	0.871 0.294	50.1 ± 1.5 48.4 ± 1.4	51.4 ± 1.5 49.6 ± 1.4	"
40.	TRcs	63°31'58"	147°06'29"	UW1698/39	Amphi-bolite gneiss	Hornblende	0.382	0.3065	--	53.2 ± 3.7****	54.9 ± 3.8	Brewer, 1982
41.	Kgr	63°13'49'	147°07'01"	69ASt-137	Grano-diorite (Tona-lite)	Biotite Hornblende	9.20 0.835	8.453 0.8332	0.36 0.54	61.2 ± 2 66.3 ± 2	62.7 ± 2.0 68.0 ± 2.1	Smith and Lanphere, 1971; Smith and Turner, 1973; Smith, 1981
42.	Jgb	63°08'38"	147°13'16"	69ASt-252A 69ASt-252	Alkali gabbro	Biotite Hornblende	8.62 1.055	17.07 2.313	0.93 0.88	130 ± 4 143 ± 4	132.6 ± 4.1 146.2 ± 4.1	"
43.	Kva	63°09'57"	147°21'15"	78ACy-207	Andesite	Hornblende	1.086	1.563	0.72	--	97.3 ± 2.9	This report
44.	KJf	63°15'38"	147°18'48"	69ASt-199	Amphi-bolite gneiss	Hornblende	0.188(2)	0.1872	0.427	66.2 ± 2.0	67.9 ± 2.1	Smith and Turner, 1973; Turner and Smith, 1974; Smith, 1981
45.	KJf	63°13'34"	147°15'29"	69ASt-1556	Pelitic schist	Biotite	8.93	7.659	0.73	57.2 ± 2	58.6 ± 2.0	Smith and Lanphere, 1971; Smith and Turner, 1973; Smith, 1981

Table 1--Selected potassium-argon age determinations from the Healy quadrangle, Alaska (Continued)

Map no.	Map unit	Location Lat. (N)	Location Long. (W)	Field no.	Rock type*	Mineral dated	K_2O** (weight percent)	$^{40}Ar_{rad}$ $\frac{moles}{gram} \times 10^{-10}$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Previously published age (millions of years)	Age calculated using the constants of Steiger and Jager, 1977 (millions of years)	References
46.	KJf	63°12'18"	147°25'41"	68ASb-638	Amphibolite schist	Hornblende	0.307(2)	0.2958	0.374	64.1 ± 1.9	65.7 ± 1.9	Smith and Turner, 1973; Turner and Smith, 1974; Smith, 1981
47.	Kgr	63°09'20"	147°20'15"	72ASt-165A	Granodiorite (Quartz monzodiorite)	Hornblende	0.989 ± 0.006(10)	0.9438	0.791	63.9 ± 1.9	65.1 ± 1.9	Turner and Smith, 1974
48.	Tgr	63°07'50"	147°51'26"	72ASt-1657	Granodiorite	Hornblende	1.149(2)	0.9646	0.857	55.9 ± 1.7	57.4 ± 1.7	"
49.	KJf	63°06'35"	147°56'45"	72ASt-1658	Schist	Biotite	8.405(2)	6.684	0.888	53.0 ± 1.6	54.4 ± 1.6	"
50.	Tgr	63°01'45"	148°04'05"	72ASt-178	Granodiorite	Biotite Hornblende	8.916(2) 0.520(4)	6.515 0.3487	0.779 0.571	48.8 ± 1.5 44.8 ± 1.3	50.1 ± 1.5 46.0 ± 1.3	"
51.	Kgr	63°00'26"	148°27'40"	TT-4-72	Quartz diorite	Biotite	8.116(2)	6.899	0.695	57.6 ± 1.7	58.1 ± 1.7	"
52.	Kgr	63°01'40"	148°29'35"	TT-6-72	Quartz diorite	Biotite	7.929(2)	6.788	0.796	57.1 ± 1.7	58.5 ± 1.7	"
53.	Tv	63°10'31"	149°03'18"	78ACy-203B	Rhyolite	Sanidine	9.07	7.145	0.80	--	53.9 ± 1.6	This report
54.	Tgr	63°27'54"	148°43'57"	UW1553/7	Granodiorite	Biotite	6.480	5.675	--	58.3 ± 2.0****	59.8 ± 2.1	Hickman, 1971; Hickman and Craddock, 1976
55.	TKgr	63°16'35"	149°24'50"	76DS-1	Quartz monzonite	Biotite	7.098 ± 0.142(4)	7.150	0.818	67.0 ± 2.0	68.6 ± 2.0	Swainbank and others, 1977
56.	TKgr	63°16'33"	149°26'30"	76DS-2	Intrusive breccia	Biotite	8.777 ± 0.033(4)	8.226	0.768	62.4 ± 1.8	64.0 ± 1.8	"
57.	TKgr	63°16'32"	149°28'05"	76DS-3	Diorite	Altered hornblende Altered hornblende	2.729± 0.011(4) 2.043± 0.057(4)	2.350 1.878	0.841 0.764	57.4 ± 1.7 Minimum age 61.2 ± 1.8 Minimum age	58.8 ± 1.7 Minimum age 62.7 ± 1.8 Minimum age	"

Table 1--Selected potassium-argon age determinations from the Healy quadrangle, Alaska (Continued)

Map no.	Map unit	Location: Lat. (N)	Location: Long. (W)	Field no.	Rock type*	Mineral dated	K_2O** (weight percent)	$^{40}Ar_{rad}$ $\frac{moles}{gram} \times 10^{-10}$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Previously published age (millions of years)	Age calculated using the constants of Steiger and Jager, 1977 (millions of years)	References
58.	TKgr	63°12'55"	149°38'50"	71ASt-264A	Diorite porphyry	Biotite	8.343(2)	8.644	0.837	68.2 ± 2.1	70.6 ± 2.2	Swainbank and others, 1977
				71ASt-265	Altered breccia pipe	Muscovite	9.359(2)	9.577	0.940	68.0 ± 2.0	69.7 ± 2.1	
				71ASt-263	Diorite porphyry	Biotite	8.328(2)	8.583	0.940	68.5 ± 2.1	70.2 ± 2.2	

*Where applicable, following the originally published rock name, in parentheses is the revised rock name according to the IUGS nomenclature of 1973, or what is suggested by subsequent modal analyses from the same plutonic body.

**Where more than one measurement was made, value is the mean, and, where available, standard deviation. Number of measurements is in parentheses.

***Age recalculated from previously published age using the method described by Dalrymple (1979).

****Age determination and corresponding potassium analysis and argon measurement performed by Krueger Enterprises, Inc. Original potassium and argon values were reported in ^{40}K ppm and $^{40}Ar_{rad}$ ppm, and have been recalculated in this report to K_2O weight percent and $\frac{moles}{gram} \times 10^{-10}$, respectively.

*****Data omitted because of suspected typographical error in Gilbert and others (1976).

For the sample under map no. 33, argon analyses and age calculation by L. B. G. Pickthorn; for the samples under map nos. 43 and 53, potassium analyses by Mark Taylor, argon analyses and age calculations by M. L. Silberman and L. B. Gray.

Table 2.--Fossil data from the Healy quadrangle, Alaska.

Map no. locations are shown on sheet 3.

[This table includes all published and all available unpublished fossil data, obtained by a number of workers, for the Healy quadrangle. The fossil locations were grouped and consecutively numbered according to geologic map units, beginning with the stratigraphically youngest unit and progressing to the oldest unit. Therefore, fossil localities occurring in a single map unit will be in a numbered sequence. Also, distinct map symbols are used to distinguish general fossil groups. The squares indicate plant fossils, the circular dots indicate invertebrate megafossils, the triangles indicate conodonts, and the diamonds indicate radiolarians. Combinations of symbols indicate the co-occurrence of fossil groups or separate localities which could not be shown separately at the map scale. The following abbreviations are used: SEM = scanning electron microscope. This instrument, a Cambridge Stereoscan 250 MK2, operated by Robert L. Oscarson of the U.S. Geological Survey, was used to examine and photograph microfossil specimens for identification. CAI = Color alteration index. This is a thermal alteration index which is based on the color of conodont microfossils. It was developed by Anita G. Harris of the U.S. Geological Survey (see Epstein and others, 1977), and it correlates the conodont color with the temperature range and metamorphic facies of the host rock. The following are the indices and corresponding temperature ranges: CAI 1 = 50-80°C, CAI 1.5 = 50-90°C, CAI 2 = 60-140°C, CAI 3 = 110-200°C, CAI 4 = 190-300°C, CAI 5 = 300-400°C, CAI 5.5 = 350-400°C, CAI 6 = 350-450°C, CAI 7 = 400-500°C, CAI 8 - 450-550°C.]

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
1 Tcbu B6	63°16'18" 149°31'09"	67ACx-190 (Paleobot. loc. 11120); 80AMM-28	Argillaceous sandstone and siltstone	Plant fossils including: Onoclea sp. Metasequoia cf. M. glyptostroboides Ceridiphyllum, crenatum Zelkova browni Alnus evidens Betula sp. Carpinus seldoviana? Corylus harrimani Populus kenaiana Salix sp. Alangium mikii Monocotylophyllum sp.	Late Oligocene or early Miocene	J.A. Wolfe in Hawley and Clark, 1974; M.W. Mullen, this report	Specimens collected near top of section at Dunkle coal mine. Recollected in 1980 during coal assessment study by G.D. Stricker of the U.S. Geological Survey
2 Tcbu D3	63°57'09" 148°18'48"	80AMM-29	Claystone and mudstone	Alnus sp. Salix sp. Monocotylophyllum sp.	Oligo-cene(?)	M.W. Mullen, this report	Healy Creek Fm. on Dexter Creek
3 Tcbu D2	63°59'21" 147°50'06"	80AMM-30	Mudstone	Metasequoia sp. Alnus? sp. Salix sp.	do.	do.	Healy Creek Fm. near Coal Creek and Mystic Mtn.
4 Tsu B4	63°22'00" 148°51'30"	81ACy-3	Sandstone	Indeterminate plant fossil fragments	Tertiary	do.	From poorly consolidated outcrops on the banks of Jack River
5 Tfv B6	63°18'44" 149°38'55"	81ACy-1	Limestone clasts in conglomerate	Conodonts: Palmatolepis transitans Polygnathus xylus Polygnathus sp ramiform elements	early Late Devonian (early to middle Frasnian)	M.W. Mullen, this report	Similar fauna in 82AMM-7A, map no. 8. CAI = 6

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
6 Tfv B6	63°18'20" 149°40'35"	82 ACy-1, 2; 82 AMM-1	Shale inter-bed in con-glomerate	Plant fossils including: *Metasequoia occidentalis*	early Eocene(?)	J.A. Wolfe, oral commun., 1982, 1984	A more detailed determination by J. A. Wolfe, U.S. Geological Survey, is still pending.
7 Tfv B6	63°18'27" 149°42'38"	82 AMM-9	do.	Plant fragments including: *Monocotylophyllum*? sp.	do.	M.W. Mullen, this report	
8 Tfv B6	63°18'34" 149°43'38"	82 AMM-7A, 82 AMM-7B	Limestone clasts in conglomerate	Conodonts: 7A: *Palmatolepis transitans* *Palmatolepis punctata* *Palmatolepis* cf. *P. foliacea* *Polygnathus xylus* *Polygnathus* cf. *P. webbi* *Polygnathus* sp. *Ancyrognathus*? sp. ramiform elements	early Late Devonian (early to middle Frasnian)	M.W. Mullen and C.A. Sandberg, this report	The *Palmatolepis* assemblage has never been reported within the quadrangle. The most similiar faunas occur in units Pzy (map no. 157) and Pzmb (map no. 149) in the northern part of the quadrangle. The *Panderodus* assemblage also occurs in limestone pebbles in unit Tc (map nos. 9, 10, 11) north of the McKinley fault and in limestone pebbles and blocks in units KJf_a (map nos. 37, 38) and m_2 (map no. 55). CAI = 4
				7B: *Panderodus* sp. indeterminate fragments	Ordovician to Devonian		
9 Tc B6	63°26'45" 149°45'45"	83 ACy-6A 83 ACy-6B 83 ACy-6C	do.	Conodonts: 6A: *Ozarkodina* sp. ramiform elements 6B: *Ozarkodina pandora*? *Panderodus* sp. icthyoliths (fish skeletal elements: selachiian denticles and placoderm plate framents, brachopod fragments	Ordovician to Early Devonian; Early Devonian	M.W. Mullen, this report	The limestone clasts were derived from the unit DOs to the south of this locality. CAI = 6
				6C: *Panderodus* sp. *Teridontus* sp. ramiform elements	Ordovician to Silurian		
10 Tc B6	63°27'34" 149°42'10"	83 AMM-7A 83 AMM-7B	do.	Conodonts: 7A: *Ozarkodina* sp. ramiform elements	Ordovician to Early Devonian	do.	do. CAI = 6
				7B: *Ozarkodina* sp. *Panderodus* sp. *Teridontus* sp. *Oulodus*? sp. ramiform elements *Tentaculites* sp. Ostracodes, sp. indeterminate	Ordovician to Silurian		

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
11 Tc B6	63°28'30" 149°32'25	83ACy-5	do.	Conodonts: Dzarkodina sp. Panderodus sp. indeterminate cone elements ramiform elements	do.	do.	do. CAI = 6
12 Tc C6	63°31'54" 149°51'18"	83 AMM-20	Siltstone and sandstone	Plant fossils, including: Alnus sp.	Paleocene?	do.	
13 Tc C6	63°34'17" 149°40'05"	83 AMM-23	Limestone clasts in conglomerate	Conodonts: Neogondolella polygnathiformis Epigondolella primitia Cypriodella sp.	Late Triassic (late Karnian-Norian)	do.	The limestone clasts probably were derived from the unit TRcs occurring about 10 km to the north of this locality. CAI = 5
14 Tc C4	63°30'09" 148°45'21"	U.W. 1574/22 (MPCC1) Univ. of Wisconsin	Siltstone	Plant fossils including: Metasequoia sp. Dicotylophyllum flexuosa	Paleocene?	J.A. Wolfe in Sherwood and Craddock, 1979	
15 Tc B4	63°29'57" 148°43'09"	81 ACy-52	Shale	Indeterminate broad-leaf plant fossils	do.	M.W. Mullen, this report	
16 Tc B4	63°29'35" 148°33'53"	U.W. 1574/21 (MP45) Univ. of Wisconsin	Siltstone	Plant fossils including: Metasequoia sp. Dicotylophyllum alaskana	do.	J.A. Wolfe in Sherwood and Craddock, 1979	
17 Tc B3	63°28'30" 148°24'25" (approx.loc.)	F13AM3 (6565) F12AP51 (6567) Moffit and Pogue, 1913	Shale	Plant fossils: F13AM3: Taxodium tinajorum Taxodium dubium Sequoia langsdortii Populus arctica Daphnogene kanii F13AP51: Aspidium heerii (6567) Taxodium dubium Ginkgo adiantoides	Tertiary	F.H. Knowlton and A. Hollick in Moffit, 1915	The plant fossil identifications were made in 1914, and need to be reexamined for a more current species and age determination
18 Tc C3	63°34'01" 148°05'52"	76ACy-106 George Saunders, U.S. Steel Co.	do.	Plant fossils including: Metasequoia occidentalis? undetermined broad-leafs	Paleocene?	M.W. Mullen, this report	
19 Tc C4	63°41'02" 148°54'47"	U.W. 1563/13 (BA73) Univ. of Wisconsin	do.	Plant fossils including: Dennstaedtia cf. D. americana Metasequoia cf. M. occidentalis Quercophyllum greenlandicus Platanus sp. Grewiopsis auriculae cordatus	Paleocene	J.A. Wolfe in Sherwood and Craddock, 1979	

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
20 Tc C4	63°41'04" 148°46'55"	U.W. 1563/14 (BA48) Univ. of Wisconsin	Shale	Plant fossils including: Metasequoia sp. Hamamelidacae sp.	Paleocene	J.A. Wolfe in Sherwood and Craddock, 1979	
21 Tc C4	63°40'47" 148°46'36"	U.W. 1563/15 (BA47) Univ. of Wisconsin	Limestone(?) cobble in conglomerate	Mollusc: Gryphaea sp.	Jurassic and Triassic	D.L. Jones in Sherwood and Craddock, 1979	The cobble probably was derived from the unit KJf cropping out to the west
22 Tc C3	63°41'53" 148°17'55"	81 ACy-4	Silty shale	Plant fossils including: Metasequoia sp.	Paleocene?	M.W. Mullen, this report	
23 Tc C2	63°43'52" 147°34'52"	81 ACy-100	Shale	Plant fossils including: Metasequoia sp.	do.	do.	
24 KJf_k B4	63°22'20" 148°33'10"	80-JH-37 (MR-2047)	Chert	Radiolarians	Jurassic or Cretaceous	D.L. Jones in Jones and others, 1983	
25 KJf_k B4	63°29'30" 148°31'44"	80 ACy-83; 81 ACy-71	Limestone	Buchia sublaevis belemnite, sp. indeterminate	Early Cretaceous (Valanginian)	J.W. Miller, written commun., 1981	Thin-bedded limestone interbedded with flysch
26 KJf_k B4	63°16'53" 148°49'14" (approx.loc.)	Bruce Castle of Anchorage, Alaska	do.	Buchia sublaevis	do.	D.L. Jones in Jones and others, 1980	Limestone float within outcrop area of unit KJf_k
27 KJcg A2	63°00'06" 147°51'15"	72 Ast-2759 (M-6086) T.E. Smith; D.L. Jones, U.S.G.S.	Shale	Buchia rugosa and other Buchia spp. Oxytoma sp. Pleuromya? sp. pectinid clam Ditripa? sp. (worm tube)	Late Jurassic (Kimmeridgian to Early Cretaceous (Valanginian)	D.L. Jones in Silberling and others, 1981a; Smith and others, 1984; D.L. Jones, personal commun., 1985	This section contains several Buchia spp. in a biostratigraphic sequence
28 KJs A6	63°11'50" 149°48'28"	76 ACy-133; FX-10	Chert, argillite	Praeconocaryomma mamillaria and other radiolarians; and bivalve mollusc fragments	Late Jurassic	E.A. Pessagno in Jones and others, 1980; Hawley and Clark, 1974, p. B7	

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
29 KJs A6	63°12'14 149°45'57"	76-J-45	Sandstone, chert, and limestone	Inoceramus sp. Stratigraphically 2 m lower: radiolarians Stratigraphically 2 m lower: Buchia sublaevis	Early Cretaceous do. (Valanginian) do. (Valanginian)	D.L. Jones and E.A. Pessagno in Jones and others, 1980	
30 KJs A6	63°12'18" 149°44'48"		Limestone	Buchia sublaevis	Early Cretaceous (Valanginian)	D.L. Jones in Jones and others, 1980	
31 KJs A6	63°13'06" 149°45'32"	77-J-12; 77-J-13	Limestone, chert	77-J-12: Buchia sublaevis JJ-J-13: Parvicingula citae and other radiolarians	Early Cretaceous (Valanginian)	D.L. Jones in Jones and others, 1980	
32 KJf_a B6	63°17'07" 149°36'04"	Fx-9	Argillite	Buchia sublaevis	Early Cretaceous (Valanginian)	D.L. Jones in Hawley and Clark, 1974	
33 KJf_a B5	63°24'35" 149°02'15" (approx.)	77-J-6	do.	Buchia sublaevis	Early Cretaceous (Valanginian)	D.L. Jones in Jones and others, 1983	
34 KJf_a B4	63°24'15" 148°54'40"	----	?	Ammonite	Late Cretaceous (Cenomanian)	do.	
35 KJf_a B4	63°24'54" 148°53'49"	80 JH-38	?	Calycoceras sp. (ammonite)	do.	do.	
36 KJf_a B4	63°25'47" 148°52'15"	U.W. 1553/09 (CTW14) Univ. of Wisconsin; same as U.S.G.S. Mesozoic locality M57B9; 80 AMM-26	Limestone (shell hash)	Inoceramus sp. Acroteuthis? sp. (belemnite) Indeterminate bivalve(s)	Early Cretaceous (Hauterivian-Barremian)	L.R. Landon (Univ. of Wisconsin in Sherwood and Craddock, 1979; D.L. Jones in Jones and others, 1980	The limestone bed at this locality is made almost entirely of coarse Inoceramus, indeterminate bivalve, and belemnite fragments with a few argillite and chert pebbles; all in a finer grained matrix of the same material
37 KJf_a B6	63°21'48" 149°38'43	81-CC-75	Limestone clasts in conglomerate	Conodonts: Belodella devonica Belodella triangularis Panderodus sp. bar and blade elements Acotretid brachiopod	Silurian to Early Devonian	Anita G. Harris, written commun., 1984	These limestone clasts may have been derived from unit DOs cropping out to the north. CAI = 4-1/2-5

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
38 KJf_a B6	63°22'02" 149°31'00"	82-CC-53	do.	Conodonts: Panderodus sp. bar elements Brachiopod fragments	Middle Ordovician to Middle Devonian	do.	do. CAI = 5-1/2
39 KJf C5	63°38'25" 149°29'50" (approx.loc.)	W.G. Gilbert, Ak D.G.G.S.	Argillite	Inoceramus cf. I. concentricus	Middle Cretaceous	D.L. Jones in Gilbert and Redman, 1977	
40 KJf C5	63°33'33" 149°16'50"	80-JH-32	Chert	Radiolarians	Jurassic or Creta-ceous	D.L. Jones in Jones and others, 1983	
41 KJf C5	63°30'30" 149°23'49"	80-JH-18 (MR-2043); 80-JH-19 (MR-2044)	do.	Radiolarians	Jurassic or Creta-ceous	do.	
42 KJf C5	63°30'35 149°12'20" (approx.loc.)	80-JH-33A (MR-2046)	do.	Radiolarians		do.	
43 ls_1 B4	63°27'14" 148°39'35"	U.W. 1574102 (CTW 88) Univ. of Wisconsin	Limestone	Solitary corals Bryozoans	Paleozoic	L.R. Landon in Sherwood and Craddock, 1979	Fault block(?) in melange of Cretaceous age
44 m_1 B4	63°25'57" 148°40'54"	U.W. 1633/40 (CTW 56) Univ. of Wisconsin	Argillite	Conodont fragment: platform blade of Palmatolepis? sp.	Ordovician to Trias-sic; Late Devonian(?)	D.L. Clark in Sherwood and Craddock, 1979; M.W. Mullen, this report	do. Fragment examined with SEM. CAI = 6
45 m_1 B4	63°25'10" 148°43'25"	81 ACy-4Ba	Chert	Radiolarians: Parasaturnalidae fragment, inde-terminate Spumellarians	Late Triassic to Late Cretaceous	N.R.D. Albert, written commun., 1982	Possible contamination during sample processing
46 ls_1 B4	63°23'47" 148°44'25"	U.W. 1553/10 (CTW 139) Univ. of Wisconsin	Limestone	Gastropods, crinoid fragments, bryozoans, corals, Astraeospongia sp. spicules	Silurian(?)	L.R. Laudon and J.K. Rigby in Sherwood and Craddock, 1979	Fault block or slide block (olisthostrome) in melange of Cretaceous age

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
47 ls_1 B4	63°23'03" 148°52'53"	A-713 (Univ. of Alaska Mus.); 76-S-285 (USGS 9709-SD); 83 AMM-1D	do.	A-713: Coelenterates: Alveolites sp. Cladopora sp. Dendrostella sp. auloporoid cf. Romingeria sp. Lyrielasma (s.l.) sp. cystiphylloid cf. Microplasma sp. lamellar stromatoporoids Brachiopods: Leiorhynchus sp. Emanuella sp. Ladjia sp. Trilobites: Dechenella sp. 1D: Two-hole crinoid ossicles Conodont fragments	Middle Devonian (Givetian)	Blodgett, 1977; W. Oliver, written commun., 1976; M.W. Mullen, this report	Fault block or slide block (olisthostrome) in melange of Cretaceous age. The two-hole crinoid ossicles (83AMM-1D) were collected from a small exposure along the Denali H.W. about 300 m east of the A-713 locality. CAI = 6
48 m_1 B4	63°23'45" 248°55'20" (approx.loc.)	77-J-3	Chert	Radiolarians	Carboniferous	B. Holdsworth in Jones and others, 1980	Melange block
49 m_1 B4	63°22'32" 148°57'30"	77-J-5	do.	do.	do.	do.	do.
50 m_1 A6	63°10'24" 149°31'04"	77-J-7	do.	do.	Late Paleo., Late Dev. or younger	do.	do.
51 m_1 A6	63°08'17" 149°33'51"	77-J-18	do.	do.	do.	do.	do.
52 ls_1 A6	63°06'51" 149°37'03"	75 ANw-75 (9743-SD)	Limestone	Dendrostella? sp. massive stromatoporoid	Silurian and Devonian, Mid. Devonian(?)	W.A. Oliver, written commun., 1977	Fault block or slide block (olisthostrome) in melange of Cretaceous age
53 ls_1 A6	63°06'27" 149°36'40"	75 ANw-76 (9744-SD)	do.	Labechia sp. Favosites sp.	Silurian or Devonian	do.	do.
54 ls_1 A6	63°03'45' 149°41'55"	75ANw-82 (9824-SD)	do.	Conodonts	Upper Silurian or Lower Devonian	A.G. Harris in Jones and others, 1980	From isolated exposures of limestone associated with serpentinite in melange of Cretaceous age.

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
55 ls_2 B4	63°27'36" 148°46'30"	82-DP-3-1/2 (10862-SD)	do.	Conodonts: Ponderodus sp. Polygnathus cf. P. varcus (Stauffer group) indeterminate bar and blade elements	late Middle Devonian (Givetian)	A.G. Harris, written commun., 1984	Fault block or slide block (olisthostrome) in melange of Cretaceous age. CAI = 5
56 ls_2 B4	63°27'17" 148°53'46"	U.W. 1553 (CTW 141) Univ. of Wisconsin	do.	Sagenites? Indeterminate clams and belemnites	Late Triassic	L.R. Laudon in Sherwood and Craddock, 1979	Fault block or slide block (olisthostrome) in Cretaceous melange
57 m_2 B4	63°27'19" 148°55'26"	80-JH-34	Chert clasts in conglomerate	Radiolarians	Jurassic and Mississippian	D.L. Jones in Jones and others, 1983	
58 m_2 B4	63°27'25" 148°56'50" (approx.loc.)	-----	Argillite	Buchia sp.	Late Jurassic to Late Cretaceous	D.L. Jones, personal commun., 1985	Equivalent of unit KJfa in Cretaceous melange
59 ls_2 B4	63°26'42" 148°55'40"	47-ACb-76; U.S. 1633/24	Limestone	Tryplasma sp. cf. Lyrielasma sp. cf. Zelophyllum sp. Clavidictyon sp. Amphipora sp.	Middle Devonian	J.M. Berdan in Moxham and others, 1959; W.A. Oliver in Sherwood and Craddock, 1979	Fault block or slide block (olisthostrome) in Cretaceous melange
60 ls_2 B4	63°27'24" 149°57'18"	47-ACb-78, 47-ACb-79	do.	78: Megalodus sp. Mysidia sp. 79: belemnite sp. indeterminate	Late Triassic	R.W. Imlay in Moxham and others, 1959	do.
61 ls_2 B5	63°26'55" 149°02'00	50-AMx-101 to 105	do.	Cladopora sp. Coenites? sp. pseudamplexoid coral unidentified horn coral stromatoporoids unidentified bryozoan	Middle Devonian	J.M. Berdan in Moxham and others, 1959	do.
62 ls_2 B5	63°25'09" 149°25'09"	80-S-494	do.	Molluscs, brachiopods, conodonts	Ordovician or Devonian	E.L. Yochelson and J.T. Dutro in Jones and others, 1983	do.
63 ls_2 B5	63°24'59" 149°16'37"	U.W. 1574/20 (FP 107) Univ. of Wisconsin; 80-S-495 (USGS 10099-SD)	do.	Crinoid fragments, corals	Devonian	T.DeKeyser in Sherwood and Craddock, 1979; W.A. Oliver in Jones and others, 1983	do.

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
64 JTRta A6	63°01'23" 149°53'04"	76-S-322, USGS Mesozoic loc. 31262	Sandy limestone and calcareous sandstone	Arnioceras cf. A. densicosta Pleuromya sp.	Early Jurassic, (early Sinemurian)	R.W. Imlay, written commun., 1976	
65 JTRta A6	63°02'23" 149°51'47"	76-S-332, USGS Mesozoic loc. 31265	do.	Arnioceras(?) sp. Psiloceras? canadense belemnite fragment Pleuromya sp.	do.	do.	
66 JTRta A6	63°02'48" 149°51'21"	76-S-3331, USGS Mesozoic loc. 31264	do.	Arietitid ammonite, Psiloceras? canadense	do.	do.	
67 JTRta A6	63°04'18" 149°49'48"	76-S-325, USGS Mesozoic loc. 31263	do.	Arnioceras cf. A. densicosta Weyla sp. Pleuromya sp.	do.	do.	
68 JTRta A6	63°07'13" 149°46'34"	76-J-41	Chert	Radiolarians	Late Jurassic (Callovian to early Tithonian)	C.D. Blome in Jones and others, 1980	
69 JTRta A6	63°07'33" 149°44'30"; 63°07'41"	76-J-27, USGS Mesozoic loc. 31260; 76-J-22	Sandy limestone and calcareous sandstone; chert	FG-J-27: Arnioceras cf. A. Densicosta 76-J-22: Radiolarians	Early Jurassic, (early Sinemurian); Late Jurassic	R.W. Imlay, written commun., 1976; C.D. Blome in Jones and others, 1980	
70 JTRta A6	63°07'36" 149°44'00"	76-J-31, USGS Mesozoic loc. 31261	Sandstone	Arctoasteroceras jeletskyi Paltechioceras (Orthechioceras?) sp. belemnite fragment Weyla sp.	Early Jurassic, (late Sinemurian)	R.W. Imlay, written commun., 1976; Jones and 1980	Sandstone interbedded with massive crystal tuff
71 JTRta A6	63°07'36" 149°38'24"	76-J-55	Chert	Radiolarians	Late Jurassic (Callovian to early Tithonian)	C.D. Blome in Jones and others, 1980	
72 TRcs C6	63°40'20" 149°42'54"	U.W. 1633/39 (X9) Univ. of Wisconsin	Silty limestone	Conodont platform blade	Triassic (?)	D.L. Clark in Sherwood and Craddock, 1979; M.W. Mullen, this report	CAI = 6

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
73 TRcs C6	63°40'07" 149°36'25"	U.W. 1633/33 (L13A) Univ. of Wisconsin	Silty limestone	Conodonts: *Epigondolella primitia* *Cypriodella* sp.	Late Triassic (early Norian)	D.L. Clark *in* Sherwood and Craddock, 1979 M.W. Mullen, this report	Conodont specimens were re-examined and photographed with the SEM. CAI = 6
74 TRcs C5	63°40'12" 149°08'12"	U.W. 1633/35 (R22) Univ. of Wisconsin	do.	Conodonts: *Epigondolella primitia*	do.	do.	do. CAI = 5.5 to 6
75 TRcs C5	63°37'45" 149°06'55"	78-S-413	do.	Conodonts	Late Triassic (Karnian-Norian)	B.R. Wardlaw *in* Jones and others, 1983	
76 TRcs C3	63°42'28" 148°02'15"	U.W. 1633/26 (K61) Univ. of Wisconsin	Argillite	Trace fossils: *Chondrites*? sp.	Triassic	N.J. Silberling *in* Sherwood and Craddock, 1979	Previously identified as possible graptolites
77 TRcs C3	63°42'22" 148°01'38"	U.W. 1633/25 (K58D) Univ. of Wisconsin	do.	Trace fossils: *Chondrites*? sp.	do.	do.	do.
78 TRcs C2	63°43'10" 147°56'20"	U.W. 1580/53 (RLA 156) Univ. of Wisconsin	do.	Trace fossils: *Chondrites* sp.	do.	do.	do.
79 TRcs C2	63°41'26" 147°50'15"	U.W. 1633/30 (TC 357A, D, E, G); U.W. 1622/31 (TC 357B)	do.	Trace fossils: *Chondrites* sp.	do.	do.	do.
80 TRcs C2	63°41'32" 147°48'48" 63°41'46" 147°49'00"	U.W. 1633/28 (TC 265); U.W. 1633/29 (TC 328A, B, C, E, F. G)	do.	Trace fossils: *Chondrites* sp. *Helminthoida* sp. *Phycosiphon* sp.	do.	N.J. Silberling and C.K. Chamberlain *in* Sherwood and Craddock, 1979	do.
81 TRcs C2	63°42'48" 147°46'52"	U.W. 1633/47 (K450) Univ. of Wisconsin	do.	Trace fossils: *Chondrites* sp.	Triassic (?)	do.	Previously identified as possible graptolites
82 TRcs C2	63°44'14" 147°49'14"	83 AMM-13	Silty limestone	Conodonts: *Neogondolelle polygnathiformis* *Epigondolella primitia* *Cypriodella*? sp.	Late Triassic (late Karnian-early Norian)	M.W. Mullen, this report	CAI = 5/5-6
83 TRcs C2	63°44'46" 147°38'55"	1633/37 (K230) Univ. of Wisconsin	do.	Conodonts: *Neogondolella polygnathiformis* *Neogondolella* sp. *Epigondolella primitia*?	do.	D.L. Clark *in* Sherwood and Craddock, 1979; M.W. Mullen, this report	Specimens were re-examined and photographed with the SEM. CAI = 6

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
84 TRcs C2	63°44'57" 147°37'12"	81ACy-18	Silty lime-stone	Conodonts: *Neogondolella* cf. *N. tadpole* *Epigondolella primitia*	do.	M.W. Mullen, this report	CAI-6
85 TRcs C2	63°44'16" 147°37'25"	U.W. 1633/31 (K 212) Univ. of Wisconsin	Argillite	Trace fossils: *Chondrites*? sp.	Trias-sic(?)	N.J. Silberling *in* Sherwood and Craddock, 1979	Previously identified as possible graptolites
86 TRcs C2	63°44'18" 147°36'40"	U.W. 1633/27 (K 214A) Univ. of Wisconsin	do.	Trace fossils: *Chondrites*? sp.	do.	do.	do.
87 TRcs C2	63°43'47" 147°36'05	U.W. 1633/36 (K 2858) Univ. of Wisconsin	Silty lime-stone	Conodonts: *Epigondolella primitia*?	Late Triassic (early Norian)	D.L. Clark *in* Sherwood and Craddock, 1979; M.W. Mullen, this report	CAI = 6
88 TRcs C2	63°44'12" 147°34'14"	83 AMM-11	do.	Conodont fragments	Ordovician to Triassic	M.W. Mullen, this report	CAI = 6
89 TRcs D2	63°44'48" 147°31'10"	U.W. 1633/34 (K 466) Univ. of Wisconsin	do.	Conodonts: *Epigondolella* sp.	Late Triassic (Karnian -Norian)	D.L. Clark *in* Sherwood and Craddock, 1979; M.W. Mullen, this report	Specimens were re-examined and photographed with the SEM. CAI = 5.5-6
90 TRcs C3	63°32'58" 148°05'05"	83 AMM-9	do.	Conodonts: *Neogondolella polygnathiformis* *Neogondolella* sp. *Epigondolella primitia* *Cypriodella* sp.	Late Triassic (late Karnian-early Norian)	M.W. Mullen, this report	CAI = 5.5-6
91 TRcs C2	63°32'50" 147°59'10"	U.W. 1622/23 (TC 2318) Univ. of Wisconsin	do.	Conodonts: *Epigondolella primitia*?	Late Triassic (early Norian)	D.L. Clark *in* Sherwood and Craddock, 1979; M.W. Mullen, this report	Specimens were re-examined and photographed with the SEM. CAI = 6
92 TRcs C3	63°36'10" 147°31'55"	---- W.M. Brewer, Univ. of Wisconsin	do.	Conodonts: *Epigondolella abneptis*	Late Triassic (Norian	D.L. Clark *in* Brewer, 1982	
93 TRcs B3	63°25'07" 148°06'14"	81 ACy-82	Sandy lime-stone	Conodonts: *Neogondolella polygnathiforms*? *Epigondolella primitia* Mollusca: *Monotis* cf. *M. subcircularis*	Late Triassic (late Karnian -early Norian); Norian	M.W. Mullen, this report; N.J. Silberling, written commun., 1982	Shelf deposits. CAI = 5

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
94 TRcs B3	63°25'58" 148°05'42"	79 ASf-3	do.	Conodonts Neogondolella polygnathiformis Epigondolella primitia Cypriodella sp.	Late Triassic (late Karnian-early Norian)	M.W. Mullen, this report; N.J. Silberling, written, commun.	Shelf deposits. CAI = 5
95 TRcs B3	63°27'03" 148°01'26"	U.W. 1633/32 (TT 34) Univ. of Wisconsin	Silty limestone	Conodonts: platform fragments of Epigondolella? or Neogondolella polygnathiformis?	Late Triassic (Karnian-Norian)	D.L. Clark in Sherwood and Craddock, 1979	
96 TRcs B3	63°20'40" 148°19'35"	81 ACy-92	do.	Conodonts: Epigondolella? sp.	Late Triassic (Karnian-Norian)	M.W. Mullen, this report	CAI = 6
96A TRcs B3	63°23'43" 148°21'36"	79ACy-8	do.	Conodonts: Epigondolella primitia	Late Triassic (late Karnian-early Norian)	do.	CAI = 5
97 TRvs A6	63°01'55" 149°37'20"	78 ACy-52,53	Marble	Hydrozoan: Heterastridium sp. Mollusc: Monotis subcircularis	Late Triassic (late Norian)	N.J. Silberling written commun., 1978	
98 TRvs A6	63°02'48" 149°34'20"	80 AMM-23	Argillite	Mollusc: Monotis cf. M. subcircularis	Late Triassic (Norian)	N.J. Silberling, written commun., 1983	Float from road-cut exposure
99 TRvs A5	63°10'05" 149°11'30"	77-S-152	do.	Hydrozoan: Heterastridium sp. Mollusc: Monotis subcircularis	Late Triassic (late Norian)	N.J. Silberling, written commun., 1978	
100 TRvs TKD2	62°58'53" 147°52'44" Talkeetna Mtns. quad	80 AMM-2	Limestone clasts	Conodonts: Neogondolella primitia Epigondolella primitia Chirodella sp. Mollusc: Leptochondria? sp.	Late Triassic (late Karnian-early Norian)	M.W. Mullen, this report; N.J. Silberling, written commun., 1983	Limestone clasts in a basaltic tuff. Clasts possibly derived from the Chitistone and Nizina Limestone of unit TRcl. CAI = 6
101 TRvs A1	63°08'26" 147°10'00"	---- T.E. Smith of AK. D.G.G.S.	Marble	Scleractinian corals, i.e., Thamnasteria? sp. Spongiomorphid coelenterates	Late Triassic(?)	N.J. Silberling in Smith, 1981	
102 TRvs A1	63°08'14" 147°10'44"	79 ARh-28	do.	Hydrozoan: Heterastridium sp.	Late Triassic (late Norian)	N.J. Silberling in Silberling and others, 1981b	

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
103 TRcl A2	63°01'38" 147°34'50"	80 ACy-8	Limestone	Conodonts: Epigondolella primitia Neogondolella cf. N. polygnathiformis Cypriodella sp. Molluscs: Halobia cf. H. superba Arcestes sp.	Late Triassic (late Karnian-early Norian)	M.W. Mullen, this report N.J. Silberling, written commun., 1983	CAI = 1.5-2
104 TRcl A2	63°03'48" 147°34'54"	80 ACy-13	do.	Barren of microfossils	Trias-sic(?)	M.W. Mullen, this report	This sample contains chert nodules and streamers
105 TRcl A1	63°09'08 147°00'22"	USGS Mesozoic loc. M 6750	do.	Molluscs: Trophites cf. T. kellyi Halobia cf. H. superba	Late Triassic (late Karnian)	N.J. Silberling in Silberling and others, 1981b	
106	63°08'28"	79 ACQ-16	do.	Mollusc:	Late	N.J. Silberling,	Fault sliver of unit TRcl,
TRn A1	147°08'22"			Halobia cf. H. superba	Triassic (late Karnian-early Norian)	written commun., 1980	or a sedimentary lense within the Nikolai Greenstone
107 JTRrs A6	63°02'07" 149°54'10"	76-N-135	Sandstone	Ammonite: Juvavites cf. J. magnus	Late Triassic (middle Norian)	N.J. Silberling, in Jones and others, 1980	
108 JTRrs A6	63°03'08" 149°55'30"; 63°03'16" 149°55'46"	76-S-303; 76-S-304	do.	Hydrozoan: Heterastridium sp.	Late Triassic (late Norian)	do.	
109 JTRrs A6	63°04'33" 149°52'08"	76-N-138	do.	Juvavites cf. J. magnus	Late Triassic (middle Norian)	do.	
110 JTRrs A6	63°05'14" 149°55'36"	77-S-131	do.	Hydrozoan: Heterastridium sp.	Late Triassic (late Norian)	do.	
111 JTRrs A6	63°08'12" 149°46'23" 63°08'29" 149°08'11"	USGS Mesozoic localities M6504 and M6505	do.	6504: Juvatinid ammonite 6505: Pseudosirenites sp. Indojuvavites sp. and other ammonites	Late Triassic (Karnian-Norian)	do.	
112 JTRrs A6	63°09'11" 149°46'30"	76-S-297	do.	Mollusc: Cassianellasp.	Late Triassic	do.	

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
113 JTRrs A6	63°12'06 149°44'23"; 63°11'59" 149°44'06"	76-S-333 USGS Mesozoic loc. 21266; 76-S-342	Sandstone	31266: Vermiceras (Paracaloceras) cf. V. (P. rursicostatum Psiloceras? canadense Weyla sp. Lima? sp. Eopecten? sp. 342: Septocardia? sp.	Early Jurassic (early Sinemurian; Late Triassic	R.W. Imlay, written commun., 1976; N.J. Silberling in Jones and others, 1980	
114 JTRrs A6	63°12'31" 149°42'42"	76-S-343	do.	Molluscs: Cassianella sp. Septocardia? sp.	Late Triassic	N.J. Silberling in Jones and others, 1980	
115 TRlb A6	63°03'55" 149°56'20"	76-S-306	Limestone	Scleractinian corals Megalodontid bivalves	do.	do.	
116 TRlb A6	63°04'48" 149°59'31"	76-S-324	do.	do.	do.	do.	
117 TRlb A6	63°13'12" 149°45'33"	77-S-111	do.	Spondylospira? sp. Scleractinian corals	Late Triassic (Norian)	do.	
118 TRcg B4	63°21'15" 148°51'05"	77-J-9	Conglomerate; chert clasts in conglomerate	Hydrozoan: Heterastridium sp.; Radiolarians	Late Triassic (late Norian); Permian	D.L. Jones and B.K. Holdsworth in Jones and others, 1980	
119 TRbd C6	63°30'30" 149°58'05" (approx.loc.	A-370 Univ. of Alaska Museum of Paleo.	Argillite	Mollusc: Halobia cf. H. superba	Late Triassic (Karnian-Norian)	Gilbert and others, 1984	Specimen is from a clastic interbed in pillowed greenstone
120 TRbd B6	63°26'43" 149°44'27"	83 AMM-8 (MR 6454)	Siltstone and argillite	Radiolarians Cantalum sp. Gorgansium sp. Laxtorum sp. Pantanellium fosteri Pseudoheliodiscus sp.	Late Triassic (late Norian)	C.D. Blome, written commun., 1984	Sample from thin-bedded turbidite sequence intercalated with pillow basalt. This sample also contains abundant sponge spicules and volcanic ash shards
121 TRPzs B6	63°25'35"	80-S-13	Chert	Conodonts and radiolarians	Late Triassic (Karnian)	B.R. Wardlaw and D.L. Jones in Jones and others, 1983	
122 TRPzs C5	63°30'05" 149°10'10"	82-DP-45 (M-33064)	Impure limestone	Conodonts: Neogondolella cf. N. shoshonensis	Middle Triassic (Anisian)	B.R. Wardlaw, written commun., 1984	Sample from fine-grained carbonate in sandstone and shale sequence

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
123 TRPzs B5	63°29'57" 149°11'12"	78-S-412 (27360-PC)	Limestone and silicified limestone clasts in conglomerate	Block A: Brachiopods: Spiriferella sp. Kutorginella? sp. Anemonaria? sp. echinodermal debris	Middle Permian (Leonardian-Wordian)	J.T. Dutro, written commun. 1978; and J.T. Dutro in Jones and others, 1983	Slump blocks and cobbles within a Triassic(?) conglomerate
				Block B: Brachiopods: Kavelousia sp. Cleiothyridina cf. C. royssiana Spiriferella? sp.	Middle Permian (Wordian)		
				Block C: Brachiopods: Kuvelousia sp.	Middle Permian (Wordian)		
				Block D: Brachiopods: linoproductoid: Kuvelousi? sp.	do.		
				Block E: phaceloid lithostrotionoid coral	Mississippian(?)	J.T. Dutro, written comm., 1978	
				Block F thamnoporoid corals: Alveolites? sp.	Late or Middle Devonian	do.	
		U.W. 1574/12 (YF 423) Univ. of Wisconsin	Limestone cobbles in conglomerate	Thamnopora cf. T. cervicornis Echinoderm, brachiopod, and bryozoan fragments	Middle or Late Devonian	T. DeKeyser in Sherwood and Craddock, 1979	
124 TRPzs C5	63°30'08" 149°07'49"	U.W. 1574/13 (YF 338) Univ. of Wisconsin	do.	Amphipora cf. A. ramosa Anostylostroma sp. Hammatostroma cf. H. albertende	Late or Middle Devonian	do.	Cobbles within a Triassic (?) conglomerate
125 TRPzs B5	63°29'20" 149°05'00" (approx.loc.)	80-S-502; U.W. 1574/14 (YF 362) Univ. of Wisconsin	Limestone clasts in conglomerate	Bryozoans, brachiopods, and echinoderm fragments	Carboniferous or Permian	Jones and others, 1983; T. DeKeyser in Sherwood and Craddock, 1979	Displaced fossil debris in Triassic(?) conglomerate
126 TRPzs B5	63°28'55" 149°05'10" (approx.loc.)	80-S-501	Limestone block in conglomerate	Conodonts	Late Early to early Middle Devonian	B.R. Wardlaw in Jones and others, 1983	Slump block of crinoidal limestone within a Triassic(?) turbidite
127 TRPzs B5	63°29'18" 149°04'03"	80-JH-13 (MR 2041), 80-JH-15	Chert	Conodonts and radiolarians	Late Triassic (Karnian)	Jones and others, 1983	Thin beds of chert interbedded with argillite
128 TRPzs B4	63°29'04" 149°55'20"	U.W. 1574/1 (MP 224) Univ. of Wisconsin	Limestone	Productid brachiopods	Pennsylvanian to Permian	L.R. Laudon in Sherwood and Craddock, 1979	

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
129 TRDs A5	63°15'12" 149°33'33"	68AHx-272 (23753-PC)	do.	Bryozoan: Rhombotrypella? sp. Echinoderm debris, including pelmatozoan columnals as much as 1 inch in diameter	Late Paleozoic, Permian(?)	J.T. Dutro in Hawley and Clark, 1974	
130 TRDs A6	63°14'02" 149°36'44"	67 ACx-74	do.	Brachiopods: Avonia? sp. Martiniopsis? sp. Bryozoan: Rhombotrypella sp. Crinoid columnals	Permian(?)	do.	
131 TRDs A6	63°12'56" 149°40'55"	77-S-101	Limestone;	Ammonites of the Meekoceras gracilitatis Zone	Early Triassic (Smithian)	K.M. Nichols in Nichols and Silberling, 1979; Wardlaw, 1982	
		78JCH-1	Phosphatic chert	Conodonts: Neogondolella jubata "Neospathodus" conservativus	Early Triassic (Spathian)		
132 TRDs A6	63°13'12" 149°38'50"	M5D27	Limestone	Ammonites of the Meekoceras gracilitatis Zone Conodonts: Ellisonia triassica Neogondolella silberlingi Neogondolella tozeri Neospathodus waageni	Early Triassic (Smithian)	K.M. Nichols in Nichols and Silberling, 1979; Wardlaw, 1982	
133 TRDs A6	63°12'39" 149°38'16"; 63°12'33" 149°38'14"	76-J-1; 76-J-2 (USGS 26672-PC)	Chert; volcanic conglomerate or breccia	Radiolarians Brachiopods: Fimbrinia sp. Antiquatonia? sp. Rugatia? sp.	Carboniferous(?); Early Permian (Wolfcampian-Leonardian)	D.L. Jones and J.T. Dutro in Jones and others, 1980	
134 TRDs A6	63°12'07" 149°41'34";	78-J-13;	Chert	Radiolarians	Mississippian;	B. Holdsworth in Jones and others, 1980	
	63°12'07" 149°40'26"	78-J-12	do.	do.	Permian(?)		
135 TRDs A6	63°11'48" 149°39'34";	78-J-15'	Chert;	Radiolarians;	Permian(?)	B. Holdsworth and A.G. Harris in Jones and others, 1980	Conodont CAI = 4.5-5
	63°11'56" 149°39'46"	9799-SD	Chert clasts in conglomerate	Conodonts	Late Devonian (Famennian)		
136 TRDs A6	63°10'53" 149°41'02"	68 ACK-218 (23402-PC)	Limestone	Brachiopods: Waagenoconch sp. Linoproductus? sp. Dieslasma cf. D. giganteum Massive and ramose bryozoans, horn coral	Permian(?)	J.T. Dutro in Hawley and Clark, 1974	

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
137 Dsb A6	63°11'08" 149°41'06"	76-J-9	Chert	Radiolarians	Late Devonian (Famennian)	B. Holdsworth *in* Jones and others, 1980	
138 Dsb A6	63°10'38" 149°41'40"	76-Nw-162	do.	do.	do.	do.	
139 Dsb A6	63°10'10" 149°40'25"	77-J-19, 20, 21; 76-Nw-164 and 165	do.	do.	do.	do.	
140 Dsb A6	63°11'59" 149°11'59"	78-J-3C	do.	do.	do.	do.	
141 Dsb A6	63°07'48" 149°45'34"	75-J-3B	do.	Conodonts	do.	A.G. Harris and B.R. Wardlaw *in* Jones and others, 1980	CAI = 4
142 TRPs	63°00'30" 147°42'50"	78JCh-21	do.	Conodonts and radiolarians	Middle Triassic	Silberling and others, 1981a	
143 TRPs A1	63°04'34" 147°16'25"	79-S-151	do.	Conodonts: *Neospathodus* cf. *N. pakistanensis*	Early Triassic (Dienerian to Smithian)	B.R. Wardlaw *in* Silberling and others, 1981b	
144 TRPs A1	63°04'02" 147°07'26"	79 JCh-1,2,3	do.	1,2: Radiolarians; 3: Conodonts and radiolarians	Late Penn. to Early Permian; Early Permian	Silberling and others, 1981b	
145 TRPs A1	63°04'18" 147°04'52"	78 JCh-24	do.	Radiolarians	Triassic	do.	
146 TRPs A1	63°04'44" 147°04'02"	78 JCh-30	do.	do.	Permian	do.	
147 TRPs A1	63°04'02" 147°03'18"	78-S-502	Limestone	Brachiopods	Early Permian	B.R. Wardlaw *in* Silberling and others, 1981b	
148 Pzts D2	63°57'06" 147°41'24"	-----	Marble	Tabulate coral: *Syringopora* sp.	Mississippian(?)	Helen Duncan *in* Warhrhaftig, 1968	
	do.	CC-Healy D-2	do.	Conodonts: *Polygnathus* sp. ramiform elements	M. Dev. to Early Missis.	A.G. Harris, written comm., 1985	CAI = 5

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
149 Pzmb D3	63°46'40" 148°26'40"	U.W. 1583/12 (YF 72) Univ. of Wisconsin	do.	Conodonts: Palmatolepis cf. P. marginata Icriodus cf. I. symmetricus or I. cf. I. alternatus Polygnathus sp.	Late Devonian (late Frasnian to early Famennian)	D.L. Clark in Sherwood and Craddock, 1979	
150 Pzmb D2	63°46'28" 147°40'28"	82 AMM-19	do.	Barren of microfossils	---	M.W. Mullen, this report	Sample from thin marble interbed in greenschist and phyllite sequence
151 Pzmb D1	63°45'28" 147°29'05"	U.W. 1622/38 (K 483) Univ. of Wisconsin	do.	Conodonts: Polygnathus sp.	Devonian to Mississippian	D.L. Clark in Sherwood and Craddock, 1979; M.W. Mullen, this report	Specimens were re-examined and photographed with the SEM. CAI = 6-6.5
152 Pzmb D1	63°45'22" 147°29'00"	U.W. 1633/04 (K 482) Univ. of Wisconsin	do.	Conodonts: lingonodinaform or a prioniodinaform element fragment	Devonian to Mississippian	D.L. Clark in Sherwood and Craddock, 1979; M.W. Mullen, this report	Specimen was re-examined and photographed with the SEM. CAI = 6-6.5
153 Pzms C6	63°39'40" 149°39'40"	---	do.	Amphipora? sp. Disphyllum? sp. cf. Grypophyllum sp.	Middle(?) Devonian	W.A. Oliver in Gilbert and Redman, 1977	
154 Pzms C6	63°40'02" 149°49'28"	---	do.	Disphyllum? sp.	Middle or early Late Devonian	do.	
155 Pzms C6	63°40'20" 149°48'55"	---	do.	Disphyllum? sp. Phillipsastraea sp. Tabulophyllum sp.	Late Devonian (Frasnian)	do.	
156 Pzms C6	63°43'12" 149°34'45"	---	do.	Echinoderm fragments, including pelmatozoan columnals	Ordovician to Permian or younger	J.T. Dutro in Gilbert and Redman, 1977	
157 Pzy C3	63°34'56" 148°14'52"	82 AMM-29	do.	Conodonts: Palmatolepis rugosa trachytera P. glabra pectinata P. sp.	Late Devonian (Middle Famennian)	M.W. Mullen and C.A. Sandberg, this report	Sample from a thin marble interbed in a metavolcanic sequence. Conodont specimens were badly distorted. CAI = 6
158 Pzy C3	63°34'00" 148°18'30" (general loc.)	81 ACy-M5, M6, M9	Chert	Barren of microfossils	--	C.D. Blome, written commun., 1982	Processed for radiolarians
159 Pzy C3	63°33'10" 148°08'30" (general loc.)	81 ACn-781, 782	do.	do.	--	do.	do.

Table 2.--Fossil data from the Healy quadrangle, Alaska (Continued)

Map No., map unit, quad. No.	Location: latitude and longitude	Field No.(s), U.S.G.S. Museum No., and/or collector	Lithology	Fossils	Fossil age	Determiner and/or reference	Comments
160 Pzy C3	63°33'40" 148°05'40" (general loc.)	81 ACy-64,65	Chert	Barren of microfossils	--	N.R.D. Albert, written commun., 1982	do.
161 Pzy C2	63°37'58" 147°56'54"	81 ACn-763	do.	do.	--	C.D. Blome, written commun., 1982	do.
162 Pzy C2	63°36'22" 147°51'52"	81 ACy-60	do.	do.	--	do.	do.
163 Pzy C2	63°37'38" 147°45'50"	81 Acy-32	do.	do.	--	N.R.D. Albert, written commun., 1982	do.
164 Pzy C2	63°37'30" 147°38'44"	81 ACy-62	do.	do.	--	C.D. Blome, written commun., 1982	
165 Dls B6	63°25'10" 149°56'30"	83 AMM-2	Limestone	do.	--	M.W. Mullen, this report	Processed for conodonts; algal laminated limestone
166 DOs B6	63°25'12" 149°50'08"	83 AMM-4	do.	do.	--	do.	Processed for conodonts; fine-grained carbonate interbedded with argillite
167 DOs B6	63°24'32" 149°47'48"	83 AMM-5	do.	Barren of conodonts; contains indeterminate radiolarians	--	do.	Processed for conodonts; dark gray, thinly laminated radiolarian-bearing limestone
168 Dls B6	63°25'56" 149°40'40"	83 AMM-6	do.	Barren of microfossils; contains recrystallized coral, bryozoan, brachiopod, and gastropod fragments	--	do.	Processed for conodonts; massive-bedded, shallow-water limestone
169 Dls B6	63°28'20" 149°17'10" (approx.loc.)	Fossils no. 3, S.R. Capps, 1919	Limestone	Corals: *Heliophyllum* sp. *Cladopora* sp. *Striatopora* sp.	Middle Devonian	Edwin Kirk; Capps, 1932, p. 255	
170 DOs B5	63°27'18" 149°03'54"	80-S-504; 80-S-503	do.	504: gastropods; 503: bivalves, gastropod	Ordovician to Devonian; post-Devonian (?)	E.L. Yochelson and J. Pojeta in Jones and others, 1983	
171 pqs D2	63°49'35" 147°53'25" (approx.loc.)	-- John Dunbier	Marble	Echinoderm clastic particles, including crinoid fragments and an echinoid spine	Possibly Ordovician or younger	A.K. Armstrong in Gilbert and Bundtzen, 1979	

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