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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TO ACCOMPANY MAP I-1174

# GEOLOGIC MAP OF THE TALKEETNA QUADRANGLE, ALASKA

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## DESCRIPTION OF MAP UNITS

### SURFICIAL DEPOSITS

#### ALLUVIAL AND MASS-WASTING DEPOSITS

Ql — Young and old landslide deposits.—Chiefly debris avalanches and large block glides in areas of steep slopes. Particularly well exposed along headwaters of Dillinger and West Fork of Yentna Rivers

Qau — Alluvium, undivided.—Includes alluvium on active flood plains, older alluvium on terraces of major streams, alluvial fans, outwash from both Alaskan and Wisconsin Glaciations, swamp, marsh, and bog deposits along the larger streams in the southeast part of quadrangle, and alluvial deposits on broad pediment surfaces. It locally includes colluvium and other deposits on valley walls and hill slopes. The unit is chiefly boulders, gravel, and sand with local areas of silt and clay

Qr — Active and recently active rock glaciers and associated talus aprons.—Chiefly rubble and diamicton; only larger rock glaciers shown

#### GLACIAL DEPOSITS

Qa — Drift of the Alaskan Glaciation.—Includes end and lateral moraines left after recession of existing glaciers (Tunnel and Tustumena Stades); chiefly rubble and diamicton and locally covered by vegetation; only larger deposits shown

Qn — Drift of the Naptowne Glaciation.—Includes end, lateral, and ground moraine, postglacial alluvial, pond, and swamp deposits, fluvial-glacial deposits of all stages of Naptowne Glaciation, and glaciolacustrine deposits formed during Knik and Naptowne Glaciations. At higher elevations, deposits merge with and are covered by colluvium and locally contain drift of the Alaskan Glaciation

Qk — Drift of the Knik Glaciation.—Well-developed end and lateral moraines shown only in northwest part of quadrangle. Possible drift of this glaciation on south side of Alaska Range is included with Naptowne and Eklutna deposits

Qe — Drift of the Eklutna Glaciation (Illinoian).—South of Alaska Range, lateral and ground moraine have subdued geomorphic expression and include alluvial, swamp, marsh, and bog deposits. North of the Alaska Range, end and lateral moraines are relatively fresh and include well-preserved pot-and-kettle topography

Qpe — Drift of pre-Eklutna age.—Recognized only as subdued lateral(?) and ground moraines on north side of Alaska Range, although glacial erratics and well-modified drift on top of Yenlo Hills (T. 24 N., R. 11 W.) are probably deposits of this extensive glaciation in the Cook Inlet region (Karlstrom, 1964)

### NORTH OF DENALI FAULT

#### Sedimentary and volcanic rocks

Tc — COAL-BEARING ROCKS.—A cumulative thickness of about 30 m of subbituminous coal, with individual beds up to 9 m thick, crops out on the west bank of the Little Tonzona River (T. 31 N., R. 20 W.). The coal-bearing rocks, which contain interbeds of ferruginous siltstone and silty shale, dip about 55° to the north. The contact with unit Pzsl is covered but in this area is probably a fault. These rocks are tentatively correlated to the east with the coal-bearing group (Oligocene and Miocene) in the Nenana coal field (Wahrhaftig and others, 1969) and to the west with a sequence of middle or late Oligocene conglomerate, sandstone, and shale (Reed and Elliott, 1968)

Ts — CONTINENTAL SEDIMENTARY ROCKS.—Chiefly medium- to dark-gray phyllitic shale, shale, sandstone, grit, and conglomerate with minor carbonaceous shale and tuffaceous sandstone. Shales are lithologically similar to dark-gray shale in unit KJs, but close examination generally reveals a few *Metasequoia* fragments and carbonaceous debris. Light- to medium-brown and maroon, fine- to coarse-grained sandstone beds 1-3 m thick typically are gradational into and interbedded with conglomerate and, in many places, contain fragments of large broadleaf plant fossils. Resistant conglomerate beds generally form lenslike units from 2 to more than 200 m thick; clasts range in size from 0.5 to 20 cm, are moderately well rounded, and consist chiefly of white quartz. Clasts of quartzite, quartz semischist, and varicolored phyllite and chert suggest derivation from Pzsv and KJs terrane. Crossbedding and channel scour features are locally well developed. Lack of granitic clasts in Ts indicates that Tonzona pluton (55 m.y.) was either not emplaced or not unroofed during deposition. Poorly preserved plant fossils are best compared to species indicative of a Paleocene age (J. A. Wolfe, written commun., 1977). The unit is believed to be an extensive continental sequence deposited during the Late Cretaceous and early Tertiary that now is preserved in fault slivers chiefly along Denali fault zone. It is correlated with the Cantwell Formation (Paleocene) as restricted by Gilbert and others (1976, p. 1). Tuffaceous sandstone may reflect distal portions of the Teklanika Formation of Gilbert and others (1976) and the onset of early Tertiary plutonism in this part of the Alaska Range. (Reed and Lanphere, 1973a)

KJb PILLOW BASALT.—Dark-greenish-gray elongate bodies of massive-weathering, resistant pillow basalt. The unit includes interbeds and lenses of mudstone, shale, and siltstone. Irregular patches and lenses of light-gray-weathering sparry calcite and reddish jasperoid breccia fillings are sporadically developed. The basalt locally includes gabbro which may represent its feeder source. Pillows range in size from 15 cm to 2 m in maximum dimension, are generally porphyritic, and contain phenocrysts of altered plagioclase, subordinate clinopyroxene, and rare olivine in an intergranular to intersertal groundmass of plagioclase and pyroxene. Groundmass plagioclase occasionally displays swallowtail and belt-buckle crystal shapes. Rare amygdules consist of quartz, calcite, chlorite, and epidote. Chemically, the rocks range from hypersthene-olivine normative to hypersthene-quartz normative tholeiitic basalt. Trace element analyses indicate that the basalts can be classified as ocean-floor basalt (Pearce and Cann, 1973). The copper content of nine samples of pillow basalt ranges from 200 to 500 ppm and averages about 280 ppm. West of Pingston Creek, the flows generally face north, have a steep to subvertical dip, are at least 1300 m thick, and are thought to have considerable vertical extent. In T. 32 N., R. 15 W. the pillow basalt appears to overlie unit KJs and has an apparent thickness of about 750 m. Tops and bottoms of flows are locally brecciated; columnar joints are also present. Although the basalt is shown as having a normal contact with unit KJs, nowhere within the quadrangle is the nature of the contact between these two units precisely known. Owing to the extreme difference in competence between the two units and to their proximity to the Denali fault zone, the contact is sheared. The basalt is, however, inferred to be part of a sequence which includes unit KJs and to represent local extrusion within a marine basin. It is discontinuously exposed northeast to Straightaway Glacier and southwest to Farewell. Pillow basalts south of the Denali fault (Pzbs) have a similar major oxide content but occur within a Paleozoic terrane

KJs UNDIVIDED MARINE SEDIMENTARY ROCKS.—Moderate- to deep-water, intertonguing marine sedimentary rocks consisting chiefly of gray to black phyllite, argillite, graywacke, and siltstone which are, in part, turbidite deposits; lesser amounts of gray, green, and red chert, conglomerate, grit, and thin beds of limy mudstone and impure limestone. The conglomerate contains clasts of medium- to dark-gray chert, phyllite, and sandstone in a fine-grained sheared graywacke matrix. Clasts range in size from 6 to 25 mm. Fossils are extremely rare, but a few fragments of belemnites, *Buchia*, and occasional *Inoceramus* shell fragments (T. 30 N., R. 19 W.) are Valanginian to Barremian (Early Cretaceous) in age (D. L. Jones, written commun., 1976). Fossils of Jurassic age have not been found; thus, the Jurassic age of its lower part is uncertain. The unit is in fault contact with units Pzsv, Pzsl, and Ts. Where observed, the contact with KJb is sheared, although bedding attitudes and pillow flows appear conformable. The thickness of the unit is unknown but is probably more than 1500 m. Rare groove casts suggest a source either to the north or south. These sedimentary rocks are intruded by units Tmt and TKi. Thermal metamorphism has produced andalusite hornfels adjacent to larger intrusive bodies. Sparse fossils indicate that this unit is, at least in part, a time equivalent of unit KJs south of the Denali fault. Lithologies of the two units are broadly similar, but unit KJs south of the fault contains significantly more sandstone, occasional plant fragments, and sedimentary structures that suggest local shallow-water deposition. Unit KJs north of the Denali fault contains more chert and shale and represents deeper marine deposition. Northeast of T. 32 N., R. 14 W. the unit is chiefly dark-gray phyllitic shale and argillaceous siltstone and is lithologically similar to dark-gray phyllite (Pzp)

Pzsl SHALE AND LIMESTONE.—Marine sedimentary rocks that typically form a thin- to medium-interbedded sequence of black, sooty, carbonaceous, and calcareous shale, dark-gray calcareous siltstone, medium- to dark-gray limestone, and minor gray quartzite. Shale locally amounts to as much as 70 percent of the unit, is generally calcareous, and contains thin laminae of dark-gray siltstone. Semiquantitative spectrographic analyses of eight samples of black shale from the northwestern part of the quadrangle show the following average metal contents (ppm): Ag=10, Cu=111, Cr=194, Mo=24, Ni=115, Pb=29, eU (equivalent uranium) =29, V=344, Zn=688. Limestone is chiefly micrite and contains varying amounts of subangular grains of quartz. Some beds emit a fetid odor when freshly broken. Siltstone and quartzite are notably different from quartzite in Pzsv in that they have calcite matrix, lack a semischistose fabric, contain rare plagioclase grains, and quartz grains lack fluid inclusions. The unit contains numerous dikes and sills of altered gabbro (MzPzg). Contact metamorphism is generally restricted to within a few meters of the dikes and sills, although where intrusive rocks are abundant, as for example, east of Pingston Creek, tan phyllite and dark argillite are common. The unit is well exposed along the northernmost foothills of the Alaska Range, especially on Pingston Creek, where rocks form tight isoclinal folds (although cleavage is not developed); abundant milky-white quartz veinlets are restricted to siltstone and calcareous quartzite; limestone (in beds as much as 2 m thick) becomes more abundant to the south. It is believed to be allochthonous on unit Pzsv. In most places the trace of the thrust has subsequently been refaulted to high-angle faults; however, a low-dipping thrust fault is moderately well documented east of Pingston Creek (T. 31 N., R. 19 W.). This unit has been traced northeast as far as the Foraker Glacier and discontinuously to the west as far as the Windy Fork area (McGrath quadrangle). It is tentatively correlated to the northwest with the lower part of the Totatlanika Schist in the Kantishna Hills (Bundtzen and others, 1975), which consists, in part, of graphitic slate and schist and impure marble which, at Kantishna, are in fault contact with Birch Creek terrane.

Pzsv QUARTZITE, SEMISCHIST, AND METAVOLCANIC ROCKS.—Tan to light-greenish-gray, low-grade (greenschist facies), regionally metamorphosed quartzite, quartz semischist, quartz grit, metavolcanic rocks, and minor conglomerate, limestone, phyllite, and quartz-muscovite schist. The unit is isoclinally folded and there is evidence of multiple folding. Moderate to well-developed schistosity is common. Schistosity and metamorphic grade increase to northeast. The base is not exposed; the unit is in fault contact with younger sedimentary rocks. Quartz-rich beds, which are more prevalent to the west, consist chiefly of thin- to medium-bedded, poorly sorted quartz wacke, quartz semischist, quartzite, and minor conglomerate. Quartz grains are angular to rounded and consist of plutonic(?), vein, and metamorphic quartz in a matrix of quartz, muscovite, and minor chlorite. Feldspar grains are noticeably absent. Tourmaline and zircon are the predominant accessory minerals. Malachite has developed on schistosity planes east of Chedotlothna Glacier. East of Pingston Creek secondary copper staining and rare lenses (2-7 cm thick) of chalcocite are noted. Quartz-muscovite schist and chlorite schist are locally present between Boulder Creek and South Fork Kuskokwim River. Talc schist is developed near MzPzu serpentinite. Conglomerate consists of gray subrounded quartz and sporadic dark siltstone clasts that range in size from 0.5 to 15 cm. Metavolcanic rocks are chiefly light-green metatuff. Small (<0.5 to 5 mm) lenticular masses of chlorite, calcite, epidote, and quartz suggest collapsed pumice fragments or filled vesicles. Euhedral phenocrysts of plagioclase, quartz, and altered mafic minerals are locally present. Metavolcanic rocks are noticeably more abundant east of the Tonzona River where they are interbedded with quartzite and phyllite. Limestone occurs as gray, medium- to massive-bedded lenticular units as much as 30 m thick in quartzite and phyllite. Skarn is developed adjacent to Tonzona pluton. Tan, light-greenish-gray, and maroon phyllite is interbedded with quartzite west of Tonzona River. East of Tonzona River phyllites are chiefly gray to dark gray and interbedded with metavolcanic rocks. Andalusite is present in phyllites adjacent to unit Tmt. The unit is inferred to correlate with so-called Birch Creek Schist in the Kantishna Hills (Bundtzen and others, 1975), but rocks of equivalent age in the Alaska Range west of the quadrangle are not presently known. The unit is considered to be lower Paleozoic or possibly upper Precambrian

**Intrusive and ultramafic rocks**

Tmt TONZONA PLUTON.—A small composite biotite-muscovite granite pluton of the McKinley sequence (see below), which crops out north of the Denali fault (T. 32 N., R. 15 W.). Includes petrographically and chemically similar rocks near Sheep Mountain (T. 31 N., R. 17 W.) that may represent a cupola of underlying granitic rocks. Three textural facies are recognized: (1) coarse-grained, locally porphyritic biotite granite, (2) medium-grained biotite granite, and (3) a late fine-grained, leucocratic, locally aplitic, muscovite-tourmaline granite in which ovoid clusters of small black tourmaline crystals give the rock a "dalmatian" appearance. The granite is classified as a tin granite; muscovite may exceed biotite in abundance; accessory minerals include tourmaline with lesser amounts of topaz, fluorite, garnet, zircon, and apatite. Late-stage greissen veinlets contain muscovite, topaz, tourmaline, locally abundant beryl, and, occasionally, cassiterite. Fractures are healed with black tourmaline. Small, apparently late, clots of beryl, topaz, muscovite, and quartz are present in granite boulders. Modal analysis given in figure 1. Lead, silver, and tin mineralization occurs in unit Pzsv along north and northeast contact

TKi UNDIVIDED INTRUSIVE ROCKS.—Intermediate altered porphyry dikes in unit KJs; most are too small to show at scale of map

MzPzg GABBRO AND QUARTZ DIORITE.—Dark-green rust-weathering coarse-grained altered gabbro and minor quartz diorite; restricted to unit Pzsl. Age unknown. Gabbro is hypidiomorphic granular to porphyritic, in places subophitic, and consists chiefly of clinopyroxene and altered plagioclase. Minor skeletal ilmenite, myrmekitic quartz, and secondary chlorite, biotite, and amphibole are also present. Plagioclase is altered to clouded masses of sericite and kaolinite(?), ilmenite partially altered to leucoxene, clinopyroxene partially altered to chlorite, green amphibole, and biotite. Average copper content of six samples is 350 ppm. These intrusive rocks are chemically equivalent to gabbro, notable differences being that they contain more $H_2O^+$ and FeO and less MgO and $Al_2O_3$

MzPzu SERPENTINITE.—Orange- to light-brown-weathering, light- to dark-green, fault-bounded body of serpentinite and minor talc schist (T. 32 N., R. 15 W.); cut by Tonzona pluton. Patches of very fine grained bladed antigorite, commonly with a core zone of serpentine minerals pseudomorphic after pyroxene(?), occur in a polygonal mosaic of coarser antigorite. Antigorite polygons are rimmed by opaque minerals. Irregular patches and veins of calcite are present; chrysotile is rare. An irregular surface texture produced by differential weathering suggests that the original rock was a peridotite containing both olivine and pyroxene. The serpentinite is chemically equivalent (calculated water free) to pyroxene peridotite. Chrome and nickel contents average 2000 ppm each; float samples of serpentinite contain pyrite, chalcopyrite, and pentlandite(?)

## SOUTH OF DENALI FAULT

**Sedimentary and volcanic rocks**

Tk KENAI GROUP, UNDIVIDED.—Fluvial sedimentary rocks correlative with estuarine and nonmarine clastic sedimentary Tertiary formations assigned to the Kenai Group in the Cook Inlet basin by Calderwood and Fackler (1972). Exposures of the Kenai Group in the Talkeetna quadrangle are limited to gently to moderately southeast-dipping beds along the foothills of the Alaska Range, shallow-dipping beds along stream cutbanks in the lowlands to the southeast, and a small outcrop of subbituminous coal in T. 31 N., R. 6 W. The group is locally divided into the Sterling(?) Formation and the Tyonek(?) Formation. The Sterling(?) unconformably overlies the Tyonek(?), and the Tyonek(?) Formation rests with angular unconformity on Mesozoic rocks

Tps STERLING(?) FORMATION (Pliocene).—Orange, light-tan, or light-gray, massive-bedded conglomerate, distinguished from conglomerate in the Tyonek(?) by its color, relative coarseness, and clast lithology. Clasts are well rounded and equant and average 5-10 cm in diameter, although clasts to 30 cm in diameter are not uncommon. The conglomerate is poorly to moderately well indurated with a clayey and, locally, ferruginous matrix. Clasts consist of the same lithologies but occur in proportions different from those of the conglomerate member of the Tyonek(?) Formation, which occurs at the same locality. Coal fragments southwest of the Yentna River (T. 25 N., R. 14 W.) suggest that the Sterling(?) is at least partly derived from the Tyonek(?) Formation. Crossbed sets in orange and tan sandstone lenses in conglomerate (T. 27 N., R. 13 W.) suggest that current directions were to the east or southeast. Bedding is approximately conformable on the Tyonek(?) Formation where the contact can be observed, but the apparent thinning of the Tyonek(?) to the northwest, culminating in overlap of the Sterling(?) directly onto basement in the foothills, and inclusion of probably Tyonek(?) coal fragments in the Sterling(?) suggest that its basal contact is an angular unconformity along the mountain front. Maximum thickness at Fairview Mountain is 770 m, but the thickness may be greater beneath the lowlands

TYONEK(?) FORMATION (Miocene).—Divided into two members:

Tts Sandstone member.—Approximately 80 percent sandstone, 20 percent siltstone and claystone, and less than 1 percent conglomerate, coal, and volcanic ash. The member occurs in repetitive cycles 7-23 m thick that grade upward from conglomerate or coarse sandstone to finer grained sandstone, to interbedded silt and clay with coal or bony coal. Conglomerate occurs in beds as much as 5 m thick; clasts have an average size of 2-6 cm and a maximum size of 10 cm. Sandstone is tan or light gray, coarse to medium grained, poorly indurated, and consists of about 75-85 percent chert and quartz grains, 10-20 percent feldspar, and about 5 percent mafic grains which include biotite, hornblende, clinozoisite, and chlorite. Sandstone beds are as much as 60 m thick, although the thicker ones were probably not deposited as a single unit. Interbedded claystone and siltstone occur in units as much as 15 m thick. Siltstone and claystone are light to medium gray and contain rootlets and coaly partings. Coal or bone, if present, is found in these units above clay beds. Coal, in beds as much as 3 m thick with an average thickness of less than 1 m, is platy or papery, soft, and in many places contains shaly or bony partings. Volcanic ash layers (1-30 cm thick) in coal beds are composed of partially devitrified glass shards altered to illite(?) and less than 0.5 percent biotite. Rootlets and other plant materials also are present in the ash. The sandstone member interfingers with or conformably overlies the conglomerate member. About 170 m of the unit crops out in the foothills, but the thickness is probably greater in the lowlands to the south

Ttc Conglomerate member.—At Fairview Mountain (T. 26 N., R. 12 W.), the member comprises at least 40 percent conglomerate, 20 percent sandstone, and less than 40 percent siltstone, claystone, and coal). Conglomerate is light brown, light gray, or bluish gray and poorly indurated. It occurs as massive beds as much as 25 m thick. Clasts are smooth and well rounded and average 5 to 10 cm in diameter, with maximum size about 15 cm. The greatest number of chert and quartz clasts is found at Nakochna River; fewer are found to the northeast. Igneous clasts reach a maximum abundance at Fairview Mountain. The proportion of shale and graywacke clasts steadily increases from Nakochna River to more than 90 percent at Ruth Glacier. Sandstone is coarse, poorly sorted and pebbly, and very poorly indurated. Siltstone, claystone, and coal occur as interbedded units that grade upward from sandy siltstone to silty claystone to coal. Coal beds range in thickness from 0.5 to 17 m but average 0.6-3 m thick. Coal is subbituminous, dull, black or brownish black, and contains clay or bone partings. One bed near the Nakochna River (sec. 7, T. 24 N., R. 15 W.) is partially burned

Tvs UNDIVIDED VOLCANIC AND SEDIMENTARY ROCKS.—Interbedded tuffs, mafic volcanic flows, sandstone, shale, and minor calcareous mudstone. Volcanic rocks are chiefly medium- to coarse-grained greenish-gray crystal lithic lapilli tuffs and volcanic rubble flows in units as much as 150 m thick. Tuffs are composed of broken euhedral crystals of plagioclase with oscillatory zonation, serpentinized olivine, quartz, and lapilli-size fragments of crystal tuff in a brownish, slightly devitrified matrix. Lapilli fragments contain altered plagioclase, amphibole, and minor biotite. Tuffs are locally pyritized; eU content of four samples averages 25 ppm; minor uranium prospecting was done in 1954 and in 1976. Interbedded with tuff is well-sorted lithic sandstone composed of angular clasts of dark chert, metamorphic rock, and rare volcanic rocks, and angular grains of quartz and plagioclase, with minor amounts of muscovite; calcite and chlorite form the interstitial cement. Shale and siltstone contain fragmentary plant remains. The source area for volcanic rocks is believed to be Round Mountain, 10 km to the northwest (T. 23 N., R. 19 W.). The volcanism is probably related to early or middle Tertiary plutonism in this part of the Alaska Range (Reed and Lanphere, 1973a)

KJs UNDIVIDED MARINE SEDIMENTARY ROCKS.—Medium- to dark-gray, generally isoclinally folded, thick sequence of lithic graywacke, phyllite, and shale with local lenses of quartz-chert conglomerate. The unit includes minor fossiliferous limestone, radiolarian chert, and red ferruginous sandstone and siltstone. Lithic graywacke is thin to massive bedded and locally shows graded bedding, ripple marks, crossbedding, and pull-apart structures. Graywacke is poorly to moderately well sorted and consists of angular to subangular, fine to coarse sand-size detritus, of which quartz and lithic fragments comprise about 50 percent. Lithic fragments are fine-grained recrystallized quartzite or metachert with lesser amounts of dark siltstone or argillite, muscovite schist, and fine-grained volcanic rocks (including porphyry). Plagioclase, potassium feldspar, and detrital muscovite are subordinate. Common, although not abundant, heavy minerals include zircon and tourmaline. Graywacke from the Yenlo Hills (T. 23 and 24 N., R. 11 W.) is significantly different in that the grains are extremely angular, and oscillatory zoned plagioclase, volcanic rock fragments, hornblende, epidote, and calcite grains are more abundant, suggesting that the sandstone may have been derived from the Jurassic magmatic arc (Reed and Lanphere, 1973b) now covered by younger rocks in Cook Inlet basin. Contemporaneous volcanism is suggested by rare interbedded light-colored tuffaceous sediments in the Yenlo Hills. Argillaceous rocks are locally thermally metamorphosed to spotted cordierite and andalusite hornfels. Graywacke is thermally metamorphosed to biotite-quartz hornfels. Elsewhere, low-grade metamorphism is indicated by the presence of metamorphic chlorite and biotite. Hydrothermal activity, probably related to emplacement of plutonic rocks at depth, locally has altered the graywackes to a soft orange-weathering quartz, chlorite, sericite, iron-oxide rock that locally contains vuggy and brecciated quartz. Gold can usually be panned from streams draining these altered zones. Extremely rare *Inoceramus* have been found, and bioclastic limestones of Early Cretaceous age (late Hauterivian to early Barremian; D. L. Jones, oral commun., 1977) are locally present. Along the Happy River (T. 22 N., R. 18 W.), dark-gray platy shale and sandstone contain indeterminate broadleaf plant fossils, and the rocks are lithologically similar to the Matanuska Formation of Late Cretaceous age. Although Upper Cretaceous fossils have not yet been found, a Late Cretaceous age cannot be ruled out. On the north side of the Tatina River, reddish-brown-weathering sandstone and dark-gray shale contain Early Jurassic ammonites, brachiopods, and pelecypods (R. W. Imlay, written commun., 1977). To the west, in the McGrath quadrangle (T. 26 N., R. 21 W.), these rocks include minor pillow basalt and volcanic flows. In most places the Early Jurassic rocks are in fault contact with the sedimentary rocks of the Dillinger River (Pzd), although in T. 27 N., R. 20 W. the contact is an angular unconformity. The contact relation of the Early Jurassic to Cretaceous strata is uncertain. The thickness of the unit is unknown but is probably more than 3000 m

Pzbs PILLOW BASALT.—Chiefly dark-greenish-gray massive pillow basalt and petrographically similar coarse-grained pyroxene gabbro and basaltic dikes and sills. The unit as mapped includes varying amounts of interstratified agglomerate, flow breccia, aquagene tuff, and thick, chaotic sequences of eugeosynclinal sedimentary rocks. The last of these are especially abundant in the roughly circular area northwest of Shellabarger Pass (T. 29 N., R. 19 W.), where about 600 m of submarine basalt flows forms the core of a north-trending structural trough (Reed and Eberlein, 1972). Pillows as much as 0.6 m in diameter show varying degrees of serpentinization and are typically porphyritic with phenocrysts of plagioclase and lesser clinopyroxene. Olivine is extremely rare, but its former presence is suggested by occasional rounded patches of chlorite and serpentine minerals of unidentified composition. Groundmass consists of very fine laths of plagioclase, some with swallowtail and belt-buckle crystal shapes, birefringent clinopyroxene variolites, and dark-brown devitrified and deuterically altered glass. Clinopyroxene is both pigeonite and subcalcic augite. Chemically the basalts are quartz-hypersthene normative tholeiites. Limited trace-element data suggest that the basalts are of the ocean-floor type (Pearce and Cann, 1973); associated rocks indicate local subaerial volcanism. The basalts are petrographically and chemically distinguishable from the Mesozoic pillow basalt by the presence of pigeonite, lower $K_2O$, Ba, and Rb contents, and higher FeO content. Copper content ranges from 200 to 300 ppm. Locally the basalts are associated with massive cupriferous sulfide deposits (Reed and Eberlein, 1972). Because of the chaotic structural features that characterize the Paleozoic sedimentary rocks (Pzus), the age of the pillow basalt is uncertain but inferred to be middle or late Paleozoic. A post-Late Devonian age is locally indicated by distinctive spherical concretions of fluorapatite present in sedimentary breccia and conglomerate that apparently underlie pillow basalt at Shellabarger Pass. The source of the concretions is a phosphatic chert unit that overlies the Middle and Upper Devonian limestone. A late Paleozoic (possibly Mississippian) age is suggested by thin units of pillow basalt interbedded with flyschoid sedimentary rocks and limestone-chert conglomerate that are gradational upward into the conglomerate of Mount Dall of Middle Pennsylvanian age. In T. 28 N., R. 18 W., a small unit of pillow basalt (not shown on the geologic map) is present within a chaotic sequence of chert, shale, limy sandstone, and limestone that contains fossils of late Middle Devonian(?) age (J. T. Dutro, Jr., written commun., 1976)

Pzv VOLCANIC AND SEDIMENTARY ROCKS.—Dark-greenish-gray massive-weathering mafic volcanic rocks that include pillow basalt, breccia, agglomerate, tuff, and massive basalt flows. Pillow basalts are porphyritic with phenocrysts of plagioclase and clinopyroxene (some with both augite and pigeonite) set in a matrix of finer grained clinopyroxene and lath-shaped plagioclase. Secondary minerals include sericite, calcite, serpentine(?), chlorite, and clinozoisite. Chemical analyses of two separate pillow basalts indicate that the rocks are quartz-hypersthene and olivine-hypersthene normative tholeiitic basalt. Volcanic rocks commonly contain interbeds of black phyllite, chert-pebble conglomerate, light-green tuff, and graywacke. The presence of massive basalt flows, breccia, and agglomerate suggests in part subaerial and (or) shallow-water ponded deposition. The unit is probably largely equivalent to but is tentatively distinguished from unit Pzbs by presence of massive basalt flows

IPd CONGLOMERATE OF MOUNT DALL.—Informal name given to dark-brown to yellowish-brown-weathering sequence of conglomerate, sandstone, siltstone, and shale mainly of continental origin that forms a broad, open, east-plunging syncline. This unit is chiefly massive lenticular beds of conglomerate and sandstone with numerous cut-and-fill channels. Conglomerate forms beds as much as 40 m thick; clasts range in size from 2 to 30 cm and are chiefly gray limestone and black chert. Limestone clasts contain Middle Devonian(?) fossils (W. A. Oliver, Jr., written commun., 1975) similar to those in Devonian limestone (Dl). Uncommon red and green chert, chert-pebble conglomerate, and graded sandstone clasts also suggest unit Pzus as its source. No granitic or volcanic clasts were recognized. Sandstone beds are commonly 2-3 cm thick and have well-developed planar and trough crossbedding and slump structures suggestive of fluvial deposition. Shale and sandstone beds 3-5 m thick locally contain abundant plant fossils of Middle Pennsylvanian age (S. H. Mamay, written commun., 1977). Conglomerate is locally bleached grayish white due to hydrothermal alteration associated with intrusive rocks (Tcp). Limestone clasts are altered to cream-colored and light-green diopside, idocrase, wollastonite, quartz, and calcite. This unit appears to be gradational downward to lithologically similar conglomerate in unit Pzus that does not contain varicolored chert clasts, is interbedded with shales that contain abundant worm trails, and in which limestone clasts are subordinate. The base of the unit consists chiefly of massive-bedded conglomerate and sandstone. The top is not exposed, but a minimum thickness of at least 1500 m is present near Mount Dall

Pzus UNDIVIDED SEDIMENTARY ROCKS.—A depositionally and structurally complex terrane of chiefly marine flyschoid sedimentary rocks which include (1) trench assemblages (and possibly intra-oceanic arc deposits) characterized by terrigenous turbidites, cherty pelagites, and basaltic pillow lavas (all of which underwent complex undersea sliding and later multiple thrusting and folding), (2) slope and shelf assemblages that include chert, shale, reefoid limestone, and, locally, terrestrial conglomerate and redbeds, and (3) a thick, locally terrestrial conglomerate and sandstone assemblage. These dissimilar middle and late Paleozoic depositional environments are now juxtaposed by large dislocated nappes and thrust faults on all scales. Structural features generally show a westerly vergency. The structural and stratigraphic relations of the contrasting rock types are known in only a few places. This terrane is allochthonous on unit Pzd, truncated on the north by Denali fault, fault bounded on the south by unit KJs, intruded by dunite and associated ultramafic rocks (Mz Pzd) along the southern contact with unit KJs, and elsewhere by units TKi, Tcp, and the middle Tertiary Foraker pluton (Tf). Intrusive rocks of McKinley sequence (Reed and Lanphere, 1973a) and calc-alkaline volcanic and intrusive rocks of Paleozoic age are notably absent. For convenience, these rocks are described in units that were locally recognized in the field; however, none of these units is differentiated on the geologic map. The unit locally includes thin pillow basalt (Pzbs), discontinuous and tectonically emplaced limestone beds (Dl), and conglomerate of Mount Dall (IPd). The base of the terrane was not recognized; the thickness is unknown but believed to be in excess of 2500 m

Flysch deposits, believed to occur both above and below units Pzbs and Psv, are characteristic of the terrane and consist of graywacke, shale, phyllite, grit, chert-pebble conglomerate, mudstone, chert, various types of volcanogenic sediments, wildflysch, and minor bioclastic limestone. Wildflysch locally contains house-sized blocks of bedded limestone (Dl, or Early to Middle Devonian limestone units locally present in unit Pzus) chaotically distributed in volcanogenic mudstone and is spatially associated with pillow basalts. Graded beds and slump folds are common. Worm trails are characteristic of the finer grained sediments. Clastic limestone beds (T. 29 N., R. 19 W.) contain echinoderm remains that suggest a late Early or early Middle Devonian age (J. T. Dutro, Jr., written commun., 1975) for the limestone

Slope, shelf, and fluvial deposition is indicated by a 0- to 10-m-thick redbed sequence of sandstone and conglomerate that contains plant and coalified wood debris. The redbeds are overlain by 125-250 m of sandstone, siltstone, and shale followed in turn by 60-90 m of locally reefoid limestone (Dl). The limestone is overlain by an unknown thickness of black shale and phosphatic chert that locally contains distinctive spheroidal concretions ("blackballs") of fluorapatite. Radiolarians from the concretions are late Devonian (Famennian) in age (D.L. Jones, oral commun., 1978). The locally abundant fauna from the clastic rocks and limestone indicates a late Middle and early Late Devonian age (J. T. Dutro, Jr., and W. A. Oliver, Jr., written commun., 1975, 1976)

Massive-bedded chert-limestone conglomerate, sandstone, and shale, in part terrestrial, is thought to be gradational downward into graywacke, shale, grit, minor pillow basalt, and local beds of echinoderm-pellet limestone and lime mudstone of Late Mississippian and Middle Pennsylvanian age (A. K. Armstrong, written commun., 1976). The chert-limestone conglomerate and sandstone are gradational upward to the nonmarine conglomerate of Mount Dall of Middle Pennsylvanian age

Dl LIMESTONE.—Middle and Upper Devonian limestone near Shellabarger Pass is more than 95 m thick. On the West Fork of the Yentna River (T. 29 N., R. 18 W.) the base of the limestone is transitional with yellow to dark-gray siltstones and shales. The lower 10 m consists of thin-bedded gray micrites that grade upward into fossiliferous, massive to reefoid, biostromal beds of colonial rugose corals and massive stromatoporoids. From 40 to 60 m above the base of the limestone, the beds are composed of a reefoid mass of colonial rugose corals, ramose bryozoans, and mamelons of large stromatoporoids. At 60 m, the limestone becomes more argillaceous, thinner bedded, and less fossiliferous and is composed of micrites. Thin (5 to 15 cm) dark-gray shale beds between limestone beds are common. A massive micritic, poorly fossiliferous gray limestone is present from 75-87 m. Massive stromatoporoid limestones are present from 90 to 95 m. The stromatoporoid beds are overlain by dark-brown to black shales with thin limestone interbeds that contain conodonts of Late Devonian (upper half of Frasnian) age (A. G. Harris, written commun., 1977). The thickness of the limestone varies through its area of exposure due to original depositional facies. It may represent a series of small patch reefs and interreef beds. Variation in thickness may also be due in part to tectonic factors. Limestone contains abundant coral and shelly faunas of late Middle and early Late Devonian age (J. T. Dutro, Jr., and W. A. Oliver, Jr., written commun., 1974, 1975, 1976). This unit locally includes discontinuous gray limestone beds of late Early or Middle Devonian age (No. 17, table 1)

Pzp PHYLLITE.—Prominent unit of dark-gray phyllite, phyllitic shale, and argillaceous siltstone that lithologically is very similar to the phyllitic shale in unit KJs both north (T. 33 N., R. 13 and 14 W.) and south (T. 26 N., R. 20 W.) of the Denali fault. The contact relation with unit Pzus is unknown but appears to be gradational southwest of Pingston Creek (T. 29 N., R. 19 W.); the unit may be allochthonous KJs. It contains worm trails, which are abundant in unit Pzus but are also locally present in unit KJs south of the Denali fault (T. 26 N., R. 20 W.)

Sl LIMESTONE.—Light-gray to light-brown massive-weathering marbleized limestone and local areas of thin-bedded to laminated limestone. Freshly broken surfaces of bedded limestone are dark gray and emit a fetid odor. Marbleized limestone contains probably Silurian dasycladacean algae and corals (J. T. Dutro, Jr., and W. A. Oliver, Jr., written commun., 1977). Bedded limestone contains rare graptolites of Silurian age (Claire Carter, written commun., 1977). This unit is mapped only as small allochthonous blocks of marbleized limestone in unit Pzus along north side of Shellabarger Pass (T. 28 N., R. 18 W.) and as a larger area of limestone on south side of pass. It may, in part, be equivalent to Silurian and (or) Devonian limestone in the Terra Cotta Mountains (Churkin and others, 1977)

Oc CHERT AND SHALE.—Chaotically folded allochthonous sequence of interbedded graptolitic shale and chert and minor sandstone and siltstone. Its thickness is unknown; some folds suggest penecontemporaneous deformation. Chert beds average about 7 cm thick and are rhythmically interbedded with black shale. Shale locally contains abundant Early to Middle Ordovician graptolites (Claire Carter, written commun., 1977). The distribution of Ordovician rocks on the north flank of Cathedral Spires (Tmc, T. 27 and 28 N., R. 19 W.) and the nature of their contact with adjacent sedimentary rocks (KJs and Pzus) is poorly understood because thermal metamorphism of Ordovician shale and siltstone (chert was not noted in this area) and KJs shale and siltstone has produced essentially identical-appearing metamorphic rocks consisting of dark-gray phyllitic shale and argillite. The presence of Ordovician rocks is indicated only by rare, poorly preserved graptolites in T. 28 N., R. 19 W. In addition, it locally contains discontinuous units of recrystallized limestone 5-30 m thick that may be tectonically emplaced slivers of unit S1. The unit is tentatively correlated with Ordovician hemipelagic graptolitic shale and ribbon chert in the Terra Cotta Mountains (Churkin and others, 1977)

Pzd SEDIMENTARY ROCKS OF DILLINGER RIVER.—A thick sequence of sedimentary rocks presently recognized to consist of an undetermined thickness of interbedded lime mudstone and shale, more than 900 m of apparently unfossiliferous deep-water, well-bedded lime mudstone (micrites), and at least 900 m of interbedded sandstone, shale, and limestone (Armstrong and others, 1977). Due to complex structural features and sparse megafossils, the relative age of these units is poorly known. Lime-mudstone and shale in the McGrath quadrangle (NW¼ sec. 14, T. 27 N., R. 21 W.) contain poorly preserved *Cardiolacea* of late Wenlockian (Silurian) age (Jiri Kriz, written commun., 1977). Limestone is medium to dark gray, weathers light gray, is uniformly bedded, and locally contains conodonts of Silurian age (A. G. Harris, written commun., 1977). Beds range in thickness from 0.1 to 1.2 m, average about 0.2 m, locally contain well-formed pyrite cubes that are partially mantled by pressure fringes of quartz and light-gray chlorite. Shale beds are locally phyllitic and average 0.15 m in thickness. A well-exposed sequence of interbedded sandstone, shale, and limestone on the east side of Jones River in the McGrath quadrangle (T. 27 N., R. 22 W.) consists of an upper 360-m-thick massive turbidite subgraywacke sequence underlain by 250 m of well-bedded argillaceous and dolomitic lime mudstone (micrite) containing Middle Silurian graptolites (Claire Carter, written commun., 1977), and a lower 300-m-thick massive-bedded subgraywacke to protoquartzite that contains interbeds of dark-gray silty shale. The lower clastic unit, which shows rhythmic and graded bedding and contains numerous shale fragments, is interpreted as a turbidite. East-trending isoclinal folds in the McGrath quadrangle, disharmonic folds on all scales north of the Tatina River, and multiple folds are also present. Intruded by dark-green, partially altered mafic dikes. These rocks can be traced westward into the McGrath quadrangle for at least 50 km and may, in part, be equivalent to the Terra Cotta sequence near the Post River (Churkin and others, 1977)

**Intrusive and ultramafic rocks**

Tf FORAKER PLUTON.—Medium-grained, equigranular biotite and hornblende granodiorite with a color index that averages about 13 but ranges from 9 to 20. Petrographic descriptions and modal and chemical analyses are given in Reed and Lanphere (1974). This pluton has nearly identical mineralogy and chemistry to the McGonagall pluton in the Mount McKinley quadrangle, and both plutons are considered to be parts of a single igneous mass that has undergone right-lateral displacement of about 38 km along the McKinley segment of the Denali fault system since the igneous mass crystallized about 38 m.y. ago. Molybdenite-bearing quartz veins are associated with the Foraker pluton, and sparse cobbles of granodiorite on the Yentna and Lacuna Glaciers contain fractures filled with molybdenite, pyrite, and chalcopyrite

McKINLEY SEQUENCE

A group of widely scattered, relatively large plutonic bodies generally restricted to unit KJs terrane south of the Denali fault. The Tonzona pluton, north of the fault, is also part of this sequence. The McKinley sequence is assigned to the Late Cretaceous and early Tertiary plutonic event in south-central Alaska. Nine K-Ar ages on biotite and muscovite from the McKinley sequence range from 52.3 to 56.2 m.y. Although previously classified as quartz monzonite and granite (Reed and Lanphere, 1973a), the classification system used herein is that recommended by the IUGS (Streckeisen, 1973), and the rocks fall within the granite and granodiorite fields (fig. 1). In general, the rocks are coarse grained, fresh, with equigranular to porphyritic hypidiomorphic textures. Biotite, generally in amounts between 3 and 10 volume percent, is the chief mafic mineral; hornblende is extremely rare or absent from most plutons. Muscovite is present in some plutons but generally makes up less than 2 volume percent of the rock. The plutons are epizonal and discordant and generally lack xenoliths, although they locally contain foundered blocks of country rock along their margins and apical parts

Tm McKinley pluton.—This pluton forms the rugged and spectacular massif of Mt. McKinley. Only one sample was collected from the massif, but glacier-transported boulders from the pluton are uniformly similar in composition and consist of medium- to coarse-grained, hypidiomorphic-granular biotite granite

Tmc Cathedral pluton.—Medium- to coarse-grained, hypidiomorphic-granular biotite and biotite-muscovite granite form the rugged and spectacular Cathedral Spires (T. 27 N., R. 19 W.). The rocks also contain minor phases of biotite-hornblende granodiorite. A small, petrographically similar body of fine-grained biotite granite occurs in T. 26 N., R. 17 W. Average color index of six samples is 8; apatite and zircon are characteristic accessory minerals, but fluorite, tourmaline, and allanite are also present

Tmk Kahiltna pluton.—A relatively large mass of granite and granodiorite geographically separated into two bodies by the Kahiltna Glacier. The body to the southwest is fine- to coarse-grained, hypidiomorphic-granular biotite and biotite-muscovite granite and granodiorite. The average color index of nine samples is 12. Apatite and zircon are characteristic accessory minerals, but tourmaline, garnet, and allanite are locally present. Samples from the northeast body are medium- to coarse-grained, hypidiomorphic-granular biotite-muscovite granite. Minor tin anomalies are associated with a quartz-tourmaline-muscovite greissen zone at the head of Hidden Creek (T. 30 N., R. 10 W.). The average color index of 10 samples is 8. A small satellitic body of fine- to coarse-grained biotite-hornblende granodiorite (T. 31 N., R. 9 W.) is included with the Kahiltna pluton

Tmr Ruth pluton.—A large granitic mass that is probably continuous at depth but is described below as a north body, a south body, and the Chulitna body. The Chulitna body (T. 30 N., R. 5 W.) is medium- to coarse-grained, weakly foliated, hypidiomorphic-granular biotite granite. Rare hornblende is present in one sample. Apatite, allanite, and zircon are characteristic accessory minerals, and tourmaline, fluorite, and an unidentified zeolite are present in some samples. The south body (T. 31 N., R. 6 W.) is characterized by coarse-grained hypidiomorphic-granular biotite granite and granodiorite that locally are intensely weathered to grus. Rare muscovite or hornblende is present in some samples. The average color index of 10 samples is 10. Accessory minerals are the same as in the Chulitna body. The north body (T. 33 N., R. 6 W.) is medium- to coarse-grained hypidiomorphic-granular biotite and biotite-muscovite granite. Average color index of seven samples is 6. The coarser grained granite typically weathers to grus. Tin anomalies from pan concentrate samples are spatially associated with iron-stained, altered, and intensely weathered zones in the granite. Tourmaline, fluorite, and topaz have been observed in some samples in addition to the characteristic apatite and zircon

Te GRANODIORITE OF MOUNT ESTELLE.—The northern part of the granodiorite of Mount Estelle crops out in the southwestern part of the quadrangle. Modal and chemical plots for these rocks are given in Reed and Lanphere (1973a) and in figure 1. The plutonic rocks are classified as silicic granodiorites and are medium grained, hypidiomorphic-granular. Plagioclase averages between 35 and 45 percent anorthite, although individual zoned crystals have a greater range in composition. Biotite equals or exceeds hornblende by as much as four times, and tourmaline is a characteristic accessory mineral. Gold-bearing quartz-sulfide veins are locally present within the pluton (Reed and Elliott, 1970). Hornblende ages of about 65 and 66 m.y. are similar in age to the composite plutons and probably reflect the same plutonic event in this part of Alaska

Tcp COMPOSITE PLUTONS.—A series of nine relatively small plutonic bodies, previously assigned to the Yentna series (Reed and

Lanphere, 1973a), that form a 65-km-long curvilinear belt extending northeast from the granodiorite of Mt. Estelle to the headwaters of Cascade Creek (T. 28 N., R. 15 W.). The average composition of the plutons is quartz monzonite (figure 1), but the larger and better exposed plutons are composite in nature and consist of distinctly different compositions that range from peridotite to granite. Where intrusive sequences have been established, the more mafic phases were the first to be emplaced. Some ultramafic bodies are distinctive in that they contain a significant amount of K-feldspar along with olivine, clinopyroxene, and biotite. Olivine is commonly rimmed by pyroxene and biotite and, in the peridotites, is altered to fibrous amphibole and iron oxide minerals. Serpentine minerals were not noted. Mafic minerals in the more felsic rocks are biotite, rare to abundant clinopyroxene or clino- and orthopyroxene, and locally olivine and hornblende. Apatite is a characteristic accessory mineral

Ptarmigan stock (T. 24 N., R. 20 W.)—Medium-grained, hypidiomorphic-granular biotite granite

Kohlsaat pluton (T. 25 N., R. 20 W.)—Composite pluton consisting of medium- to coarse-grained, hypidiomorphic-granular biotite granite, hornblende-biotite granite, and pyroxene-biotite monzonite. K-Ar age date of 65.6 ± 1.9 m.y. (Reed and Lanphere, 1973a)

Threemile stock (T. 25 N., R. 19 W.)—Fine- to medium-grained, locally porphyritic, pyroxene-bearing biotite quartz monzonite that contains altered phenocrysts of pyroxene

Kichatna stock (T. 26 N., R. 18 W.)—Composite stock consisting chiefly of medium- to coarse-grained, hypidiomorphic-granular olivine-bearing pyroxene quartz monzonite; locally contains disseminated pyrite, pyrrhotite, and chalcopyrite

Fourth of July stock (T. 26 N., R. 17 W.)—Small pipelike body of porphyritic peridotite containing euhedral phenocrysts of green clinopyroxene as much as 5 cm long in a groundmass of clinopyroxene, bladed biotite, rounded olivine, and interstitial potassium feldspar

Lower Yentna pluton (T. 28 N., R. 17 W.)—Elongate composite body of medium- to coarse-grained pyroxene and (or) biotite quartz monzonite and porphyritic biotite granite with potassium feldspar phenocrysts as much as 2 cm in length

Upper Yentna pluton (T. 28 N., R. 17 W.)—Elongate composite body consisting of medium-grained equigranular biotite peridotite, medium- to coarse-grained pyroxene quartz monzodiorite, porphyritic biotite-hornblende quartz monzonite, and biotite-pyroxene quartz syenite that contains blue chatoyant potassium feldspar phenocrysts as much as 2.5 cm in length

Cascade pluton (T. 28 N., R. 16 W.)—Composite pluton consisting of potassium feldspar-bearing peridotite, medium-grained hornblende quartz monzodiorite and biotite granodiorite, and a late phase of medium- to coarse-grained porphyritic pyroxene-biotite quartz monzonite. Copper and gold mineralization indicated by stream sediment and pan concentrate samples from Cascade Creek. K-Ar age date of 64.6 ± 1.8 m.y. (Reed and Lanphere, 1973a)

East Fork Yentna stock (T. 28 N., R. 15 W.)—Medium-grained, hypidiomorphic-granular, pyroxene-bearing biotite granodiorite

Shellabarger stock (T. 28 N., R. 18 W.)—Small, poorly exposed stock of altered biotite-pyroxene gabbro northwest of the main composite plutonic belt. Relation to the composite plutons unknown. Locally contains abundant disseminations of specular hematite. Semiquantitative spectrographic analyses of three grab samples average 1000 ppm copper

*TKk* KICHATNA PLUTONS.—Nine small plutons, some of which were previously assigned to the Yentna series (Reed and Lanphere, 1973a), located southeast of the belt of composite plutons (TKc). The average composition of these rocks is granodiorite, but quartz monzodiorite and quartz diorite are also present (fig. 1). The rocks are predominantly medium grained and hypidiomorphic-granular; dark-reddish-brown biotite and light-green hornblende comprise about 22 volume percent of the rocks. Biotite generally exceeds hornblende. Allanite, apatite, and zircon are characteristic accessory minerals. A K-Ar age date of 67.4 ± 2 m.y. (Reed and Lanphere, 1973a) from a hornblende-biotite quartz diorite (T. 23 N., R. 17 W.) suggests that these rocks may be slightly older than the composite plutons

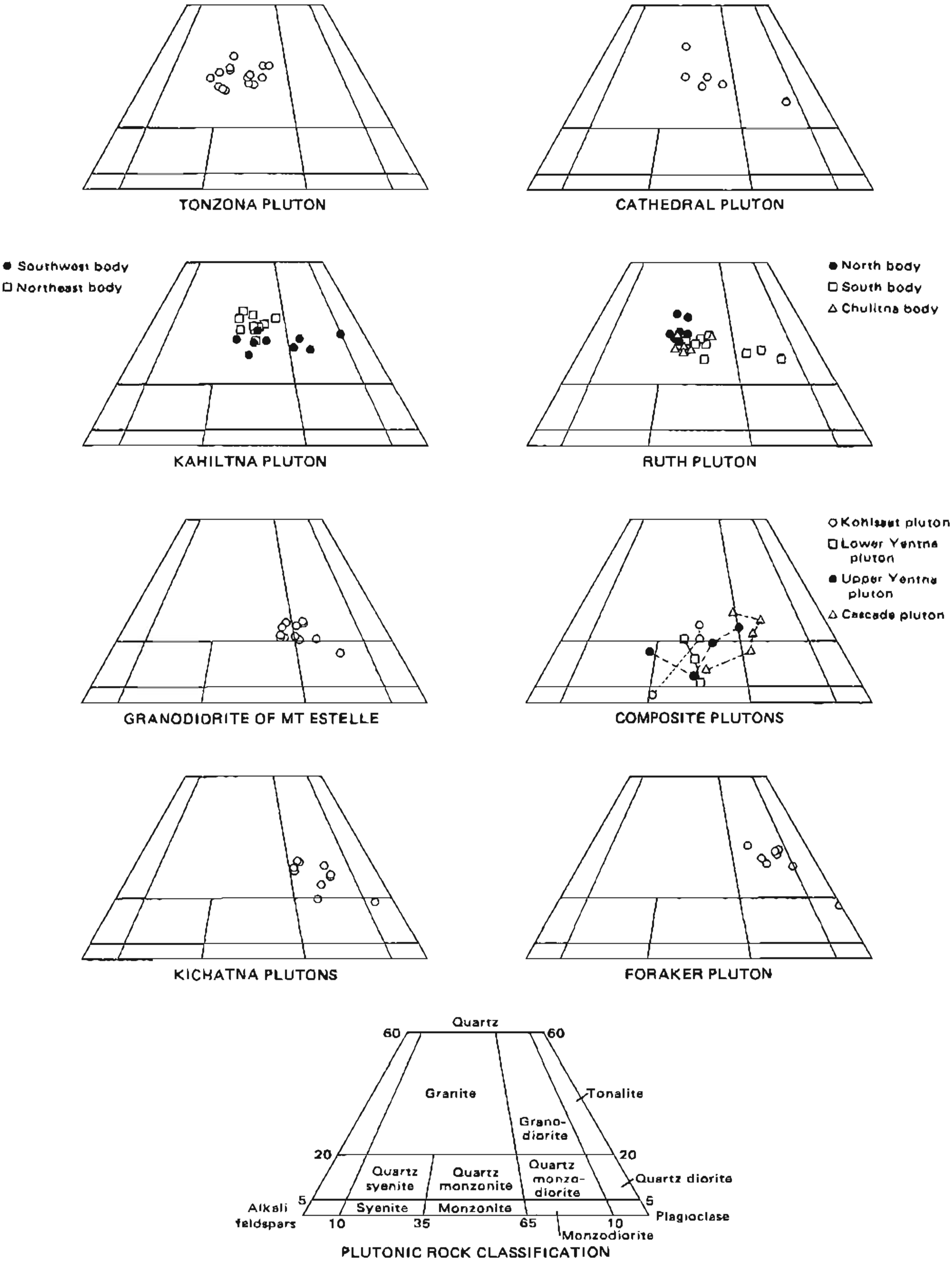


**Figure 1.**—*Modal analyses of plutonic rocks in the Talkeetna quadrangle. Classification after Streckeisen (1973).*

TKi UNDIVIDED INTRUSIVE ROCKS.—Small intrusive bodies of Late Cretaceous or Tertiary age with compositions that preclude definite assignment to the above intrusive sequences. Owing to difficult accessibility, many of these bodies could not be sampled; their contacts were mapped from the air. The petrography and composition of these rocks are incompletely known. The rocks sampled range in composition from granite to tonalite. The small body located along the Susitna River (T. 29 N., R. 4 W.) is a weakly foliated, fine- to medium-grained, hypidiomorphic-granular biotite granodiorite. The two small intrusive bodies of biotite granite and biotite-hornblende granodiorite (T. 32 N., R. 5 W., and T. 33 N., R. 4 W., respectively) may be satellitic bodies of the Ruth pluton. At Little Peters Hills (T. 26 N., R. 8 W.) a small body of equigranular medium-grained biotite granite, thought to belong to the McKinley sequence, cuts argillite and graywacke hornfels. The small body on the east side of the Kahiltna Glacier (T. 31 N., R. 10 W.) is a foliated, recrystallized, fine- to medium-grained biotite-hornblende granodiorite. In thin section, hornblende is dark bluish green in color. The small intrusive body located in T. 30 N., R. 14 W. is a medium-grained porphyritic biotite tonalite and may be a satellitic body of the Foraker pluton. The intrusive mapped as TKi in T. 25 and 26 N., R. 4 W. is reported to be an altered biotite-hornblende quartz diorite (Bela Csejtey, oral commun., 1976)

MzPzi UNDIVIDED INTRUSIVE ROCKS.—Dark-gray to greenish-gray dikes and sills that range in composition from basalt to granodiorite. Most bodies are porphyritic and contain altered phenocrysts of plagioclase and amphibole in a matrix of fine-grained feldspar, quartz, and alteration minerals. Clinopyroxene is rare. The age is unknown. Most bodies are too small to show at scale of map

MzPzd UNDIVIDED DUNITE AND SERPENTINITE.—Alpine-type ultramafic rocks and minor talc schist exposed discontinuously for approximately 25 km along the Lacuna and Yentna Glaciers and as small isolated occurrences in T. 31 N., R. 14 W. and T. 30 N., R. 15 W. Chromite-bearing dunite occurs as sills as much as 90 m thick and 7 km long (T. 31 N., R. 12 W.) and as a larger irregular body of dunite and serpentinite in T. 30 N., R. 13 and 14 W. A magnetic high suggests that similar rocks may intrude Pzus at depth in T. 30 N., R. 14 W. Dunite forms massive light-orange-brown-weathering exposures that have a rough-textured surface. It is intruded by the main mass and dikes of Foraker pluton (Tf). Olivine is recrystallized and (or) altered to serpentine minerals, talc, and amphibole; shearing and deformation banding are common. Chromite occurs chiefly in dunite sills as (1) disseminated rounded grains 1-3 mm in diameter, (2) streaks and lenses, (3) disrupted and irregular pods of various shapes as much as 2 m in maximum dimension that are cut by dunite, and (4) lenslike bodies as much as 2 m thick and 20 m in length. Chrome content of typical dunite ranges from 0.7 to 1 percent. The average of 3 microprobe analyses from one sample of chromite (T. P. Thayer, written commun., 1976) is 58.4 percent $Cr_2O_3$, 21.1 percent FeO, 8.9 percent MgO, and 9.7 percent $Al_2O_3$. Serpentinite, composed of dark-green serpentine minerals and magnetite, locally contains relict olivine crystals altered to antigorite and chrysotile. It is cut by veins of fine-grained carbonate and unidentified clay minerals. Emerald-green chrome-nickel garnets, locally present in calc-silicate rocks (Dl?) adjacent to dunite, suggest that the dunite was emplaced at moderately high temperatures

**Chulitna sequence**

The informal term "Chulitna sequence" refers to an allochthonous sequence of upper Paleozoic limestone, tuff, and argillite, Lower and Upper Triassic limestone, basalt, and volcanic redbeds, and Upper Triassic and Lower Jurassic marine sandstone and argillite that crop out on the south flank of the Alaska Range along the Chulitna Valley northeast of the Talkeetna quadrangle (Jones and others, 1976, and written commun., 1977; Hawley and Clark, 1974; Clark and others, 1972). In the Chulitna area these rocks include a dismembered ophiolite (oceanic crust) sequence of Late Devonian age (D. L. Jones, oral commun., 1977) which has not been observed in the Talkeetna quadrangle. Within the Talkeetna quadrangle the Chulitna sequence consists of Upper Triassic limestone and basalt, Upper Triassic volcaniclastic and clastic sedimentary rocks, and Upper Triassic(?) and Lower Jurassic massive- to well-bedded siliceous argillite, chert, and minor pillow basalt. These rocks structurally overlie Jurassic(?) and Cretaceous graywacke, shale, and phyllite (KJs) and are locally cut by small intrusive bodies of biotite granite (Tmr) and biotite-hornblende granodiorite (TKi)

JTRsv SEDIMENTARY AND VOLCANIC ROCKS.—Massive cliff-forming outcrops of silicified argillite, radiolarian chert, siltstone, minor pillow basalt, and impure micritic limestone. Yellowish-gray to black silicified argillite and chert is well bedded, and individual beds average about 8 cm in thickness. Siltstone is dark gray, rust weathering, and well sorted and contains abundant angular quartz, feldspar, and metachert fragments that average 0.2 mm in size. Minor pillow basalt in units as much as 3 m thick is composed of medium-grained plagioclase and clinopyroxene. Clinopyroxene is altered to blue-green amphibole and chlorite

TRvs VOLCANIC AND SEDIMENTARY ROCKS.—Distinctive light-green to maroon volcaniclastic rocks that range from tuffaceous shale to a quartz-pebble conglomerate with a tuffaceous matrix. These rocks commonly contain interbeds of massive micritic and bioclastic limestone, minor chert, argillite, rust-weathering siltstone and sandstone, and basaltic tuff. The coarser grained tuffaceous volcaniclastic beds average about 0.6 m in thickness and contain angular to subrounded clasts of quartz, chert, volcanic rocks, and siltstone as much as 7 cm in maximum dimension. In places the texture appears cataclastic, and in others the rock is a sedimentary breccia. Unit contains locally abundant fossils including *Thecosmilia*, *Heterastridium*, and *Septocardia*(?) of Upper Triassic (Norian) age (N. J. Silberling, written commun., 1977). Basaltic tuff consists of plagioclase crystals and volcanic rock fragments in a semischistose matrix of chlorite and altered glass

TRlb LIMESTONE AND BASALT.—Upper Triassic limestone and basalt form a distinctive unit northeast of the Eldridge Glacier (Clark and others, 1972) and apparently grade southwestward into interbedded gray limestone, dark-green pillow basalt, massive and locally semischistose basaltic tuff, calcareous sandstone, and minor black chert and silty limestone. The limestone is discontinuously exposed and usually interbedded with or included within basalt. It is commonly massive and marbleized but locally is well bedded and contains volcanic rock fragments. Dark-green basaltic rocks form massive-weathering outcrops. Recognizable pillow basalt is subordinate to basaltic tuff, but pillows as much as 45 cm in diameter are locally present. Irregular masses of chlorite, epidote, fibrous amphibole, and iron oxides suggest the former presence of mafic minerals. The pillow basalt contains interbeds of black chert and phyllite. Basaltic aquagene(?) tuff is dark green, massive, and locally semischistose and consists of lapilli-size fragments of various types of volcanic rocks. Also present are coarse lenses of chlorite and calcite with unidentified birefringent microlites, and sparse plagioclase. Schistose basaltic tuffs contain lenses of clinopyroxene phenocrysts and amygdules of calcite, quartz and epidote, and chlorite and quartz. Locally abundant fossils from this unit include *Monotis subcircularis* Gabb, *Heterastridium*, and *Cassianella* of Late Triassic (Norian) age (N. J. Silberling, written commun., 1977)

## REFERENCES CITED


Armstrong, A. K., Reed, B. L., and Carter, Claire, 1977, Paleozoic sediments in the northwest part of the Talkeetna quadrangle, Alaska Range, Alaska: U.S. Geological Survey Circular 751-B, p. B61.

Bundtzen, T. K., Smith, T. E., and Tosdal, R. M., 1975, Progress report: Geology and mineral deposits of the Kantishna Hills, Alaska: Alaska Division of Geological and Geophysical Surveys open-file report 98, 80 p.

Calderwood, K. W., and Fackler, W. C., 1972, Proposed stratigraphic nomenclature for Kenai Group, Cook Inlet basin, Alaska: American Association of Petroleum Geologists Bulletin, v. 56, no. 4, p. 739-754.

Churkin, Michael, Jr., Reed, B. L., Carter, Claire, and Winkler, G. R., 1977, Lower Paleozoic graptolitic section from the Terra Cotta Mountains, southern Alaska Range: U.S. Geological Survey Circular 751-B, p. B37.

Clark, A. L., Clark, S. H. B., and Hawley, C. C., 1972, Significance of upper Palezoic oceanic crust in the Upper Chulitna district, west-central Alaska Range, *in* Geological Survey research 1972: U.S. Geological Survey Professional Paper 800-C, p. C95-C101.

Gilbert, W. G., Ferrell, V. M., and Turner, D. L., 1976, The Teklanika Formation—a new Paleocene volcanic formation in the central Alaska Range: Alaska Division of Geological and Geophysical Surveys Geologic Report 47, 16 p.

Hawley, C. C., and Clark, A. L., 1974, Geology and mineral deposits of the Upper Chulitna district, Alaska: U.S. Geological Survey Professional Paper 758-B, p. B1-B47.

Jones, D. L., Pessagno, E. A., Jr., and Csejtey, Bela, Jr., 1976, Significance of Upper Chulitna ophiolite for the late Mesozoic evolution of southern Alaska: Geological Society of America Abstracts with Programs, v. 8, no. 3, p. 385-386.

Karlstrom, T. N. V., 1964, Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 443, 69 p.

Pearce, J. A., and Cann, T. R., 1973, Tectonic setting of basic volcanic rocks determined using trace element analyses: Earth and Planetary Science Letters, v. 19, p. 290-300.

Reed, B. L., and Elliott, R. L., 1968, Results of stream sediment sampling in parts of the southern Alaska Range: U.S. Geological Survey Open-File Report, 9 p.

___ 1970, Reconnaissance geologic map, analyses of bedrock and stream sediment samples, and an aeromagnetic map of parts of the southern Alaska Range: U.S. Geological Survey Open-File Report, 158 p.

Reed, B. L., and Eberlein, G. D., 1972, Massive sulfide deposits near Shellabarger Pass, southern Alaska Range, Alaska: U.S. Geological Survey Bulletin 1342, 45 p.

Reed, B. L., and Lanphere, M. A., 1972, Generalized geologic map of the Alaska-Aleutian Range batholith showing potassium-argon ages of the plutonic rocks: U.S. Geological Survey Miscellaneous Field Studies Map MF-372.

___ 1973a, Alaska-Aleutian Range batholith: Geochronology, chemistry, and relation to circum-Pacific plutonism: Geological Society of America Bulletin, v. 84, p. 2583-2610.

___ 1973b, Plutonic rocks of the Alaska-Aleutian Range batholith, *in* International Arctic Symposium, 2d, Proceedings: American Association of Petroleum Geologists Memoir 15, p. 421-428.

___ 1974, Offset plutons and history of movement along the McKinley segment of the Denali fault system, Alaska: Geological Society of America Bulletin, v. 85, p. 1883-1892.

Streckeisen, A. L., chm., 1973, Classification and nomenclature recommended by the IUGS Subcommission on the systematics of igneous rocks: Geotimes, v. 18, no. 10, p. 26-30.

Wahrhaftig, Clyde, Wolfe, J. A., Leopold, E. B., and Lanphere, M. A., 1969, The coal-bearing group in the Nenana coal field, Alaska: U.S. Geological Survey Bulletin 1274-D, p. D1-D28.

NOTE ADDED IN PRESS..................

Fieldwork in 1979 north of the Denali fault indicates that Late Triassic conodonts are present in the sooty carbonaceous and calcareous shale, interbedded siltstone, limestone and quartzite (Pzsl) exposed along Pingston Creek in the S1/2 T. 45 N., R. 19 W.(D.L. Jones, N.J. Silberling, Bruce Wardlaw, and D.H. Richter, written commun., 1979). In the foothills northeast of Pingston Creek (NE1/4 T. 45 N., R. 19 W.), a lens of crinoidal limestone contains Early Pennsylvanian conodonts. These workers have divided unit Pzsl into two stratigraphic units. The units appear to be in fault contact, but the Triassic rocks are clearly infolded with the Pennsylvanian strata. In addition, the gabbro and quartz diorite dikes and sills (MzPzg) that cut these sedimentary rocks must be Mesozoic or younger in age.

Another important result of this recent investigation is the discovery of Permian conodonts and radiolarians of Permian and possibly Mississippian ages in chert exposed in the SE1/4 T. 45 N., R. 18 W. In this report the chert was mapped as part of the undivided marine sedimentary rocks (KJs). The chert is probably in fault contact with the adjacent clastic rocks. Although undivided KJs north of the fault locally contains rocks of Early Cretaceous age (locality 4, this report), its age is now known to extend into the upper Paleozoic.