UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RECONNAISSANCE GEOLOGIC MAP AND GEOCHRONOLOGY, TALKEETNA MOUNTAINS QUADRANGLE, NORTHERN PART OF ANCHORAGE QUADRANGLE, AND SOUTHWEST CORNER OF HEALY QUADRANGLE, ALASKA

OPEN-FILE REPORT 78-558-A

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature

Menlo Park, California
1978

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By

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Description of map units, Structure, Tectonics, Reference list, and tables to accompany Open-file Report

DESCRIPTION OF MAP UNITS

SEDIMENTARY AND VOLCANIC ROCKS

Qs SURFICIAL DEPOSITS, UNDIFFERENTIATED (Quaternary)--Glacial and alluvial deposits, chiefly unconsolidated gravel, sand, and clay.

Tv VOLCANIC ROCKS, UNDIFFERENTIATED (Paleocene to Miocene, uppermost part may be as young as Pleistocene)--Over 1,500-m-thick sequence of felsic to mafic subaerial volcanic rocks and related shallow intrusives. Lower part of sequence consists of small stocks, irregular dikes, lenticular flows, and thick layers of pyroclastic rocks; made up dominantly of medium- to fine-grained, generally medium-gray quartz latite, rhyolite, and latite. A few dikes and intercalated flows of brown andesite are also present. Rocks of the lower part of the sequence, occurring mostly in the upper Talkeetna River area, are interpreted to be vent facies deposits and near vent deposits of stratovolcanos. The upper part of the sequence consists of gently dipping brown andesite and basalt flows interlayered with minor amounts of tuffs. A few lenses of fluviatile conglomerate are also present. Locally, at Yellowjacket Creek for instance, the feeder dikes of the mafic flows make up more than half the volume of the underlying country rocks. According to E. M. MacKevett, Jr. (oral commun., 1975), the andesite and basalt flows are lithologically identical to the basal andesites of the Wrangell Lava in eastern Alaska.

Contact between the dominantly felsic lower part and mafic upper part of the sequence is gradational through intertonguing of the two rock types. The three samples for potassium-argon age determinations (map numbers 7, 8, 13 in table 1), indicating Paleocene and Eocene ages, were obtained from andesite flows near the middle of this sequence.

Tim HYPABYSSAL MAFIC INTRUSIVES (Paleocene to Miocene, youngest rocks may be Pleistocene)--Small stocks and irregular dikes of diorite porphyry, diabase, and basalt. They probably are the subvolcanic equivalents of the andesite and basalt flows of unit Tv.

Tif HYPABYSSAL FELSIC INTRUSIVES (Paleocene to Miocene, some rocks may be as young as Pleistocene)--Small stocks and irregular dikes of rhyolite, quartz latite, and latite. Lithologically, they are identical to, and thus probably correlative with the felsic subvolcanic rocks of unit Tv.

Ttw TSADAKA (Miocene) AND WISHBONE (Paleocene and Eocene) FORMATIONS, UNDIVIDED--Tsadaka Formation, occurring only at Wishbone Hill, consists of cobble-boulder conglomerate with thin interbeds of sandstone, siltstone, and shale; about 200 m thick. The Wishbone Formation, which unconformably underlies the Tsadaka, comprises well-indurated fluviatile conglomerate with thick interbeds of sandstone, siltstone, and claystone; about 600 to 900 m thick (Detterman and others, 1976; Barnes, 1962). The present map unit also includes over 150 m of fluviatile conglomerate and coaly sandstone (unit Tf of Grantz, 1960a, b) in the eastern Talkeetna Mountains.

Tc CHICKALOON FORMATION (Paleocene)--Well-indurated, continental, dominantly fluviatile sequence of massive feldspathic sandstone, siltstone, claystone, and conglomerate, containing numerous beds of bituminous coal; over 1,500 m thick (Barnes, 1962).

Tsu SEDIMENTARY ROCKS, UNDIFFERENTIATED (Tertiary)--Fluviatile conglomerate, sandstone, and claystone with a few thin interbeds of lignitic coal. Lithologically, these rocks look similar to the Tertiary sedimentary rocks of the southern Talkeetna Mountains, but lack of fossil evidence does not permit more definitive correlation. The largest exposure of these rocks is along Watana Creek, and, according to Smith (1974a), the sequence is over 160 m thick. Lithologically, it resembles the Paleocene Chickaloon Formation of the Matanuska Valley.

PLUTONIC AND METAMORPHIC ROCKS

Tgd TERTIARY GRANODIORITE (Eocene)--Contains hornblende and biotite. This granodiorite is part of a small pluton along the northern edge of the map area. Turner and Smith (1974) report an Eocene age for this pluton, determined by the potassium-argon method on biotite (48.8±1.5 m.y.) and on hornblende (44.8±1.3 m.y.) from a sample just north of the present map area.

Thgd BIOTITE-HORNBLENDE GRANODIORITE (Paleocene, in part may be Eocene)--Rocks of this unit occur in one large and several smaller, poorly exposed plutons in the western and northern Talkeetna Mountains. All of the plutons were forcibly intruded in the epizone of Buddington (1959). Granodiorite is the dominant rock, but locally it grades into adamellite (= granite with plagioclase and alkali feldspar in approximately equal proportions), tonalite, and quartz diorite. All these rocks are medium to dark gray, medium grained, generally structureless, and have granitic to seriate textures. In all of them, hornblende is the chief mafic mineral. Biotite- and hornblende-rich xenoliths of reconstituted country rock are common in every pluton. The lithologic compositions and available age determinations (see table 1) indicate that these granitic rocks are the plutonic equivalents of some of the felsic rocks in the lower portion of unit Tv.

Tbgd BIOTITE GRANODIORITE (Paleocene, in part may be Eocene)--Biotite granodiorite and adamellite in approximately equal proportions. Biotite is the chief mafic mineral, hornblende is occasionally present. Color is light to medium gray, grain size is from medium to coarse, texture is granitic to seriate. Very faint flow structures have developed only locally. These rocks occur in shallow, forcibly emplaced epizonal plutons in the northwestern Talkeetna Mountains. Aplitic and pegmatitic dikes are common in all the plutons. Just north of the map area, these plutonic rocks grade into felsic volcanic rocks. Potassium-argon age determinations (see table 1) indicate that the biotite granodiorite and adamellite of the present unit are essentially of the same age as the biotite-hornblende granodiorite (unit Thgd). Thus, the rocks of these two units, in view of their spatial proximity, probably are the products of differentiation of the same parent magma, either in situ or at some deeper levels in the Earth's crust. The biotite granodiorite intrusives are also considered to be the plutonic equivalents of some of the felsic volcanic rocks in the lower portion of unit Tv.

Tsmg SCHIST, MIGMATITE, AND GRANITE (Paleocene intrusive and metamorphic ages)--Undifferentiated terrane of andalusite and (or) sillimanite-bearing pelitic schist, lit-par-lit type migmatite, and small granitic bodies with moderately to well-developed flow foliation. These rocks occur in approximately equal proportions, and the contacts between them are generally gradational, as is the contact between the schist and its unmetamorphosed pelitic rock equivalents (unit Kag) outside the present map unit.

The pelitic schist is medium to dark gray, medium grained, has well-developed but wavy foliation, and contains lit-par-lit type granitic injections in greatly varying amounts. Rock-forming minerals of the schist include biotite (pleochroism Nz = dark reddish brown, Nx = pale brown), quartz, plagioclase, minor K-feldspar, muscovite, garnet, and sillimanite which locally coexists with andalusite.

The lit-par-lit type granitic injections within the schist are medium gray, medium grained, and consist of feldspar, quartz, and biotite.

The rocks of the small, granitic bodies range in composition from biotite adamellite to biotite-hornblende granodiorite. They are medium gray and medium grained, generally have granitic textures, and, in addition to the flow foliation, locally display flow banding of felsic and mafic minerals. These granitic bodies appear to be the source of the lit-par-lit intrusions.

The proximity of the schist to the small granitic bodies, the occurrence of the lit-par-lit injections, and the presence of andalusite in the schist indicate that the schist is the result of contact metamorphism. Perhaps this metamorphism took place in the roof zone of a large pluton, the cupolas of which may be the small granitic bodies.

TKt TONALITE (Upper Cretaceous and Lower Paleocene)--Dominantly biotite-hornblende tonalite, locally grades into quartz diorite. The tonalite is medium gray, coarse to medium grained, has a granitic texture and a fairly well-developed primary foliation. It occurs in a large, possibly composite, batholith, approximately 75 to 61 m.y. old (see table 1), which was emplaced in the epizone and mesozone of Buddington (1959). The tonalite is described in more detail in Csejtey (1974).

TKa ADAMELLITE (Upper Cretaceous and Lower Paleocene)--Occurs in a large epizonal pluton in the southwestern part of the map area. The dominant rock type is adamellite but locally includes granodiorite. Biotite is the chief mafic mineral, muscovite occurs in subordinate amounts. The typical adamellite is medium to light gray, medium to coarse grained, its texture ranges from granitic to seriate. The adamellite appears to be intrusive into the tonalite (unit TKt), but concordant potassium-argon ages on one sample (map no. 24, table 1) indicate the adamellite to be essentially the same age as the tonalite. These rocks apparently are comagmatic.

TKgr GRANITIC ROCKS, UNDIVIDED (Cretaceous and (or) Tertiary)--These rocks of uncertain age occur in four smaller epizonal plutons of granodiorite and tonalite. Their color is medium to dark gray, grain size is medium, texture is granitic. Mafic minerals are hornblende and (or) biotite. The largest of these plutons, in the northeast corner of the map area, is reported by Smith and others (1975) to be of Cretaceous age.

TKlg LEUCOGABBRO (Cretaceous and (or) Tertiary)--Small, poorly exposed intrusive of uncertain age in west-central part of map area, essentially consisting of plagioclase (around An70 and about 80 percent of volume), and pale-green hornblende. The leucogabbro is medium to light gray, coarse to medium grained, with a granitic to seriate texture.

SOUTHEASTERN TALKEETNA MOUNTAINS

Sedimentary and volcanic rocks

Kar ARKOSE RIDGE FORMATION (Cretaceous)--Arkosic sandstone, conglomerate, graywacke, siltstone, and shale (Detterman and others, 1976; Grantz and Wolfe, 1961). Clastic components consist chiefly of granitic and metamorphic rock fragments, quartz, feldspar, and biotite, indicating a dominantly plutonic and, to a lesser extent, metamorphic provenance (G. R. Winkler, oral commun., 1977). Numerous plant fragments suggest a dominantly terrestrial origin. Recent field and petrographic studies (Csejtey and others, 1977) indicate that this formation is of Cretaceous age. A pre-Tertiary age is also indicated by a potassium-argon age determination on biotite (map no. 37, table 1). The biotite was separated from a sample of graywacke with secondary biotite, obtained from near the tonalite pluton (unit TKt). The formation rests unconformably on Jurassic granitic and metamorphic rocks and is as much as 700 m thick. In this report the Arkose Ridge is considered to be a dominantly nonmarine facies of the Cretaceous Matanuska Formation.

Km MATANUSKA FORMATION (Lower and Upper Cretaceous)--Well-indurated shale, siltstone, sandstone, graywacke, with subordinate conglomerate interbeds; occurs along the southern edge of the map area, mostly in the Matanuska Valley. These rocks, having a total thickness in excess of 1,200 m, are generally dark gray and thinly bedded, and for the most part were deposited in a marine environment of moderate to shallow depths. Some of the sandstone beds contain fragmentary plant remains. Age of the formation ranges from Maestrichtian at the top to Albian at the base (Grantz, 1964). The formation rests with a pronounced angular unconformity on Lower Cretaceous and older strata. In part, the Matanuska Formation correlates with the Kennicott, the Shulze, the Chititna, and the MacCall Ridge Formations of the southern Wrangell Mountains (Jones, 1967).

Ksu SEDIMENTARY ROCKS, UNDIVIDED (Lower Cretaceous)--A shallow water marine sequence of thinly bedded calcareous sandstone, siltstone, claystone, minor conglomerate, and thick-bedded to massive clastic limestone; interpreted as a continental shelf-type deposit; over 100 m thick. These strata occur in the southeastern Talkeetna Mountains, and they have been previously mapped and dated by Grantz (1960a, b). The present undivided unit includes Grantz' units Ks, Kc, and the Nelchina Limestone. The contact between these strata and the underlying Jurassic Naknek Formation (unit Jn) is a slightly angular unconformity. The Nelchina Limestone correlates with the Berg Creek Formation of the southern Wrangell Mountains (E. M. MacKevett, Jr., oral commun., 1977).

Jn NAKNEK FORMATION (Upper Jurassic)--Shallow water marine, thin to thick bedded, intercalated strata of fossiliferous gray siltstone, shale, sandstone, and conglomerate; over 1,400 m thick. Previously mapped and dated by Grantz (1960a, b). The Naknek Formation is restricted to the southeastern Talkeetna Mountains, lacks any contemporaneous volcanic material, and appears to have been deposited in a continental shelf environment. Its contact with the underlying Chinitna Formation is a very slightly angular unconformity. The Naknek correlates with the Root Glacier Formation of the southern Wrangell Mountains (E. M. MacKevett, Jr., oral commun., 1977).

Jct CHINITNA FORMATION (Upper Jurassic) AND TUXEDNI GROUP (Middle Jurassic), UNDIVIDED--The Chinitna Formation consists of a shallow marine, intercalated sequence of dark-gray shale, siltstone, and subordinate graywacke; contains numerous large limestone concretions; it is as much as 600 m thick. The Tuxedni Group unconformably underlies the Chinitna, and consists of shallow marine, well-indurated, thinly to thickly bedded graywacke, sandstone, and massive conglomerate in its lower part, and thinly to thickly bedded dark siltstone and shale in its upper part. The Tuxedni is about 300 to 400 m thick. Both the Chinitna and Tuxedni have been previously mapped and dated by Grantz (1960a, b; 1961a, b), by Grantz and others (1963), and by Detterman and others (1976). Both formations occur in the southeastern part of the map area, are devoid of coeval volcanic material, and are interpreted to have been deposited in a continental shelf environment. The contact between the Tuxedni Group and the underlying Talkeetna Formation (unit Jtk) is a major angular unconformity. The Chinitna and Tuxedni are partly correlative with the Nizina Mountain Formation of the southern Wrangell Mountains (E. M. MacKevett, Jr., oral commun., 1977).

Jtk TALKEETNA FORMATION (Lower Jurassic)--Andesitic flows, flow breccia, tuff, and agglomerate; subordinate interbeds of sandstone, siltstone, and limestone (mapped separately as unit Jls), especially in upper part of the formation. A dominantly shallow marine sequence, about 1,000 to 2,000 m thick (Grantz, 1960a, b; 1961a, b; Grantz and others, 1963; Detterman and others, 1976). This formation occurs only in the southeastern half of the mapped area and its base is nowhere exposed. The occurrence of marble (units Jmb and Jmbr) within the plutonic and metamorphic rocks just northwest of the Talkeetna Formation outcrop area suggests that the formation is underlain by volcanogenic rocks of Triassic (unit TRv) and of Paleozoic age (unit Pzv).

Jls LIMESTONE (Lower Jurassic)--Light- to dark-gray, fine- to medium-grained unfossiliferous limestone; near granitic rocks recrystallized to medium- to coarse-grained marble. Forms discontinuous lenticular bodies, as much as 30 m thick, within Talkeetna Formation.

Plutonic and metamorphic rocks

Kum SERPENTINIZED ULTRAMAFIC ROCKS (Lower and (or) Upper Cretaceous)--These rocks occur in small, tectonically emplaced, discordant bodies (protrusions) within the probably Lower to Middle Jurassic pelitic schist (unit Jps) near Willow Creek. They are medium greenish gray to black in color, and are composed of aphanitic masses of serpentine, talc, minor amounts of actinolite-tremolite, chlorite, and opaque minerals. Relict textures were nowhere observed, and all these bodies are strongly sheared. Semiquantitative spectrographic analyses indicate chromium contents to be between 1,000 and 5,000 ppm and nickel between 1,000 and 2,000 ppm (analyses by D. F. Siems and J. M. Motooka, 1973). Fire assay analyses of ten samples show both platinum and palladium contents to range from 0.0 ppm to 0.030 ppm (analyses by R. R. Carlson, 1973). However, the average platinum to palladium ratio is only about three to one. Potassium-argon age determinations on actinolite-tremolite from two samples yielded early Late Cretaceous minimum ages (map nos. 32, 36, table 1). These minimum ages coincide in time with a middle to Late Cretaceous period of intense, alpine-type orogenic deformation (see Structure and Tectonics sections) of the Talkeetna Mountains region. Thus, the serpentinite bodies, whose original age is unknown, are assumed to have been emplaced during this orogeny.

Jtr TRONDHJEMITE (Upper Jurassic)--Forms a discordant, northeast-trending, elongate, epizonal pluton of fairly uniform lithology in the central Talkeetna Mountains. Large portions of the pluton have been sheared and saussuritized. Typically, the trondhjemite is light gray, medium to coarse grained with a granitic texture. A faint flow foliation is locally developed. Major rock forming minerals are plagioclase (oligoclase to sodic andesine), quartz, K-feldspar (between 0 to 10 percent of volume), and biotite, with subordinate amounts of muscovite, and opaque minerals. Color index ranges from 3 to 9. Average oxide percentages, by weight, of seven trondhjemite analyses are: SiO_2 - 70.30, Al_2O_3 - 16.74, K_2O - 1.27, Na_2O - 5.07, CaO - 3.33. Potassium-argon age determinations (map nos. 21, 22, 26, 31, table 1) from the southern part of the pluton show considerable variation in age, which is attributed to resetting. However, three age determinations from the northern half of the pluton (map nos. 10, 11, 14, table 1), including concordant ages on a mineral pair of muscovite and biotite, yielded very similar numbers indicating the emplacement of the trondhjemite pluton between 145 to 150 m.y. ago. The trondhjemite is the youngest member of a group of Jurassic plutonic and metamorphic rocks in the Talkeetna Mountains.

Jgd GRANODIORITE (Middle to Upper Jurassic)--Dominantly granodiorite but includes minor amounts of tonalite and quartz diorite.

These epizonal plutonic rocks, underlying considerable areas in the central and eastern Talkeetna Mountains, were probably emplaced as multiple intrusion of consanguineous magmas. They are medium to dark gray, medium grained, and in undeformed rocks the texture is granitic. Mafic minerals are hornblende and biotite in various proportions. Along the northwestern border of its exposure area, the granodiorite and related rocks have been cataclastically deformed, resulting in a pronounced northeast-trending secondary foliation and, to a lesser degree, lineation. The width of the deformed zone varies from about 2 km to 25 km. Isotopic age determinations (map numbers 15-17, 27, tables 1, 2) from four separate localities indicate that emplacement, probably multiple intrusions, took place approximately 150 and 175 m.y. ago. While the Upper Jurassic trondhjemite intrudes the granodiorite, the granodiorite itself intrudes the Talkeetna Formation of Lower Jurassic age (Grantz and others, 1963).

Jgdm MIGMATITIC BORDER ZONE OF GRANODIORITE (Middle to Upper Jurassic)--Forms a terrane of poorly exposed, intricately intermixed contact schist, amphibolite, and small dikes and veinlets of granodiorite; all of these rock types occur in approximately equal proportions.

The contact schist is dark to medium gray, medium grained; rock-forming minerals are quartz, biotite, and subordinate plagioclase.

The amphibolite is dark gray, medium grained, and consists of hornblende and plagioclase; megascopic schistosity is seldom conspicuous.

The granodiorite is the same as that of unit Jgd; most of the veinlets have been intruded along foliation planes.

The metamorphic rocks of this unit were probably derived from either the Talkeetna Formation (unit Jtk) or from the upper Paleozoic volcanogenic sequence (unit Pzv), or possibly in part from the Upper Triassic basaltic sequence (unit TRv).

Jmrb MARBLE (Middle to Upper Jurassic metamorphic age)--Contact metamorphosed marble bed more than 40 m thick within migmatitic border zone (unit Jgdm). The marble is poorly exposed and occurs only along John Creek, a tributary of upper Kosina Creek. The rock is white, coarse to medium grained, and contains numerous porphyroblastic crystals of andradite garnet and diopside. The marble was derived from a limestone bed, probably within the upper Paleozoic volcanogenic sequence (unit Pzv) or possibly within the Upper Triassic basaltic sequence (unit TRv).

Jqd QUARTZ DIORITE (Lower to Middle Jurassic)--Epizonal intrusive in the southern Talkeetna Mountains. Dominantly quartz diorite but also includes diorite and tonalite. Large portions of this rock have been sheared and intensively altered. The fresh quartz diorite is medium to dark greenish gray, medium to coarse grained, and has a granitic texture. Rock-forming minerals are plagioclase (andesine), quartz, hornblende, subordinate biotite and K-feldspar. Where altered, the quartz diorite consists of mineral aggregates of epidote, chlorite, and sericite, as well as some remnants of the primary minerals. The age of the quartz diorite is probably late Early Jurassic or early Middle Jurassic because it intrudes the Talkeetna Formation and is intruded by the Middle to Upper Jurassic granodiorite of unit Jgd.

Jam AMPHIBOLITE (Lower to Middle Jurassic metamorphic age)--Forms a metamorphic terrane consisting dominantly of amphibolite but includes subordinate amounts of greenschist and foliated diorite. This metamorphic terrane also includes several interbeds of coarsely crystalline marble which are mapped and described separately (unit Jmb).

The amphibolite is generally dark greenish gray, medium to coarse grained, but fine-grained varieties also occur. Foliation and lineation are generally poorly developed, and segregation layering is rare. Major rock-forming minerals are, in approximately equal proportions, anhedral to euhedral hornblende (Z = dark green to brownish green, occasionally bluish green) and anhedral, generally twinned plagioclase ranging from labradorite to calcic andesine. Accessory minerals are quartz, garnet, sphene, apatite, opaques, occasional epidote, and, in some of the rocks, shreds of biotite.

The greenschist is dark greenish gray, fine to medium grained, with a moderately well-developed schistosity. Major minerals are actinolite, untwinned plagioclase (probably albite), epidote, chlorite, quartz, and opaques. Some of the actinolite-like amphibole may actually be aluminous hornblende, thus some of these rocks may be transitional to amphibolite.

The foliated diorite is very similar to the amphibolite in appearance. It is dark greenish gray, medium to coarse grained, with a generally well-developed shear foliation. A remnant granitic texture is always discernible in thin section. Rock-forming minerals are hornblende, twinned and occasionally zoned plagioclase (andesine to sodic labradorite), with subordinate amounts of chlorite and epidote, minor quartz and biotite, and opaques.

All of the above rocks, as well as the quartz diorite of unit Jqd, apparently are the earliest products of a Jurassic plutonic and metamorphic event which appears to have started in the Talkeetna Mountains in late Early Jurassic time after the deposition of the Talkeetna Formation (unit Jtk). A potassium-argon age determination on hornblende of a diorite or amphibolite sample (map no. 5, table 1) from the northeast part of the map area yielded an age of 176.6 m.y. (Turner and Smith, 1974), suggesting an Early to Middle Jurassic age for the amphibolite and associated rocks. The quartz diorite of unit Jqd in the southern Talkeetna Mountains is probably correlative with the sheared diorite of the amphibolite terrane.

The metamorphic rocks of the amphibolite terrane probably were derived from any or all of the following dominantly basic volcanic formations: Talkeetna Formation (unit Jtk), upper Paleozoic volcanogenic sequence (unit Pzv), or the Upper Triassic basaltic sequence (unit TRv). The pods of greenschist, intercalated with the amphibolite, suggest that the metamorphism in the amphibolite terrane was not of uniform intensity.

Jmb MARBLE (Lower to Middle Jurassic metamorphic age)--White, medium- to coarse-grained marble. It occurs in massive interbeds, as much as 30 m thick, within the amphibolite terrane of unit Jam. The marble contains subordinate amounts of garnet and diopside. Its parent rock was a limestone bed, probably within the Talkeetna Formation (unit Jtk) or within the upper Paleozoic volcanogenic sequence (unit Pzv), or, least likely, within the Upper Triassic basaltic sequence (unit TRv).

Jmi AMPHIBOLITE AND QUARTZ DIORITE (Lower to Middle Jurassic metamorphic and plutonic ages)--Forms a terrane of intricately intermixed amphibolite and quartz diorite in about equal amounts in the southern Talkeetna Mountains.

The amphibolite is very similar to the amphibolite of unit Jam, thus the two amphibolites are considered to be correlative, and no description is given here. One difference is that segregation layering of mafic and felsic components is more prevalent in the amphibolite of unit Jmi. A thin wedge of biotite-quartz-feldspar gneiss, probably derived from a nonvolcanic clastic interbed, is intercalated with the amphibolite along lower Granite Creek (Detterman and others, 1976; Travis Hudson, oral commun., 1978).

The quartz diorite is petrographically identical to the quartz diorite in adjacent unit Jqd (see rock description there), and the two rocks are considered to be correlative. The quartz diorite of the present unit is generally more altered than that of unit Jqd.

Jgs GREENSTONE (Probably Lower to Middle Jurassic metamorphic age)--The basic metavolcanic rocks of this unit form small, isolated hills along the eastern edge of the map area near the Susitna River. The typical greenstone is a dark greenish gray, fine grained, generally structureless rock. Original rock-forming minerals were pyroxene, amphibole, and plagioclase (andesine to labradorite) which more or less altered to chlorite, epidote, serpentine, calcite, and minor sericite and quartz. The proximity of the amphibolite terrane (unit Jam) strongly suggests that the metavolcanic greenstones of the present unit represent a low-grade facies of the same metamorphism which produced the amphibolite. The relative position of the greenstone within the northeasterly structural trend of the Talkeetna Mountains suggests that the greenstone was probably derived from the Talkeetna Formation (unit Jtk) or, possibly, from either the upper Paleozoic volcanogenic sequence (unit Pzv) or the Upper Triassic basaltic sequence (unit ŦRv).

Jps PELITIC MICA SCHIST (Probably Lower to Middle Jurassic metamorphic age)--This rock occurs only in the southwestern corner of the map area near the headwaters of Willow Creek. The schist is medium to dark gray, medium grained, with uniform lithology throughout its exposure area. Its ubiquitous mineral constituents are quartz, muscovite, albite, chlorite, chloritized crystals of garnet and subordinate biotite. Very thin laminae of carbonaceous material occur sparsely. Small open folds and crenulations form an incipient slip cleavage at a large angle to the primary schistosity. Numerous thin veins and stringers of hydrothermal quartz occur throughout the schist. Detailed petrographic descriptions of the mica schist are given in Ray (1954).

The present mineralogy of the schist is indicative of the greenschist metamorphic facies of Turner (1968). However, it is probably retrograde from higher metamorphism, possibly the amphibolite facies. Evidence for this is the chloritized garnet and biotite crystals and the sparse mineral outlines consisting of chlorite which probably are pseudomorphs after hornblende.

The age of the schist is imperfectly known, but, based on regional geologic interpretations, the primary metamorphism is considered to be Early to Middle Jurassic in age. Thus, the schist and the amphibolite of unit Jam are interpreted to be the products of the same metamorphism. The retrograde metamorphism is assumed to be of middle to Late Cretaceous in age and related to an alpine-type orogeny in the Talkeetna Mountains at that time. However, the Late Cretaceous Arkose Ridge Formation, which lies unconformably on the schist, has not been affected by this retrograde metamorphism. The three potassium-argon age determinations, measured on muscovite from the schist (map nos. 33-35, table 1), yielded obviously reset Paleocene ages.

The parent rock of the schist is unknown because no pelitic rocks of comparable thickness (the schist is at least several hundred meters thick) are known to occur in the pre-Middle Jurassic rocks of the Talkeetna Mountains.

Jpmu PLUTONIC AND METAMORPHIC ROCKS, UNDIFFERENTIATED (Lower to Upper Jurassic plutonic and metamorphic ages)--This unit consists of an intricately intermixed mosaic of most of the previously discussed Jurassic metamorphic and plutonic rocks (units Jtr, Jgd, Jgdm, Jqd, Jam, Jgs, and Jps). Within the terrane of the present unit, the exposure area of an individual rock type is not more than a few square kilometers. Two rock types, amphybolite and sheared quartz diorite, comprise approximately 60 percent of the terrane. Next in importance are sheared granodiorite and associated migmatites. Subordinate amounts of pelitic mica schist and greenstone also occur. Numerous apophyses of trondhjemite, as much as several meters thick, occur along the eastern edge of the terrane adjacent to the large trondhjemite pluton (unit Jtr). All of these rocks are lithologically very similar to their correlative map units, and they will not be described here. At two localities, the sheared granodiorite (unit Jgd) was mapped separately to show the proximity of sheared Jurassic granitic rocks to the Late Cretaceous and early Paleocene unsheared tonalite (unit TKt).

NORTHWESTERN TALKEETNA MOUNTAINS AND UPPER CHULITNA RIVER AREA

Sedimentary and volcanic rocks; rocks of each column occur in separate fault blocks.

Central and northern Talkeetna Mountains

ŦR v BASALTIC METAVOLCANIC ROCKS (Upper Triassic)--This shallow water marine unit consists of amygdaloidal metabasalt flows with very subordinate amounts of thin interbeds of metachert, argillite, metavolcaniclastic rocks, and marble (Smith and others, 1975). Rocks of this unit have been mapped only in the northeast portion of the map area. However, small blocks of the basaltic rocks may occur within the complexly deformed late Paleozoic volcanogenic sequence (unit Pzv) toward the southwest. The basaltic rocks rest with angular unconformity on the late Paleozoic volcanics (unit Pzv); the top of the basalts is unexposed. The minimal thickness of the basaltic metavolcanic rocks is 800 m.

The individual metabasalt flows are as much as 10 m thick, and, according to Smith and others (1975), display columnar jointing and locally pillow structures. The typical metabasalt is dark greenish gray, fine grained, and generally contains numerous amygdules. Thin sections show the metabasalts to consist of labrodorite, augite, and opaques in an intergranular or subophitic texture. Secondary minerals are chlorite, epidote, clinozoisite, very subordinate allanite, sericite, and possibly some kaolin. The amygdules consist of chlorite, silica, and zeolites. The present mineralogy is probably the result of deuteric alteration and low-grade regional metamorphism which apparently did not reach the intensity of the greenschist facies of Turner (1968).

From a marble interbed in upper Watana Creek (locality 1, table 3), T. E. Smith (unpub. data, 1974) collected fossil specimens which were identified and interpreted by K. M. Nichols and N. J. Silberling to be *Halobia* cf. *H. symmetrica* Smith, indicating a latest Karnian or early Norian age. Previously, Smith (1974a) and Smith and others (1975) have correlated the basaltic metavolcanic rocks of the present unit with the Amphitheater Group of the central Alaska Range. Accordingly, the fossils collected by T. E. Smith suggest that the Amphitheater Group is younger than, and thus not correlative with the lithologically very similar Nikolai Greenstone of pre-late Karnian age in eastern Alaska (Jones and others, 1977).

Pzv BASALTIC TO ANDESITIC METAVOLCANOGENIC ROCKS (Pennsylvanian(?) and Early Permian)--Rocks of this unit occur in a northeast-trending belt across the center of the Talkeetna Mountains, and they form an interlayered heterogeneous, dominantly marine sequence over 5,000 m thick. The base of the sequence is nowhere exposed, and the contact with the overlying Triassic metabasalts is an angular unconformity. The metavolcanogenic sequence consists dominantly of metamorphosed flows and tuffs of basaltic to andesitic composition, and of coarse- to fine-grained metavolcaniclastic rocks with clasts composed chiefly of mafic volcanic rocks. Mudstone, bioclastic marble (mapped and described separately as unit Pls), and dark-gray to black phyllite are subordinate. The various rock types of the sequence form conformable but lenticular units of limited areal extent. The crudely layered and poorly sorted metavolcaniclastic units have thicknesses in excess of 1,000 m, and the thickness of the phyllites ranges from a few meters to several hundred meters. The whole sequence has been tightly folded and complexly faulted, and the rocks have been regionally metamorphosed into mineral assemblages mostly of the greenschist and the prehnite-pumpellyite facies, but locally along Tsisi Creek of the amphybolite facies of Turner (1968). Detailed petrographic descriptions of these rocks were given by Csejtey (1974).

The age of the metamorphism is uncertain. The most intensive metamorphism in the mapped area probably took place in Early to Middle Jurassic time, contemporaneously with the development of the amphibolite terrane (unit Jam). Subsequent but less severe metamorphism, primarily shearing, occurred probably in middle to Late Cretaceous time during the alpine-type orogenic deformation of the Talkeetna Mountains (see discussions in Structure and Tectonics sections).

The composition and lithologic character of the metavolcanogenic sequence strongly suggest that this sequence is a remnant of a complex volcanic arc system (Csejtey, 1974, 1976). Fossil evidence (see description of unit Pls) from a marble interbed near the top of the sequence indicates an Early Permian age. However, because of the considerable thickness of the sequence, its lowermost portion may be as old as Late Pennsylvanian.

Pls MARBLE (Pennsylvanian(?) and Early Permian)--Forms lenticular interbeds, as much as a few tens of meters thick, within the basaltic to andesitic late Paleozoic metavolcanogenic sequence (unit Pzv). Most of the rock is light gray to white, medium to coarse grained, thick-bedded to massive marble, but some less metamorphosed varieties also occur. Still discernible organic remains and bedding features indicate that the marble interbeds were derived from bioclastic limestone which probably was deposited by high energy currents on shallow banks of limited areal extent. A number of the marble interbeds contain poorly preserved and generically unidentifiable crinoid columnals, brachiopods, bryozoans, and rarely corals (see table 3) of late Paleozoic or probable late Paleozoic ages. However, one of the marble interbeds near the top of the sequence (locality 8, table 3) yielded well-preserved brachiopods and crinoid columnals which were identified and interpreted by J. T. Dutro, Jr. (Csejtey, 1976) to be late Early Permian, that is, late Leonardian to early Guadalupian in age. The regional correlation of these rocks and that of the late Paleozoic metavolcanogenic sequence (unit Pzv) has been previously discussed by Csejtey (1976).

Northern Watana Creek area

Js SEDIMENTARY AND VOLCANIC ROCKS, UNDIVIDED (Upper Jurassic)--These rocks only occur in a small, apparently tectonic sliver along the northern edge of the map area. They comprise a section of intercalated argillite and graywacke, pebble conglomerate, and flows and dikes of andesitic to latitic feldspar porphyry. Some of these rocks are sheared but some, mostly the pebble conglomerates, are not sheared.

The argillite and fine-grained graywacke are thinly to moderately thickly bedded and generally are dark gray. However, dark-greenish-gray varieties also occur, suggesting the presence of volcanic ash or fine-grained tuffaceous material. The conglomerates are massive, and the well-rounded to subrounded pebbles consist chiefly of unmetamorphosed andesite, latite, and subordinate amounts of dacite. A minority of the pebbles are composed of dark-gray argillite and white quartz. The feldspar porphyry is dark gray, with flow alined phenocrysts of zoned andesine and oligoclase as much as 1 cm long, and some hornblende and biotite, in an aphanitic matrix.

An argillite bed at the top of the 5,053-ft hill in the Healy A-2 quadrangle, just north of the present map area, yielded well-preserved fossils of *Buchia rugosa* (Fischer), indicating a Late Jurassic age for these rocks (D. L. Jones, oral commun., 1977). On the basis of lithology and age, the rocks of the present unit are considered to be the westernmost occurrence of the Gravina-Nutzotin terrane of Berg and others (1972).

Northwest Talkeetna Mountains

Kag ARGILLITE AND LITHIC GRAYWACKE (Lower Cretaceous)--These rocks occur in a monotonous, intensely deformed flyschlike turbidite sequence, probably several thousand meters thick, in the northwest part of the mapped area, north of the Talkeetna thrust fault. The whole sequence has been compressed into tight and isoclinal folds and probably has been complexly faulted as well. The rocks are highly indurated, and many are sheared and pervasively cleaved as a result of low-grade dynamometamorphism, the intensity of which is only locally as high as the lowermost portion of the greenschist metamorphic facies of Turner (1968).

Most of the cleavage is probably axial plane cleavage. Neither the base nor the top of the sequence is exposed and, because of the intense deformation, even its minimal thickness is only an estimate.

The argillite is dark gray or black. Commonly it contains small grains of detrital mica as much as 1 mm in diameter. Because of the dynamometamorphism, in large areas the argillite is actually a slate or fine-grained phyllite. Thin sections show that some of the argillites are derived from very fine grained siltstone and that they 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 various 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 the more metamorphosed rocks, biotite and possibly some amphibole.

Analyses of paleocurrent features, such as small-scale cross-stratification, found in several exposures near the western edge of the mapped area, suggest that depositional currents came from the east or northeast (A. T. Ovenshine, oral commun., 1974).

Because fossils are extremely sparse, the exact age of the argillite and lithic graywacke sequence is imperfectly known. A poor specimen of *Inoceramus* sp. of Cretaceous age was found just west of the map area between the Chulitna and Susitna Rivers, and a block of *Buchia*-bearing limestone of Valanginian age was found in float near Caribou Pass in the Healy quadrangle north of the mapped area (D. L. Jones, oral commun., 1978).

Northwestern Talkeetna Mountains

ŦR vs METABASALT AND SLATE (Upper Triassic)--Shallow water marine, interbedded sequence of amygdaloidal metabasalt flows and slate, found only in two allochthonous klippen near the northwest corner of the mapped area. The sequence is tightly folded, along with the underlying Cretaceous rocks (unit Kag), and is slightly metamorphosed and unevenly sheared. The basalt and slate are intercalated in approximately equal proportions in individual units as much as 15 m thick.

The metabasalt is dark greenish gray, aphanitic, with numerous amygdules. In thin sections the primary minerals are twinned labradorite, augite, and opaques which probably are, for the most part, 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 uralite after augite), and possibly some very subordinate albite. The original texture was intersertal and subophitic. The amygdules consist of chlorite, zeolites (primarily prehnite), quartz, and some feldspar.

The slate is dark gray to black. Thin sections show that some of the rock is fine-grained metasiltstone. All of the rocks contain considerable carbonaceous material and some amounts of fine-grained, secondary sericite. Secondary biotite is present in some of the slates.

The secondary mineral assemblages suggest that, in addition to deuteric alteration, the metabasalt and slate sequence underwent very low grade regional metamorphism.

The metabasalt and slate sequence has been dated in the Healy quadrangle, north of the present map area, near the East Fork of the Chulitna River where D. L. Jones and N. J. Silberling (oral commun., 1977) found upper Norian fossils of *Monotis subcircularis* and *Heterostridium* sp. in slightly metamorphosed argillaceous beds. Thus, the age of the present sequence is similar to, and the lithology of its basalt is identical to, that of the Upper Triassic metabasaltic sequence (unit TRv) in the northeast Talkeetna Mountains. These two rock sequences may represent different facies, brought closer by thrusting, of the same geologic terrane.

Upper Chulitna River area

DSga GRAYWACKE, ARGILLITE, AND SHALE (Silurian(?) to Middle Devonian) --These rocks occur in an apparently allochthonous tectonic block along the western side of the Chulitna Valley and comprise a poorly and inaccessibly exposed, complexly deformed and sheared sequence. As a result, the sequence is poorly known; it was briefly examined in outcrop only along Long Creek. There the component rocks are medium to dark gray, sheared and tightly folded with vertical dips, and occur intercalated in beds as much as 1 m thick. The graywackes are fine grained and appear to contain some volcanogenic detritus. Reconnaissance field checking by D. L. Jones (oral commun., 1977) further to the north indicates that the sequence also includes some chert, cherty tuff, and phyllite.

In Long Creek, two fossiliferous limestone beds (mapped and described separately as unit DSls) were found; they probably are in depositional contact with, and thus date, the enveloping unfossiliferous clastic rocks. It is possible, however, that some of the limestone contacts are tectonic and that some of the enveloping rocks are of a different age.

DSls LIMESTONE (Silurian(?) to Middle Devonian)--Massive to thick-bedded, medium-gray, fine-grained, moderately sheared bioclastic limestone, probably formed in patch reefs. It occurs at three separate localities, in apparent depositional interbeds as much as 20 m thick, within fine-grained clastic rocks (unit DSga). Of the two limestone beds in Long Creek, one yielded fossils of Devonian, probably Middle Devonian, age, the other of Silurian or Devonian age (map nos. 12, 13, respectively, table 3). The fossils also indicate shallow marine deposition. The types of fossils and the characteristics of the host limestones and the enveloping clastic rocks suggest deposition along an ancient continental margin. These continental margin-type deposits crop out only about 6 km to the southeast of Upper Devonian ophiolitic rocks (unit Dbs) that are indicative of ocean floor deposition. The proximity of these rocks that are close in age but different in depositional environment is additional evidence for large-scale Alpine-type orogenic deformation in south-central Alaska (Csejtey and others, 1977; Jones and others, 1978).

Upper Chulitna River area

Jta CRYSTAL TUFF, ARGILLITE, CHERT, GRAYWACKE, AND LIMESTONE (Lower to Upper Jurassic)--Shallow to moderately deep marine sequence, tightly folded and internally faulted, at least several thousand meters thick. These rocks are interpreted to occur in a thrust block along the western slope of the upper Chulitna Valley. 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 map 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 radiolaria 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, 1978; fossil locality in Silberling and others, 1978). According to R. W. Imlay (written commun. to D. L. Jones, 1976), these fossils indicate a late Sinemurian age.

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 radiolaria of late Kimmeridgian or early Tithonian age (Late Jurassic), and at five different localities, the limy rocks yielded Early Jurassic ammonite faunas of early Sinemurian age (Jones and others, 1978; fossil localities in Silberling and others, 1978). Probably these Lower and Upper Jurassic rocks originally formed a coherent stratigraphic sequence which subsequently was disrupted by folding and faulting.

Ohio Creek area

Dsb SERPENTINITE, BASALT, CHERT, AND GABBRO (Upper Devonian)--Tectonically intermixed assemblage that forms a northeast-trending belt of apparent thrust slivers in the northwest corner of the mapped area. 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 (1978).

The serpentinite is dark gray to dark greenish gray, always sheared, and consists almost entirely of clinochrysotile 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.

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 radiolaria and conodonts in chert samples from eight separate localities reliably indicate a Late Devonian (Famennian) age for the ophiolitic rocks (Jones and others, 1978; Silberling and others, 1978).

Long Creek area

TRr RED BEDS (probably Upper Triassic)--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 JTRs. Also, a thin conglomerate bed containing angular clasts of rhyolite is locally present at the base. These rocks lie with depositional unconformity on late Paleozoic, possibly Triassic, and older strata in the map area. Just north of the map area, the red beds rest on Lower Triassic limestone (Jones and others, 1978). 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, 1978).

Pzsv VOLCANOGENIC AND SEDIMENTARY ROCKS, UNDIVIDED (Upper Devonian to Lower Permian)--Heterogeneous intercalated sequence of greenish-gray to black tuffaceous chert, lesser amounts of maroon volcanic mudstone, breccia composed largely of basaltic detritus, laminated flyschlike graywacke and shale, and large lenses of light-gray, thick-bedded limestone. Fossils from the thick-bedded limestone are Early Permian in age; brachiopods from the conglomerate are also of Early Permian age; and fossils from the chert are Devonian and Carboniferous, but some poorly preserved fossils may possibly, though not likely, be as young as Triassic (Jones and others, 1978). The stratigraphic and structural relations between these diverse rocks are obscured by abundant folds and poor exposures. A detailed discussion of these rocks is given by Jones and others (1978), and fossil localities are shown in Silberling and others (1978).

Ohio Creek area

JTRs RED AND BROWN SEDIMENTARY ROCKS AND BASALT, UNDIVIDED (Upper Triassic and Lower Jurassic)--The basal part of this 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 massive 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 TR1b that lies unconformably below the red beds and from massive 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 Upper Triassic age, and those from the yellowish-brown limy concretions are of Upper Triassic and Lower Jurassic age.

Detailed discussions of both the red and brown beds are given by Jones and others (1978), and fossil localities are shown in Silberling and others (1978).

TR1b LIMESTONE AND BASALT (Upper Triassic)--Interlayered sequence 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 faulted zone in the northwest corner of the mapped area.

The limestone is medium gray, massive to thick bedded, but locally it has altered to fine- to medium-grained marble.

It contains 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, 1978; fossil localities shown in Silberling and others, 1978).

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 might be the product of very low-grade regional metamorphism. 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.

Upper Copeland Creek area

KJs ARGILLITE, CHERT, SANDSTONE, AND LIMESTONE (Upper Jurassic and Lower Cretaceous)--This 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 Upper Jurassic and Lower Cretaceous radiolarias 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. 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. A more detailed discussion of these rocks is given by Jones and others (1978), and fossil localities are shown in Silberling and others (1978).

Structure

The rocks of the Talkeetna Mountains region have undergone complex and intense thrusting, folding, faulting, shearing, and differential uplifting with associated regional metamorphism and plutonism. At least three major periods of deformation are recognized: a period of intense metamorphism, plutonism, and uplifting in the late Early to Middle Jurassic, the plutonic phase of which persisted into Late Jurassic; a middle to Late Cretaceous alpine-type orogeny, the most intense and important of the three; and a period of normal and high-angle reverse faulting and minor folding in the middle Tertiary, possibly extending into the Quaternary.

Most of the structural features in the Talkeetna Mountains region are the result of the Cretaceous orogeny which produced a pronounced northeast-southwest-trending structural grain of the region. The vergence of this structural grain is steeply to moderately toward the northwest, but across the Chulitna Valley in the northwest part of the map area, it abruptly reverses toward the southeast with steep attitudes. This Cretaceous deformation is most intense in the central and northwestern part of the map area, and it rapidly decreases toward the southeast. The complex fault pattern along and near the southern edge of the Talkeetna Mountains is part of the late Cenozoic Castle Mountain-Caribou fault systems, consisting chiefly of high-angle reverse and normal faults of probably local significance.

Evidence for the Jurassic deformation is provided by the post-Talkeetna Formation major unconformity and the apparently coeval regional metamorphism, up to the amphibolite grade, and associated plutonic rocks (all the Lower to Middle Jurassic metamorphic and plutonic units). The higher crustal level manifestation of this Jurassic tectonic event was regional uplift and consequent rapid denudation of the intruded epizonal plutons.

Complex folding produced by the Cretaceous orogeny is especially pronounced in the areas northwest of the belt of Jurassic metamorphic and plutonic rocks. The folds are chiefly tight or isoclinal, with amplitudes of several hundred to several thousand meters. The limbs are generally sheared out or faulted out. As a result, no individual beds can be traced in the field for more than a few kilometers. Many of the large folds, especially in the Cretaceous argillites and graywackes (unit Kag), have a well-developed axial plane slaty cleavage. Fine-grained sericite and biotite are commonly developed along these cleavages. The folding must have taken place in several episodes during the orogeny because thrust faults not only truncate folds within both the upper and lower plates but are themselves folded. The folded thrusts are especially evident in the Chulitna area where, in contrast to the regional northwest vergence, the axial planes of the folds steeply dip toward the northwest.

Most prominent of the Cretaceous faults is the Talkeetna thrust which has placed Paleozoic, Triassic, and, locally, Jurassic rocks over Cretaceous sedimentary rocks across the whole map area. The thrust is generally poorly exposed except near the Lower Talkeetna River. There it dips steeply toward the southeast. Another thrust, the one delineating the klippe of rocks of unit TRys, has been sharply folded. The thrusts in the northwest corner of the map area are very complex, also have been intensely folded, and are more numerous than could be shown on the present map. A number of them are not fully understood, and thus their subsurface configuration is speculative. It is certain, however, that these thrusts stack and bring together on top of the Kag unit a wide variety of rock sequences of different ages and depositional environment. The root zone of all the thrusts in the northwest half of the map area is herein interpreted to be the Talkeetna thrust (see cross section).

Another Cretaceous feature is an intense shear zone, locally as much as 25 km wide, trending across the Talkeetna Mountains, parallel to, but southeast of the Talkeetna thrust. Although not supported by any evidence, it is possible that the shear zone marks a thrust zone of significant displacement. (The center of this shear zone is shown as a postulated thrust on the map.) The dips in the zone are generally southeasterly. The shearing is penetrative, and its most spectacular result is that portions of all the Jurassic plutonic rocks, including the Upper Jurassic trondhjemite, have been transformed to cataclastic gneiss. The 75 to 61 m.y. old Upper Cretaceous and lower Paleocene tonalite pluton (unit TKt) truncates this shear zone and is not affected by it.

The age of the Cretaceous orogeny, or at least its major phase, is rather well bracketed by stratigraphic evidence. The youngest rocks involved are the Cretaceous argillites and graywackes (unit Kag) which are as young as Valanginian or possibly even younger in age. A maximum upper age bracket is provided by the late Paleocene granitic plutons, which are structurally unaffected, and intrude the already folded and faulted country rocks in the northwest half of the map area. Two of the Cretaceous thrusts, including the Talkeetna thrust, are actually intruded by these plutons. A slightly older upper age bracket is provided by the previously discussed 61 to 75 m.y. old tonalite pluton (unit TKt) that cuts and is unaffected by the prominent shear zone in the central Talkeetnas. Thus, the most important orogenic deformation in the Talkeetna Mountains region must have taken place during middle to Late Cretaceous time. Such an age assignment for the orogeny is further supported by potassium-argon age determinations of 88 and 91 m.y. for the serpentinite protrusions in the southwest corner of the map area (unit Kum).

The dominant features of the middle Tertiary to Quaternary deformation are the already mentioned Castle Mountain-Caribou fault systems, along which the southern Talkeetna Mountains have been uplifted locally as much as 2,800 m (Detterman and others, 1976). The only other features of this Cenozoic deformation recognized within the map area are the two poorly exposed normal faults in the Chulitna River valley (see map and cross section). In addition to field observations, the existence of these faults is also supported by gravity data (R. L. Morin, oral commun., 1977; N. B. Harris, oral commun., 1977). No other Cenozoic faults, or any other faults with obvious Recent movement, were observed within the map area.

Tectonics

The Talkeetna Mountains and adjacent areas are part of the dominantly allochthonous terrane of southern Alaska. Previously, this terrane has been interpreted to have developed by accretion of allochthonous continental blocks to the ancient North American plate (Richter and Jones, 1973; Csejtey, 1974) in late Mesozoic time (Csejtey, 1976; Jones and others, 1978). Although the exact number or even the extent of these allochthonous blocks is still imperfectly known, they appear to have moved northward considerable distances prior to their collision with the North American plate. For one of the blocks in eastern Alaska (Wrangellia of Jones and others, 1977), a probable northward movement of several thousand kilometers has been shown by Hillhouse (1977). The results of the present investigations and those of Jones and others (1978) not only lend credence to the accretionary concept of southern Alaska but also provide additional evidence for the time, method, and direction of emplacement.

One of the keys to the tectonic history of the Talkeetna Mountains region, and to southern Alaska as well, is the occurrence of the tectonically emplaced diverse rock packages in the Chulitna area in the northwest part of the map area. Most of the Triassic and Jurassic rocks there, especially the Triassic red beds, do not occur anywhere else in Alaska, and the fossil faunas and lithologic characteristics of these Mesozoic rocks strongly suggest deposition in warm water at low paleolatitudes (Jones and others, 1978). Furthermore, the pre-middle Cretaceous rocks above the Talkeetna thrust, above the root zone of the Chulitna faults, are either structurally part of the allochthonous Wrangellia terrane of Jones and others (1977) or belong to a different terrane lying south (that is outboard) of Wrangellia. Thus, all available evidence strongly indicates that, with the exception of unit Kag, all pre-middle Cretaceous rocks of the Talkeetna Mountains region are allochthonous, and, after the collision of their parent continental blocks with the middle Cretaceous North American continent, they were thrust upon, that is obducted onto the margin of the continent. In turn, the middle Cretaceous Alaskan margin of the continental North American plate itself probably developed by still earlier accretions (D. L. Jones, oral commun., 1977). The distance the allochthonous rocks of the Talkeetna Mountains region were thrusted beyond the edge of the continent is not known with certainty, but it must be at least several hundred kilometers. In accordance with the present obduction concept, all the tectonic and depositional rock assemblages normally associated with the continental upper plate of a subducting system, especially trench deposits and volcanic arc rocks, are now hidden by the overthrust rock masses. Possibly the small tectonic sliver of Upper Jurassic sedimentary and volcanic rocks (unit Js) along the Talkeetna thrust is the only exposed remnant of these hidden assemblages. As shown on the cross section, the main thrust along which most movement presumably occurred is the Talkeetna thrust, and all other thrusts northwest of it are interpreted to be slivers below it.

The northeast-southwest-trending compressional structural features, that is the folding and thrusting, indicate a general northwestward tectonic transport. This is further supported by the sharp character of the suture zone in eastern Alaska, along which the allochthonous rocks of southern Alaska, especially the Wrangellia terrane, are in contact with the pre-middle Cretaceous North American continent. This suture zone in eastern Alaska trends northwesterly and is devoid of the structural complexities of the Chulitna area. This part of the suture, the part southeast of Paxson, which also coincides with the middle Tertiary to Holocene Denali fault, is thus interpreted to have been a transform or a wrench fault. In contrast, the great variety of tectonically juxtaposed rock packages in the Chulitna area may be the result of "bulldozing" by a large continental block drifting toward the northwest.

The age of this orogenic period of continental collision and subsequent obduction is indicated by the age of its structural features, which are discussed in the Structure section, to be middle to Late Cretaceous.

In summary, southern Alaska is interpreted to have developed geologically by the accretion of an indeterminate number of northwestward drifting continental blocks to the North American continent. After collision, at least parts of these blocks were thrust several hundred kilometers onto the North American continent in middle to Late Cretaceous time. The resulting structural features are truly alpine in character and compare favorably with the classic structures of the Alps in their grandeur and complexity.

A corollary of the present tectonic interpretation of southern Alaska is that the present Denali fault, a middle Tertiary and younger feature (Richter and Jones, 1973), has not played a significant role in the tectonic development of southern Alaska. The eastern, that is strike-slip portion of the Denali fault (Csejtey, 1976), may not have more than a few tens of kilometers of total movement.

An interesting, but still unresolved, tectonic problem in the Talkeetna Mountains region is the shallow depth of the present Benioff zone (Lahr, 1975). The 50-km contour (below sea level) for the upper surface of the Benioff zone strikes northeasterly and is approximately below the Jurassic trondhjemite batholith (unit Jtr). The 100-km contour, also striking northeasterly, is located approximately under the northwest corner of the map area. According to plate tectonic concepts, in conjunction with a subducting system, the top of the undergoing slab should descend at least 100 km below sea level for magma generation. It appears that in the Talkeetna Mountains region there is not enough thickness of upper plate for magma to form. For the Jurassic and older igneous rocks the problem can be explained that these rocks are allochthonous and have been tectonically cut off and transported away from their roots. However, for the Upper Cretaceous and younger igneous rocks, this mechanism cannot be invoked. Two explanations are possible. First, that the present shallow position of the Benioff zone is a relatively recent phenomenon achieved by shearing and cutting away of the base of the upper plate by the downgoing slab. Perhaps the development of the present Denali fault and other middle Tertiary and younger faults of southern Alaska could be related to this process. The other possibility is that all the Upper Cretaceous and younger igneous rocks of the Talkeetna Mountains region were formed in a thin upper plate by exceptionally high heat flow of unknown origin and mechanism (atectonic anatexis by Reed and Lanphere, 1974).

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Table 1.--Potassium-argon age determinations from the Talkeetna Mountains quadrangle and the northern part of the Anchorage quadrangle, Alaska

Map no.	Location Lat. (N)	Location Long. (W)	Field No.	Rock type	Mineral dated	K_2O* (weight percent)	$^{40}Ar_{rad}$ $\left(10^{-10}\ \frac{mole}{gram}\right)$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Calculated age*** (millions of years)	Reference
1.	62°59'30"	149°23'48"	75ACy92	Granite (adamellite)	Biotite	7.54(2)	6.218	0.49	57.8±1.7	This report
2.	62°57'25"	148°48'18"	75ACy146	Granodiorite	Biotite	9.08(2)	7.583	0.89	58.6±1.8	This report
3.	62°58'28"	148°25'50"	TT-1-72	Grandiorite	Biotite	--	--	--	58.7±1.7	Turner and Smith (1974)
4.	62°45'46"	149°56'20"	75ACy2	Granite (adamellite)	Biotite	8.68(2)	6.970	0.78	56.3±1.7	This report
5.	62°45'36"	147°10'30"	72ASt290	Diorite or amphibolite	Hornblende	--	--	--	176.6±5.1	Turner and Smith (1974)
6.	62°37'30"	149°24'34"	75ACy7	Granite (adamellite)	Biotite	5.35 (2)	4.468	0.60	58.6±1.8	This report
7.	62°28'38"	149°29'30"	75ASj520	Andesite	Hornblende	0.555(2)	0.4077	0.56	50.4±2.0	This report
8.	62°35'24"	148°53'40"	75ASj521B	Andesite	Whole rock	2.348±0.045(4)	1.757	0.34	51.3±2.5	This report
9.	62°27'28"	148°18'34"	73ACy109	Quartz diorite	Biotite	8.68(2)	18.79	0.92	144±4.3	This report
					Hornblende	0.590(2)	1.365	0.63	154±4.6	This report
10.	62°30'43"	147°52'35"	73ASt275	Trondhjemite	Biotite	--	--	--	148.5±4.3	Turner and Smith (1974)
11.	62°34'55"	147°41'55"	73ASt256	Trondhjemite	Biotite	--	--	--	146.5±4.3	Turner and Smith (1974)
12.	62°18'42"	149°46'32"	73ACy101	Tonalite	Biotite	8.48(2)	6.783	0.83	54.8±1.6	This report
13.	62°16'51"	148°43'26"	75ASj526	Andesite	Whole Rock	0.843(2)	0.6942	0.31	56.3±2.5	This report
14.	62°19'03"	148°10'09"	62AE4	Trondhjemite	Biotite	6.21(2)	13.33	0.91	143±4.3	This report
					Muscovite	9.77(2)	21.49	0.92	146±4.4	This report
15.	62°21'22"	147°49'18"	59AGrM58	Granodiorite	Biotite	--	--	--	174	Grantz and others (1963)
					Hornblende	--	--	--	167±6.0	Detterman and others (1965)

See footnotes at end of table

Table 1.--Continued

Map no.	Location Lat. (N)	Location Long. (W)	Field No.	Rock type	Mineral dated	K_2O* (weight percent)	$^{40}Ar_{rad}$ $\left(10^{-10}\frac{moles}{gram}\right)$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Calculated ages*** (millions of years)	Reference
17.	62°12'50"	148°06'35"	59AGzH26	Quartz diorite	Biotite	--	—	—	173	Everaden and others (1961)
					Biotite	--	—	—	170±6	Detterman and others (1965)
					Biotite	--	—	—	161	Grantz and others (1963)
					Hornblende	--	—	—	163±6	Detterman and others (1965)
18.	62°09'00"	149°13'30"	72ACy117	Quartz diorite	Biotite	9.33	9.207	0.79	67.3±2	Csejtey, 1974
					Hornblende	1.042(2)	9.869	0.77	64.6±2	Csejtey, 1974
19.	62°08'46"	149°18'30"	72ACy127	Tonalite	Biotite	9.30	9.055	0.87	66.4±2	Csejtey, 1974
					Hornblende	0.782(2)	0.7371	0.78	64.3±2	Csejtey, 1974
20.	62°06'27"	148°59'44"	73ACy95	Granodiorite	Biotite	9.64(2)	8.705	0.94	61.7±1.9	This report
					Hornblende	1.024(2)	1.071	0.88	71.3±2.1	This report
21.	62°04'51"	148°45'58"	73ACy114	Trondhjemite	Biotite	9.70(2)	9.643	0.88	67.8±2.0	This report
22.	62°04'49"	148°30'29"	73ACy115	Trondhjemite	Muscovite	9.91(2)	19.98	0.93	135±4.0	This report
					Biotite	9.62(2)	14.16	0.97	99.4±3.0	This report
23.	62°04'38"	149°11'14"	73ACy94	Tonalite	Biotite	9.46(2)	8.593	0.81	61.7±1.9	This report
					Hornblende	0.970(2)	0.8669	0.71	61.0±1.8	This report
24.	61°59'18"	149°25'00"	75ACy135	Granodiorite	Muscovite	10.64(2)	10.21	0.72	67.2±2.0	This report
					Biotite	9.68(2)	9.025	0.67	65.0±2.0	This report
25.	61°56'31"	148°59'38"	73ACy97	Quartz diorite	Biotite	8.70(2)	8.594	0.83	67.4±2.0	This report
					Hornblende	0.918(2)	0.9669	0.72	71.8±2.2	This report
26.	61°56'47"	148°41'04"	74ACy146	Trondhjemite	Muscovite	3.46(2)	6.680	0.69	129±3.9	This report
27.	61°59'33"	148°26'15"	74ACy149	Granodiorite	Biotite	8.06(2)	20.44	0.89	168±5.0	This report
28.	61°49'36"	149°14'30"	60AGz40	Tonalite	Hornblende	0.759(2)	0.8153	0.74	73.1±2.2	This report

See footnotes at end of table

Table 1.--Continued

Map no.	Location Lat. (N)	Location Long. (W)	Field no.	Rock type	Mineral dated	K_2O* (weight percent)	$^{40}Ar_{rad}$ $\left(10^{-10}\frac{moles}{gram}\right)$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Calculated ages*** (millions of years)	Reference
29.	61°48'48"	149°12'48"	66AGsW2	Tonalite	Biotite	8.61(2)	8.711	0.89	69.0±2.1	This report
					Hornblende	0.880(2)	0.9475	0.86	73.3±?2.2	This report
30.	61°47'12"	149°13'06"	66AGsW4	Tonalite	Biotite	7.22(2)	7.624	0.91	72.0±2.2	This report
					Hornblende	0.492±0.003(3)	0.5374	0.41	74.4±2.2	This report
31.	61°49'38"	148°53'30"	74ACy151	Trondhjemite	Muscovite	10.58(2)	21.23	0.95	134±4.0	This report
32	61°45'03"	149°25'08"	73ACy17	Serpentinite	Actinolite	0.032**	0.04194	0.064	88.9±4.4	This report
33.	61°43'00"	149°32'30"	73ACy85	Muscovite schist	Muscovite	8.34(2)	7.189	0.85	59.0±1.8	This report
34.	61°43'50"	149°26'05"	73ACy27	Muscovite schist	Muscovite	8.86(2)	8.554	0.89	65.9±3.0	This report
35.	61°44'32"	149°25'28"	73ACy11a	Muscovite schist	Muscovite	9.10(2)	7.928	0.84	59.6±1.8	This report
36.	61°44'03"	149°23'37"	74ASj100a	Serpentinite	Actinolite	0.029**	0.03897	0.10	91.0±4.6	This report
37.	61°46'20"	149°10'20"	76ACy19	Metamorphosed graywacke	Biotite	1.078(2)	1.067	0.45	67.5±2.4	This report

*Mean and, where more than two measurements were made, standard deviation. Number of measurements is in parentheses.
**Potassium determined by isotope dilution. Potassium determined by flame photometry for other samples.
***$\lambda_e = 0.572X10^{-10}yr^{-1}$, $\lambda_e' = 8.78X10^{-13}yr^{-1}$, $\lambda\beta = 4.963X10^{-10}yr^{-1}$. $^{40}K/K = 1.167X10^{-4}$ mol/mol. The ± figures are estimates of analytical precision at the 68 percent level of confidence. All previously published ages were recalculated using these decay constants. For this report, potassium analyses were done by L. B. Schlocker, G. E. Ambats, J. G. Smith, H. C. Whitehead, S. T. Neil, and M. L. Silberman; and argon measurements were done by M. A. Lanphere, J. C. von Essen, A. L. Berry, B. M. Myers, S. B. Sims, J. G. Smith, and M. L. Silberman.

Table 2.--*Lead-alpha age determinations on zircon from southeastern part of Talkeetna Mountains quadrangle, Alaska*

Map no.	Location		Field no.	Rock type	Apparent age (m.y.)	References
	Lat. (N)	Long. (W)				
15	62°21'22"	147°49'18"	59AGzM58	Granodiorite	165±20	Grantz and others (1973)
16	62°21'17"	147°49'12"	59AGzM57	Granodiorite	125±15	Grantz and others (1973)

Table 3.--List of fossils from selected map units (units TRv, Pls, and DSls) in the northwest half of the Talkeetna Mountains quadrangle and the southwest corner of the Healy quadrangle, Alaska

Map number and map unit	Field number	Fossils	Age	Identification and age determination	Reference
1 TRv	73ASt-63	*Halobia* cf. *H. symmetrica* Smith	Latest Karnian or Early Norian	K. M. Nichols and N. J. Silberling	T. E. Smith, written commun., 1974.
2 Pls	76ACy-47	Crinoid columnals 2 cm in diameter; echinoderm and brachiopod debris, indet.	Late Paleozoic	D. L. Jones	This report.
3 Pls	73ASt-1400	Echinoderm debris, indet. Platycrinitid, indet. (partial cup and columnals). Horn coral, indet. Fenestrate and ramose bryozoans, indet. (abundant). *Sulcoretepora*? sp. Rhynchonelloid brachiopod, indet. Productoid brachiopod (large, indeterminate). Spiriferoid brachiopod (perhaps *Spiriferella*). Martinioid brachiopod (perhaps *Pseudomartinia*). Phricodothyrid brachiopod fragments, indet. Punctate brachiopod (perhaps *Hustedia*). Pelecypods, indet. (several kinds). Pectenoid pelecypods, indet.	Late Paleozoic, probably Permian	J. T. Dutro, Jr.	T. E. Smith, written commun., 1974.
4 Pls	72ACy-15, 72ACy-21	Crinoid columnals as much as 1.6 cm in diameter. Bryozoan, indet. Brachiopod and coral fragments.	Probably late Paleozoic	A. K. Armstrong	Csejtey, 1974.
5 Pls	73ASt-309	Echinoderm debris, indet. Fenestrate and ramose bryozoans, indet. Horn coral, indet. Productoid brachiopod (indeterminate).	Late Paleozoic, possibly Permian	J. T. Dutro, Jr.	T. E. Smith, written commun., 1974.
6 Pls	74ACy-7	Crinoid columnals 1 cm in diameter.	Probably Paleozoic	A. K. Armstrong	This report.
7 Pls	75ANw-10	*Horridonia*? sp. Spiriferoid brachiopod. Crinoid columnals as much as 1.5 cm in diameter.	Late Paleozoic, probably Permian	A. K. Armstrong	-----Do.----
8 Pls	74ACy-16	*Arctitreta* sp. *Horridonia* sp. *Spiriferella* sp. Echinoderm debris, indet. Crinoid columnals as much as 2.5 cm in diameter.	Early Permian	J. T. Dutro, Jr.	Csejtey, 1976.
9 Pls	74ACy-80	Crinoid columnals as much as 1.5 cm in diameter.	Probably Paleozoic	A. K. Armstrong	This report.
10 Pls	74ACy-21	Crinoid columnals as much as 1 cm in diameter.	------do-------	-------do------	-----Do.----
11 Pls	74ACy-43	------------------do----------------	------do-------	-------do------	-----Do.----
12 DSls	75ANw-75	*Dendrostella*? sp. Massive stromatoporoid, indet.	Devonian, probably Middle Devonian	W. A. Oliver, Jr.	-----Do.----
13 DSls	75ANw-76	*Labechia* sp. *Favosites* sp.	Silurian or Devonian	-------do--------	-----Do.----