# Age and Structural Significance of Ophiolite and Adjoining Rocks in The Upper Chulitna District, South-central Alaska

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# AGE AND STRUCTURAL SIGNIFICANCE OF OPHIOLITE AND ADJOINING ROCKS IN THE UPPER CHULITNA DISTRICT, SOUTH-CENTRAL ALASKA


Triassic and Jurassic rocks of the Chulitna terrane exposed on north side of upper Shotgun Creek, Upper Chulitna district, Alaska. Section is overturned and dips northwest. Black and white banded rocks are Upper Triassic limestone and pillow basalt (Ŧ lb). conformably overlain by Upper Triassic redbeds (Ŧ rb). These grade up into Triassic and Jurassic brown sandstone and argillite (J Ŧ s) with abundant marine fossils. Distance of view from northwest to southeast about 2½ km. Vertical relief over 600 m. View to northeast.

# Age and Structural Significance of Ophiolite and Adjoining Rocks in the Upper Chulitna District, South-central Alaska

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GEOLOGIC FRAMEWORK OF THE UPPER CHULITNA DISTRICT, ALASKA

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# AGE AND STRUCTURAL SIGNIFICANCE OF OPHIOLITE AND ADJOINING ROCKS IN THE UPPER CHULITNA DISTRICT, SOUTH-CENTRAL ALASKA

By D. L. Jones, N. J. Silberling, Béla Csejtey, Jr., W. H. Nelson, and Charles D. Blome

## ABSTRACT

Paleozoic and Mesozoic rocks in the Upper Chulitna district, south-central Alaska, are subdivided into six discrete allochthonous stratigraphic and structural parts, as follows:

*Chulitna terrane.* Includes Upper Devonian ophiolite (serpentinite, gabbro, pillow basalt, red radiolarian chert); upper Paleozoic chert, tuff, volcanic conglomerate and sandstone, flysch, and limestone; Triassic limestone, basalt, redbeds, marine sandstone, and shale; Jurassic sandstone, shale, and chert; and Cretaceous sandstone, argillite, and chert. This terrane is internally faulted and folded, and structurally overlies the West Fork and Eldridge terranes.

*West Fork terrane.* Includes highly folded and sheared Upper Jurassic chert and argillite with enclosed blocks of Lower Jurassic phosphatic limy sandstone; and massive siliceous crystal tuff, graywacke, and minor conglomerate of Triassic (?) and Jurassic age. This terrane is in fault contact on the southeast with the Broad Pass terrane.

*Broad Pass terrane.* Includes a complexly deformed and little-studied assemblage of chert, tuff, andesitic volcanic rocks, pods and lenses of limestone, and gray phyllite. Fossils from limestone are Middle Devonian or older; those from tuff and chert are latest Devonian (?) to early Carboniferous. Rocks of this terrane are in fault contact on the southeast with the Susitna terrane.

*Jack River block.* Includes volcanic conglomerate containing Late Triassic fossils in the matrix and cobbles of Permian red radiolarian chert. Total known extent limited to a small area southeast of Cantwell.

*Susitna terrane.* Includes highly deformed flyschlike rocks of Cretaceous age and large folded slabs of pillow basalt and associated deep-water tuffaceous sedimentary rocks of Late Triassic age. The Cretaceous flysch is generally similar to and of the same age as the flysch of the Eldridge terrane.

*Eldridge terrane.* Lies north of the Chulitna terrane and includes deformed graywacke, chert, minor limestone, phyllite, and conglomerate. Early Cretaceous fossils locally are present.

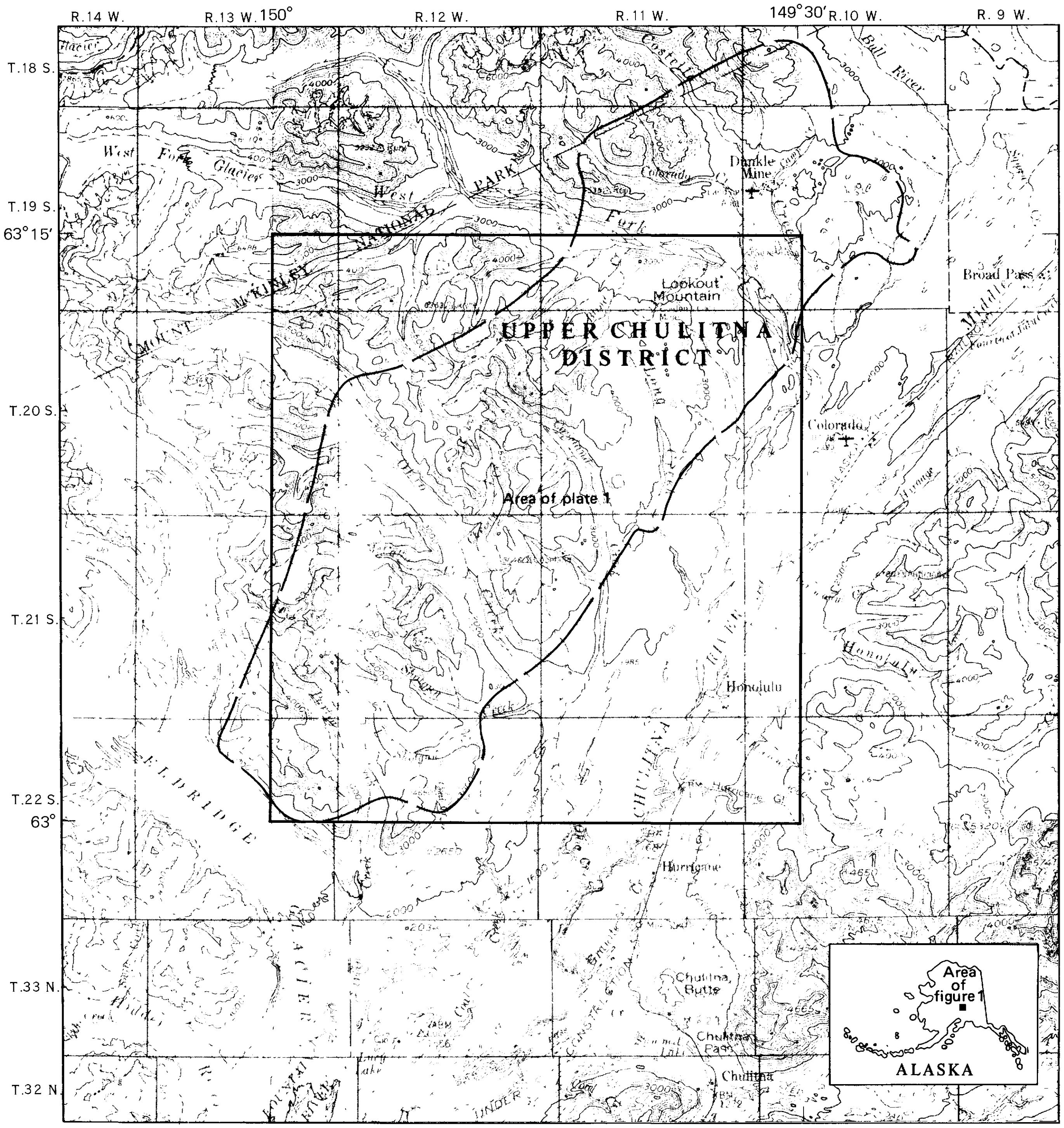
The presence of coeval but unlike rocks in these adjoining terranes suggests that large-scale tectonic juxtapositions have occurred. Thrust faulting may be the dominant structural style, but large amounts of strike-slip displacement may have occurred also. The intimate involvement of Lower Cretaceous rocks in some of these terranes suggest that the main juxtaposition occurred in middle and Late Cretaceous time.

Geologic and paleontologic evidence suggest that some of the rocks, such as the Triassic redbeds, originated far to the south. Perhaps they were transported north as part of the same tectonic regime that brought Wrangellia north from southern (equatorial) paleolatitudes.

## INTRODUCTION

Paleozoic and Mesozoic sedimentary and volcanic rocks in the Upper Chulitna district, south-central Alaska (fig. 1), associated with ophiolitic rocks (oceanic crust), were first described in detail by Clark, Clark, and Hawley (1972) and Hawley and Clark (1974). Their descriptions of seemingly unique rock sequences, although not precisely dated, immediately raised questions as to their correlation with nearby coeval rocks. The presence of ophiolitic rocks so far inland from the coast suggested the existence of a major suture zone (Csejtey, 1974, 1976), but uncertainties in the age and distribution of some of these rocks, as well as their overall structure and lithologic association, resulted in uncertainty in interpreting their tectonic history.

Because of these problems, further work was undertaken in 1976 by a team of geologists, paleontologists, and geophysicists, including the above authors, plus John Hillhouse and Sherman Grommé (paleomagnetics) and Robert Morin and James Case (gravity), all of whom were directly involved in field studies. Additional laboratory support was provided by Bruce R. Wardlaw and Anita G. Harris (conodonts), Ralph W. Imlay (Jurassic mollusks), Kathryn Nichols (Early Triassic ammonities), Thomas Dutro, Jr., and William Oliver (Paleozoic megafossils), Emilie A. Pessagno, Jr., University of Texas, Dallas (Mesozoic radiolarians), and Brian Holdsworth, The University, Keele, England (Paleozoic radiolarians). Further field studies were carried out in 1977 and 1978 by Jones and Silberling. The collaborative effort of all these people has produced much new data that now permit reassessment of the age, structure, and tectonic significance of the ophiolite and adjoining rocks in the Upper Chulitna district. This report briefly describes the




Base from U.S. Geological Survey 1:250 000: Mt. McKinley and Talkeetna, 1958; Healy, 1956; Talkeetna Mountains, 1954

FIGURE 1.—The Upper Chulitna district showing area of plate 1.

stratigraphic and structural relations as we now understand them, with emphasis on ages of some of the rocks for which age control previously either was lacking, inconclusive, or misinterpreted. This report supersedes a preliminary geologic map with accompanying tables that was released in 1978 by Silberling, Jones, Csejtey, and Nelson.

Fossil localities referred to in the text are numbered sequentially from 1 through 57. Localities 1 through 47 are shown and tabulated on the geologic map of the Upper Chulitna district (pl. 1). Localities 43 and 44 are plotted on the more generalized small-scale map (fig. 6) that places the Upper Chulitna district in regional context. On this map the additional localities, 48 through 57, are also plotted.

## GENERAL SETTING

The Upper Chulitna district is located on the north side of the Chulitna River valley (fig. 1). This mountainous terrane, part of the Alaska Range, is geologically and topographically distinct from the Talkeetna Mountains to the south.

Rocks in the Upper Chulitna district are arranged in a series of parallel terranes that generally trend N. 30°–40° E. (pl. 1). Each terrane is characterized by a distinctive sequence or assemblage of stratified rocks and is separated from adjoining terranes by conspicuous faults. The terranes are named, from northwest to southeast, the Eldridge, Chulitna, West Fork, and Broad Pass, and their distribution is shown on plate 1 and in figure 6. An additional terrane, the Susitna, lies to the southeast of the Broad Pass terrane; its distribution is also shown in figure 6.

The Chulitna terrane is the key tectonostratigraphic unit in the Upper Chulitna district, as it contains a distinctive suite of rocks found nowhere else in Alaska or, for that matter, in North America. The most distinctive parts of the Chulitna terrane are ophiolitic rocks of Late Devonian age and Triassic redbeds; both of these differ markedly from nearby coeval rocks in other terranes. Other rocks present include upper Paleozoic flysch, conglomerate, sandstone, chert, and limestone, Lower Triassic limestone and Upper Triassic, Jurassic, and Cretaceous clastic rocks. The complex geologic history recorded by the rocks in the Chulitna terrane is important for understanding the tectonic evolution of southern Alaska, and it also contributes to our understanding of a much larger part of North America. For these reasons the bulk of this report is devoted mainly to a description of the rocks and structures of the Chulitna terrane: rocks of the other terranes are described in less detail because the geologic history they record is more fragmentary and less well known.

## CHULITNA TERRANE

### OPHIOLITE

Intensely sheared serpentinite is the most abundant rock type in the ophiolite; it generally lacks a preexisting igneous or metamorphic texture, but locally it exhibits bastite texture (Hawley and Clark, 1974, p. B8) typical of serpentinized harzburgite. Most of the serpentine is clinochrysotile and lizardite; both minerals indicate a lack of high-temperature metamorphism. Hawley and Clark (1974) report the occurrence of one massive chromite body with values as high as 39.5 percent $Cr_2O_3$. Such occurrences are rare, and we recognized no additional ones during our fieldwork. Associated with the serpentinite are scattered tectonic blocks of gabbro, some with possible cumulate texture, diabase, pillow basalt, basaltic breccia, and abundant red radiolarian chert. Many chert lenses occur within or capping pillow-basalt sequences, but some are isolated blocks engulfed in serpentinite.

Although the original ophiolitic sequence is now thoroughly dismembered, we found no evidence of mixing with nonophiolitic rocks, such as shallow-water carbonate rocks, clastic sedimentary rocks, or metamorphic rocks. Hence, this is not a serpentinite melange in the sense of Gansser (1974), which is characterized by a wider range of mixed rock types in a serpentinite matrix. The original ophiolite sequence probably was disrupted by tectonic shearing during emplacement of oceanic crust into the continental suprastructure, however that was accomplished. The ophiolite is included in the Chulitna terrane because it is in part structurally interleaved with other rocks characteristic of the terrane and because detritus derived from the ophiolite is found in Upper Triassic strata of the Chulitna terrane.

Fossils from red chert have been obtained from nine localities within the ophiolite belt, six (locs. 28–33) in the main belt, two (locs. 26 and 27) in a subsidiary northwestern belt, and one (loc. 26A) from a small faulted sliver on Long Creek. Locality 33 yielded poorly preserved radiolarians and sparse conodonts. The conodonts were identified by A. G. Harris and B. R. Wardlaw (written commun., 1977) as:

1 p element of *Polygnathus* cf. *P. glaber* Ulrich and Bassler,
1 N element (synprioniodinan) probably of *Polygnathus*, and
1 simple cone element fragment (possibly acodid).

They assign a Late Devonian (Famennian) age to this assemblage.

Well-preserved radiolarians from red chert in and overlying pillow basalt are currently being studied by Brian Holdsworth (written commun., 1977), who reports that these fossils include, among others, *Entactinosphaera*, which is close to Late Dovonian forms known from the Urals such as *E. aitpaiensis* Nazarov (1975) and a new species of *Holoeciscus* Foreman, a genus known only from rocks of Famennian age.

Based on these two independent determinations, a Late Devonian age for the ophiolite seems to be well established. This corrects an erroneous determination of a Jurassic age, reported by Jones, Pessagno, and Csejtey (1976), which resulted from the rudimentary level of understanding of Paleozoic radiolarian morphotypes that existed as recently as 1976 and because of the poor preservation of the fossils available at that time.

## ROCKS STRUCTURALLY ABOVE THE OPHIOLITE

Rocks lying structurally above the ophiolite within the Chulitna terrane include three fault-bounded lithologically distinctive belts: (1) a northeastern belt characterized by upper Paleozoic and Lower Triassic rocks unconformably overlain by Upper Triassic redbeds; (2) a northwestern belt characterized by a massive and very thick sequence of pillow basalt and interbedded limestone overlain depositionally by redbeds which grade upward into brown marine sandstone and shale; and (3) a central belt composed only of redbeds and overlying brown marine sandstone and shale. The Shotgun Creek or McCallie Creek faults separate the northwestern belt from the central belt, which at its northeast end is juxtaposed against the northeastern belt by the Blind Creek fault (pl. 1).

### NORTHEASTERN BELT

#### UPPER PALEOZOIC AND LOWER TRIASSIC ROCKS

Upper Paleozoic rocks comprise a heterogeneous suite of volcanic conglomerate, sandstone, and siltstone, greenish-gray to maroon chert and argillite, lenses of fossiliferous limestone, and flyschlike sandstone and siltstone with abundant trace fossils. The cherty rocks locally contain well-preserved radiolarians and abundant sponge spicules.

Stratigraphic relations of these diverse rocks are difficult to establish because unfaulted stratigraphic sequences are rare, and only a few fossiliferous beds have been adequately dated. Hawley and Clark (1974) record several Paleozoic fossil collections, the best of which (their loc. 3) contains brachiopods, bryozoans, and rare corals of Permian age that were found in a massive limestone. We recovered several brachiopods from a volcanic conglomerate or breccia at locality 22 (USGS loc. 26672–PC) that J. T. Dutro, Jr. (written commun., 1976), identified as:

*Fimbrinia* sp.,

a large reticularid, probably *Antiquatonia* sp.

an internal pedicle mold that might be *Rugatia*

Dutro assigns a Wolfcampian to early Leonardian (Early Permian) age to this assemblage.

Well-preserved radiolarians, conodonts, and abundant sponge spicules were extracted from several chert samples. Localities 21 and 23A yielded Mississippian forms and localities 23B and 24 yielded probable Permian radiolarians (Brian Holdsworth, oral commun., 1978). From these ages and a few observed depositional relations, a stratigraphic section can be pieced together, as shown in figure 2. We assume that the ophiolite forms the basement of the Paleozoic section. Greenish-gray argillite and chert of Late Devonian(?) and Mississippian ages succeed the ophiolite and are in turn overlain (unconformably?) by massive conglomerate containing cobbles and boulders of andesite and chert (fig. 3). Fossils from chert clasts at locality 23 include both conodonts and radiolarians. The conodonts were indentified by A. G. Harris (written commun., 1977) as:

4 p elements of *Polygnathus* cf. *P. glaber* Ulrich and Bassler

1 p element fragment of *P.* aff. *P. webbi* Stauffer

A Famennian (Late Devonian) age is indicated by these fossils; this age is about the same as determined for the red chert occurring in the ophiolite. Other clasts from this locality yielded radiolarians of Mississippian age (Brian Holdsworth, oral commun., 1977).

The volcanic conglomerate grades upward into volcanic sandstone and siltstone, and then into gray chert of Permian age. This succession is particularly well exposed in Long Creek, southwest of the Golden Zone mine. Elsewhere, in different exposures, the Permian chert is in turn gradationally overlain by a thin-bedded flyschlike unit containing abundant helminthoid feeding tracks. The flysch has yielded no datable fossils, but it grades upward into the highest Paleozoic unit consisting of a few tens of meters of massive crinoidal bryozoan limestone intercalated with red or brown fossiliferous argillite of middle(?) Permian age. In the overturned section about 1½ km west of Long Creek, the upper contact of the Permian limestone and associated clastic rocks is interpreted to be an unconformity at the base of Upper Triassic redbeds. East of Long Creek, however, near the Golden Zone mine, Lower Triassic rocks crop out in limited areas and are re-

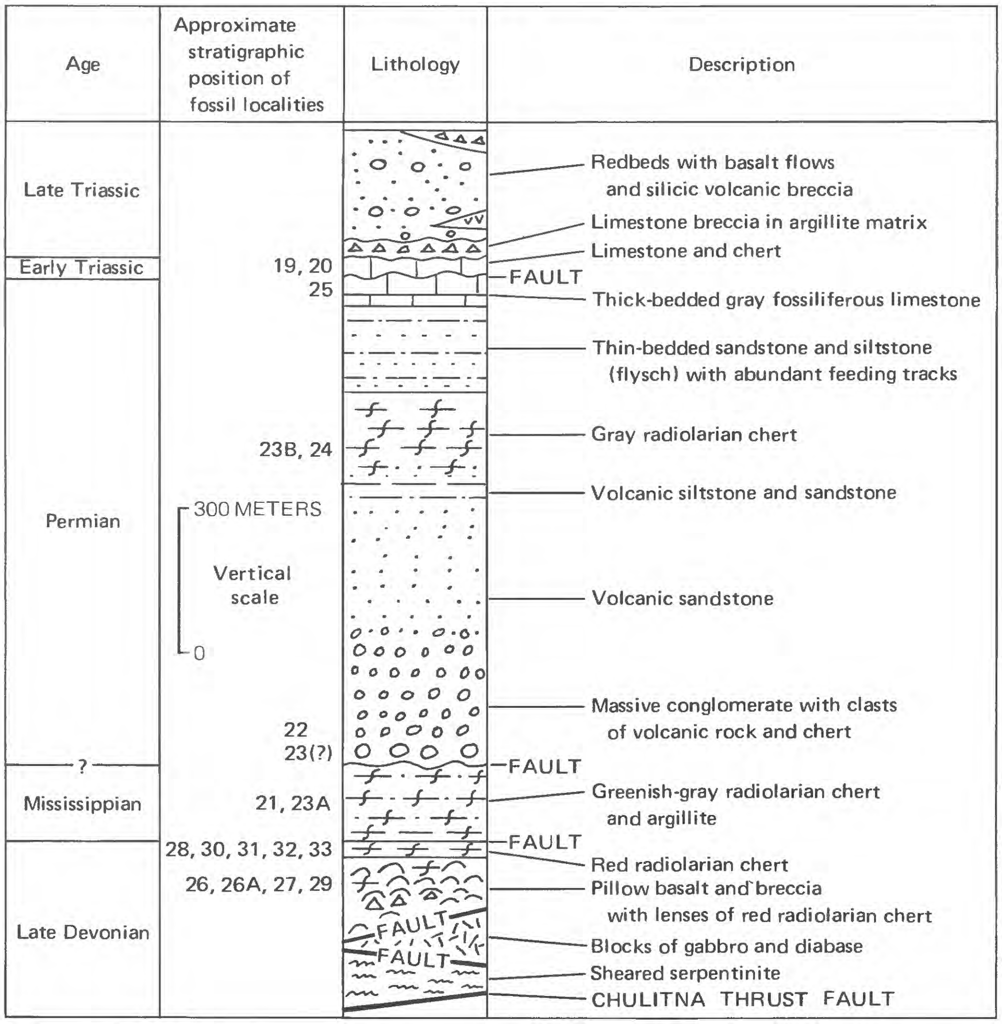



FIGURE 2.—Interpretation of stratigraphic sequence in northeastern belt of the Chulitna terrane. Composite schematic section pieced together from isolated fault-bounded exposures.

FIGURE 3—Volcanic conglomerate of late Paleozoic (Permian?) age, northeastern belt of Chulitna terrane.

garded as the youngest strata of the upper Paleozoic and Triassic unit locally preserved beneath this unconformity. Presumably the Lower Triassic beds were deposited on the Permian limestone unit, the next older unit known in the area, but their mutual contact is nowhere exposed.

Early Triassic (Smithian) ammonites were discovered in limestone at locality 20 by Hawley and Clark (1974, loc. 6 on their pl. 1) in a small, isolated artificial exposure near the Golden Zone mine. Several hundred more well-preserved specimens were collected from this locality during our field study. On the basis of the original collection, Silberling (in Hawley and Clark, 1974, p. B4–B5) reported that this ammonite fauna has close affinities both with that of the *Meekoceras gracilitatis* Zone in the conterminous United States and the correlative *Euflemingites romunderi* Zone of northern Canada and the Arctic, but that the closest resemblance is with the more southern faunas. On the basis of detailed comparisons of the abundant Chulitna material with correlative faunas from elsewhere in North America, K. M. Nichols (unpub. data, 1978) finds that the Chulitna fauna is essentially that of the more southern *Meekoceras gracilitatis* Zone, as typified in southeastern Idaho, and that it has, in fact, little in common with the fauna of the *Euflemingites romunderi* Zone which characterizes high paleolatitudes. Moreover, interpretation of the carbonate petrology of the fossiliferous Lower Triassic limestone by Nichols also suggests deposition in water temperatures characteristic of lower latitudes.

The relation of the Lower Triassic limestone at locality 20 to nearby strata, including flyschlike sedimentary rocks, tuffaceous argillite, and basalt, is obscured by glacial drift, soil cover, and thick vegetation. The strike and steep dip of the Lower Triassic rocks is about the same as those of nearby rocks, but the distribution of these rocks is at least partly controlled by faults. The limitation of this fossiliferous limestone to an exposure in a bulldozer cut in the tundra about 30 m long and 10 m wide precludes establishing any definitive relations.

A second locality (loc. 19) containing the same Early Triassic ammonites was discovered in 1976 several kilometers to the northwest of the original locality. Here only a meter or so of fossiliferous limestone and sugary textured diagenetic chert is exposed in fault contact with massive basalt overlain by red conglomeratic sandstone. On strike with locality 19, and about 200 m farther south in the gully from which the water ditch to the Golden Zone mine emerges, relations between the Lower Triassic limestone and younger strata are better displayed. Here the Lower Triassic limestone forms an outcrop belt a few tens of meters wide, and although it is tightly folded, at least 10 m of section is involved. In addition to the bed containing Smithian ammonites like those at locality 19, much of the limestone is coarsely crinoidal, some contains scattered grains of coarse quartz sand, and several beds are replaced by white secondary chert. On one side, the Lower Triassic limestone is faulted against Upper Triassic redbeds, but on the upsection side, it is unconformably overlain by a few meters of sandy limestone, the base of which is conglomeratic. Next above, across a covered interval of a few meters, is greenish-gray argillite containing blocks of diverse gray limestone throughout a stratigraphic thickness of several meters. This in turn grades upward into a meter or two of red mudstone with boulder-size limestone clasts which is succeeded by channel fillings of red conglomeratic sandstone. A few meters above the lowest redbeds is a 1-m-thick basalt flow.

The section described above seems to record two unconformities within the Triassic sequence. The lowest unconformity separates Lower Triassic limestone from sandy limestone and argillite containing displaced limestone blocks. These beds are at least as young as Late Triassic because conodonts from the limestone blocks have been identified by B. R. Wardlaw (written commun., 1978) as *Neogondolella polygnathiformis* (Budunov and Stefanov) of Karnian age. Brachiopods and fragments of *Halobia*-like bivalves also suggest a Late Triassic age for the limestone blocks. Rocks resembling these are not known to crop out anywhere else in the Chulitna area. A second unconformity is clearly recorded by the presence of the nonmarine redbeds, which contain debris from the Devonian ophiolite, and which elsewhere overlie Permian limestone and Paleozoic (Mississippian?) cherty argillite.

The very presence of Lower Triassic limestone in southern Alaska is a major anomaly, as it is the only occurrence of this age known along the entire western border region of North America. Force (1973) recently summarized the distribution of circum-Pacific Triassic rocks and pointed out that Lower Triassic rocks only occur in an inland belt, whereas Middle and Upper Triassic rocks rest unconformably on Paleozoic rocks in a coastal belt. Lower Triassic rocks within the Chulitna terrane are approximately in the middle of his coastal belt, and this is the only such locality recognized to date. The significance of this anomalous occurrence is discussed later in this report.

## REDBEDS

Red clastic rocks, including conglomerate, sandstone, and argillite, occur in several patches in the northeastern belt of the Chulitna terrane where they unconformably overlie either the Paleozoic or older Triassic strata. No fossils have been found in these rocks, but a Late Triassic age is indicated by their lithologic similarity to known Upper Triassic redbeds of the central belt (pl. 1), across the Blind Creek fault and by the presence of limestone clasts of Karnian age in disconformably underlying beds at one locality.

Conglomeratic rocks are abundant, and they contain well-rounded clasts, some more than 10 cm in diameter, of gabbro, diabase, serpentinite, basalt, tuffaceous chert, fossiliferous (Permian?) limestone, and red radiolarian chert of Late Devonian age. All these rock types are present nearby in the Paleozoic rocks, so the local derivation of the redbed clasts is obvious. Sandstone associated with these conglomerates contains grains of these same rock types. In addition, the sandstone contains sparse metaquartzite grains which suggest the same peculiar mixed provenance shown by the fossiliferous Upper Triassic redbeds of the Chulitna terrane farther to the southwest in the central part. At one place on Long Creek, rhyolitic clasts occur at the base of the redbeds, and a thick sequence of silicic tuffs and breccias occur at the top of the redbeds. The rhyolite clasts appear to be similar to rhyolitic breccias and flows that occur with redbeds interbedded with the pillow basalt and limestone unit in the northwestern belt.

## NORTHWESTERN AND CENTRAL BELTS

The northwestern and central belts of Chulitna terrane differ from the northeastern belt by the absence of Paleozoic and Lower Triassic strata and by the presence of Upper Triassic, Jurassic, and Cretaceous strata (pl. 1). In the northwestern and central belts, four map units are now recognized, and they are described in ascending order, as follows.

### LIMESTONE AND PILLOW BASALT

Hawley and Clark (1974, p. B6) briefly described a strikingly banded unit of interlayered limestone and pillow basalt which they regarded either as the youngest part of the Triassic section or something still younger. We now understand that this limestone and pillow basalt unit is the lowest of the Upper Triassic units in the sections of which it is a part and that it stratigraphically underlies conspicuous redbeds of Late Triassic age. The limestone and basalt unit crops out only in the northwestern belt of the Chulitna terrane; it is not associated with the fault-bounded strips of redbeds in the central belt of the terrane.

The thickness of the limestone and pillow basalt unit is difficult to measure because it is extensively faulted and repeated several times, and its base is not preserved. At least several hundred meters of basalt is exposed in continuous sections in which limestone occurs most abundantly in the upper part. There, four or five thick beds of limestone, each as much as several tens of meters thick, are separated by thin basalt flows or by layers of aquagene tuff containing scattered pillows and broken pillows. The tuff is generally sheared and altered to featureless chloritic rock. Thin flows and breccias of rhyolitic rocks associated with redbeds occur interbedded with basalt at the head of Shotgun Creek and also about 3 km to the north. These occurrences may represent the same bed repeated by faults. Similar fragments of rhyolite are at the base of the redbeds on Long Creek in the northeastern belt. At one locality in the northern part of the belt, a thin unit of brown quartzite occurs with massive limestone.

The limestone, mainly thick bedded, is recrystallized in most places to marble in which are preserved only large fragments of poorly preserved colonial corals and cross sections of large thick-shelled megalodontid(?) bivalves up to 20 cm in length. One sample from a less recrystallized limestone interlayer preserves original lime mud-supported to mud-filled textures. This lime wackestone and packstone contains abundant echinoderm ossicles along with mosaic calcite replacements of colonial coral fragments and shelly bioclasts. Bioclasts that were originally aragonitic have undergone selective dissolution, indicating diagenesis affected by meteoric waters. This evidence, along with the kinds of fossils and bioclasts found in the limestone interstratified with the pillow basalt, suggests a shallow marine site of deposition.

Several tens of meters of uninterrupted limestone forms the stratigraphically highest part of the limestone and pillow basalt unit. Beds low in this limestone layer are mostly vaguely peloidal lime mudstone containing few bioclasts but having abundant fenestrae irregularly distributed parallel to the bedding. These beds, which are interpreted as intertidal desiccated deposits, contain some layers distinguished in outcrops by conspicuous cross sections of large megalodontid(?) bivalve shells, an association like that in the peritidal Lofer facies of Dachsteinkalk in the Upper Triassic of the northern Alps as described by Fischer (1964). The highest beds of limestone, directly beneath the redbed unit, are grainstones composed of abundant crinoid ossicles along with peloids and bioclasts which include micritized molluscan shell fragments whose interiors have undergone dissolution and have been filled by sparry calcite. Again, a shallow marine, peritidal environment of deposition and diagenesis is indicated.

None of the organic remains in the limestone and pillow basalt unit is definitively age diagnostic. Nonetheless, large megalodontid bivalves of the kind probably represented by cross sections seen in the rocks of the Chulitna terrane are not known in Triassic rocks older than Karnian and are most characteristic in Norian rocks. A single incomplete but well-preserved brachiopod shell, tentatively referred to *Spondylospira*, also suggests a Norian age for the unit.

### REDBEDS

Conformably overlying the limestone and pillow basalt unit is a thick sequence of volcanogenic redbeds, including red argillite, siltstone, sandstone, and conglomerate, brown marine fossiliferous sandstone, pink to light-gray dense limestone, and white quartz-pebble conglomerate. A layer of light-greenish-gray volcanic argillite at the base of the unit rests on peritidal limestone of the underlying limestone and pillow basalt unit. Similar redbeds occur in the central belt of the

Chulitna terrane, but there they lack a depositional base.

Although much of the detrital material composing the redbeds is of mafic volcanic (dominantly basaltic) origin, a diverse source terrane is indicated by the presence of thick lenses (up to 10 m or more) of nearly pure white quartz-pebble conglomerate, whereas other conglomerate contains very abundant clasts of angular red radiolarian chert. We presume that the source of the chert is the nearby ophiolite, and this is borne out by similarities in radiolarian faunas. However, we have not identified clasts consisting of the other components of the ophiolite, such as we found in the northeastern belt of the Chulitna terrane. In thin sections of finer grained parts of the redbeds, quartzose sand grains and granules are mostly foliated polycrystalline metaquartzite rock fragments. Detrital white mica is also present in these rocks and may have had the same source. The principal sources for coarse clastic detritus found in the redbeds represents an unusual combination. Basaltic grains were probably derived in part from the Upper Triassic shallow marine or subaerial basalt depositionally associated with the redbeds and in part from the ophiolite. Red chert clasts were derived from the ophiolite, which thus must have been exposed during Triassic deformation. Quartzite clasts and mica flakes indicate substantial contribution of clastic material from a crystalline terrane of siliceous metamorphic rocks.

The upper part of the redbed unit grades into overlying brown fossiliferous marine sandstone and siltstone. The transition occurs through several tens of meters in which marine and nonmarine beds alternate. Beds a meter or more thick commence with brown sandstone containing marine mollusks and *Heterastridium* and grade upward directly into red sandy nonfossiliferous siltstone.

A thick sequence of Upper Triassic redbeds forms a separate central belt bounded on the northwest by the Shotgun Creek fault and on the southeast by the Blind Creek and Copeland Creek faults. These redbeds are faulted against the Upper Triassic brown sandstone and siltstone or the limestone and pillow basalt units of the northwestern belt on the northwest, and on the southeast they structurally overlie the ophiolite or are interslivered with serpentine related to the ophiolite. They differ from the redbeds in the northwestern belt by containing thick lenticular nonpillowed basalt flows. Several thin limestone and brown sandstone beds have yielded marine fossils.

Two ammonite collections from the ridge crest east of Christy Creek are in a mainly normal stratigraphic sequence. The stratigraphically lower collection (loc. 15) contains a juvavitid of latest Karnian to middle Norian age. The higher collection (loc. 14) contains: *Hauerites* n. sp. (="*Metacarnites* sp." of McLearn, 1960), the age of which is middle Norian according to E. T. Tozer (written commun., 1974), *Indojuvavites*, also of middle Norian age, and *Rhacophyllites*, well-dated occurrences of which are restricted to the middle and late Norian. Farther southwest within the redbeds, ammonites provisionally identified as the lower middle Norian species *Juvavites magnus* McLearn were collected at localities 16 and 17. Based on these fossils, the redbeds of the central belt and the limestone and pillow basalt unit of the northwestern belt are approximately contemporaneous.

### BROWN SANDSTONE AND ARGILLITE UNIT

Thick-bedded brown-weathering quartzose limy sandstone gradationally overlies the redbeds in the northwestern and central belts. This in turn grades upward into grayish-brown argillite with abundant yellowish-brown limestone nodules and minor sandstone. In the lower part of the section fossils are locally very abundant and consist of colonial corals, snails, bivalves (especially *Cassianella* and *Septocardia*) in the central belt and some of these plus the distinctive late Norian (Late Triassic) hydrozoan *Heterastridium* (found, for example, at loc. 13) in the northwestern belt. A single specimen of the long-ranging Norian ammonite genus *Placites* was collected at locality 13. In keeping with the shallow marine character of this fauna, large-scale low-angle tabular crossbedding of the sandstone observed at one locality north of Long Creek is suggestive of a beach deposit.

Fossils are rare in the argillaceous part of the section, but Early Jurassic ammonites and bivalves were found in a silty limestone lens at locality 8 (USGS Mesozoic loc. 31266). These fossils were identified by R. W. Imlay (written commun., 1976) as:

*Paracaloceras rursicostatum* Frebold
*Badouxia canadense* (Frebold)
*Weyla* sp.
*Lima*? sp.
*Eopecten*? sp.

An early Sinemurian age is assigned by Imlay to this fauna. As the lowest beds of the sandstone and argillite unit contain definite late Norian fossils, deposition evidently continued into the Early Jurassic, although fossils of Hettangian age have not been found.

The total thickness of the unit is difficult to estimate because of complex folding, but at least 1,000 m is probably present.

### ARGILLITE, SANDSTONE, AND CHERT UNIT

The youngest stratigraphic unit of the Chulitna terrane consists of a heterogeneous assemblage of dark-gray argillite, gray to black chert, thin beds of fossiliferous limestone composed of comminuted *Buchia* shells, and sandstone of two types—thick-bedded sandstone with abundant fragments of *Inoceramus*, and thin-bedded gray micaceous sandstone. These rocks occur mainly in the northern part of the Upper Chulitna district, but a thin septum of sheared black argillite occurs along a fault within the limestone and pillow basalt unit. Because of complex isoclinal folds, abundant faults, and only scattered observations, little is presently known concerning the thickness and stratigraphic relations of these rocks to one another or to contiguous units. They appear to overlie Triassic and Lower Jurassic brown sandstone and argillite (pl. 1), but the contact may be a fault.

Fossils from this unit are of Late Jurassic and Early Cretaceous age. Radiolarians were extracted from chert at localities 5 and 6 (pl. 1) and identified by E. A. Pessagno, Jr. (written commun., 1976), as follows:

*Locality 5*

*Parvicingula* cf. *P. procera* Pessagno
*P. turrita* (Rüst)
*Praeconocaryomma mamillaria* (Rüst)
*Mirifusus* sp.
*Emiluvia pessagnoi* Foreman
*Hsuum maxwelli* Pessagno

This assemblage is indicative of Zone 1 or Zone 2 of Pessagno (1977) and is thus of Callovian to early Tithonian (Late Jurassic) age.

*Locality 6*

*Parvicingula citae* Pessagno
*P. boesii* (Parona)
*P. rothwelli* Pessagno
*P.* sp.
*Pseudodictyomitra* sp.
*Thanarla conica* (Aliev)
*Praeconocaryomma* cf. *P. prisca* Pessagno
*Archaeodictyomitra apiarum* (Rüst)

Pessagno assigns this assemblage to his Zone 5, subzone 5C (Pessagno, 1977) of late Valanginian age. This determination is strongly supported by the stratigraphic occurrence of the sample, which is underlain within 2 meters by *Buchia*-bearing limestone of Valanginian age and immediately overlain by *Inoceramus*-bearing sandstone of Hauterivian to Barremian age.

No fossils were found in the micaceous sandstone which appears to overlie the *Inoceramus*-bearing sandstone. Because other similar dated micaceous sandstones in southern and western Alaska are Albian or younger, this sandstone could be the same age.

## DEPOSITIONAL HISTORY OF THE CHULITNA TERRANE

The geologic record of the Chulitna terrane commences with formation of oceanic crust (ophiolite) in Late Devonian time, as evidenced by the presence of radiolarian chert of that age intercalated in pillow basalt. Deposition of deep-water radiolarian chert and argillite on top of the basalt continued from Late Devonian into the Mississippian, with the color of the chert changing from red at the base to greenish gray higher in the section. Presumably, this depositional site was far from any landmass, as no terrigenous detritus has been recognized.

Conditions changed markedly after Mississippian time, with the influx of coarse conglomerate and breccia composed of andesite, tuff, and chert clasts. The chert clasts appear to have been derived from the underlying chert unit, but the source of the andesite has not been found. Presumably, an active volcanic arc was nearby that shed large blocks into deeper water, but that source seems to have disappeared. The time of initiation of coarse clastic sedimentation is not known precisely because of a paucity of fossils within the sequence. It continued at least into Early Permian time, as evidenced by the presence of brachiopods of that age within the matrix of the conglomerate.

The clastic unit fines upward, from conglomerate through flyschlike sandstone and siltstone to chert, also of Permian age. Following deposition of the chert, another clastic depositional cycle commenced with fine-grained nonvolcanogenic flysch with abundant feeding tracks and ended in shallow-water clastic limestone that contains beds of red fossiliferous argillite. The limestone is also Permian in age, but its position within the Permian has not been determined, nor has the relation of the Lower Triassic ammonite-bearing limestone to the Permian limestone been established. We presume that a depositional hiatus separated the two, but as they are nowhere in contact, it is impossible to reconstruct this important boundary.

Conditions changed drastically during Triassic time, with initiation of deposition of nonmarine redbeds and extrusion of large quantities of basalt and silicic volcanic rocks. Several significant events occurred: the depositional marine basin that had persisted from the Late Devonian was destroyed, and the older rocks were folded and faulted and were incorporated into a continental framework. Evidence of folding is seen by the presence of ophiolite debris in the redbeds and by the unconformity at the base of the redbeds that cuts across several of the older units. Incorporation into a continental framework is shown by the abundance of detrital quartz, metaquartzite, and mica that also is found in the redbeds.

Facies relations of the Late Triassic rocks, as expressed in the three fault-bounded, juxtaposed belts of the Chulitna terrane, show a transition from nonmarine redbeds, minor basalt, and abundant silicic volcaniclastic rocks on the southeast to entirely marine basalt, minor silicic volcaniclastic rocks, and abundant limestone with rare quartzose clastic rocks on the northwest. This suggests that a northeast-trending shoreline existed with a continental mass lying to the southeast and more open marine conditions to the northwest. A few observations of crossbedding in sandstone tend to support this reconstruction.

The significance of the Late Triassic volcanism is uncertain. The bimodal character of basalt and rhyolite is rare in Alaska, although it is well developed in coeval rocks in southeastern Alaska (Muffler, 1967; H. C. Berg, D. L. Jones, and Peter Coney, unpub. data). Presumably this volcanism reflects rifting, although what was rifted and where it occurred are unknown.

Subsequent deposition within the Chulitna terrane records the cessation of volcanism and a gradual return to shallow-water marine conditions during latest Triassic time. From then on, into the Early Cretaceous, the sequence is incomplete, but it seems to record dominantly deep-water sedimentation until late Valanginian time when shallow-water limestone was deposited. From this time on, deposition within and outside of the Chulitna terrane appears generally similar.

### STRUCTURE

The general structural style within the Chulitna terrane is that of stacked thrust sheets folded and faulted into a large complex synform overturned to the southeast. The northwestern limb of the synform is sheared along several nearly parallel high-angle (thrust?) faults. The southeastern limb is also complexly faulted and sheared, so that the entire lower unit of upper Paleozoic and Lower Triassic rocks is missing south of Copeland Creek and the Upper Triassic redbeds are in fault contact with the ophiolite. The southeastern limb also displays repetition and imbrication of redbeds and serpentinite; this structural mixing is most pronounced in the southwest corner of the area. A major northeast-trending fault, the Shotgun Creek fault, separates the two major limbs of the synform. Rocks in the core of the synform are intensely crumpled and refolded; no attempt has been made to map these smaller structures. The general structural style is shown on a series of cross sections (pl. 1). We interpret the Chulitna terrane to be an allochthonous assemblage thrust northward (?) onto deformed Cretaceous flysch and then redeformed by southeastward-verging folds and northwest-dipping faults. Timing of movement along the various fault strands is complex and not well understood. A master "sole fault" along which the assemblage moved originally has not been identified; it has probably been modified by younger structures.

## WEST FORK TERRANE

A major thrust fault, designated the Chulitna fault (equals in part the Upper Chulitna fault zone of Hawley and Clark, 1974, p. B11) separates the Chulitna terrane from the structurally underlying West Fork terrane. This fault dips steeply to the northwest but locally flattens to a moderate dip.

The West Fork terrane consists of three fault-bounded mappable units. These are described below in descending structural order. It must be stressed that stratigraphic relations have not been established nor are the ages of some of the rocks adequately determined. Another terrane, Broad Pass, lies to the southeast of the West Fork Terrane and is described further on.

### ARGILLITE, CHERT, AND SANDSTONE

Multiple deformed isoclinally folded beds of argillite, chert, and sandstone structurally underlie the ophiolite of the Chulitna terrane throughout most of its length. Gray to black chert locally predominates, but argillite and thin-bedded sandstone are the most common rock types; on Long Creek, massive graded siltstone and sandstone with interbedded argillite form the bulk of exposures.

Several samples of chert have yielded well-preserved radiolarians. From dense black chert immediately below silica carbonate rock at localities 35 and 36 the following forms were obtained and identified by Blome (see pl. 2):

- *Paronaella* sp. A.
- *Parvicingula* aff. *P. khabakovi*
- *P.* sp. A.
- *Hsuum*(?) sp. indet.
- *Praeconocaryomma magnimamma* (Rüst)
- *P. mamillaria* (Rüst)
- *Archaeodictyomitra* cf. *A. rigida*

Samples of chert from nearby locality 36 yielded about the same fauna (fig. 4) as did dark-gray chert from locality 34 on Long Creek.

These radiolarians are indicative of a Callovian to early Tithonian (Late Jurassic) age, based on the diagnostic ranges of *Praeconocaryomma magnimamma*, *P. mamillaria*, and *Parvicingula* aff. *P. khabakovi*, as established by Pessagno (1977) and shown in figure 5. The base of radiolarian zone 1 is characterized by the first appearance of *Parvicingula*, and *P. khabakovi* first appears, along with *Praeconocaryomma mamillaria*, in the upper half of this zone. *Praeconocaryomma mag-*

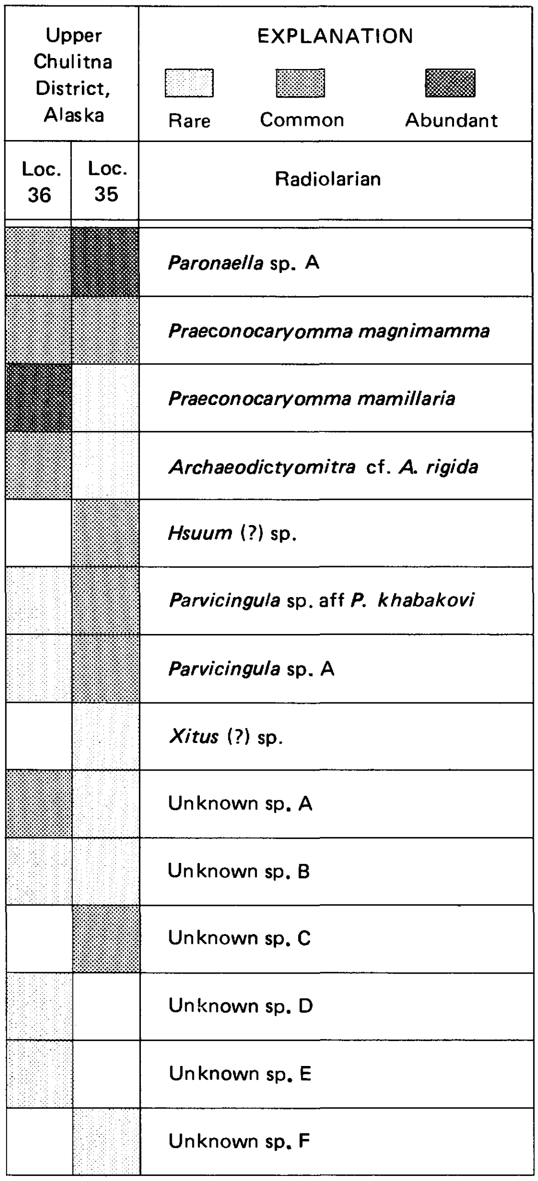



FIGURE 4.—Abundance of Jurassic (Callovian to early Tithonian) radiolarians from localities 35 and 36 (see pl. 1 for fossil locations).

*nimamma* ranges to the top of subzone 2A of zone 2 and is not recorded from younger beds. Based on these data, the dated cherts appear to fall within the range of radiolarian zones 1 to subzone 2A (fig. 5).

Fault-bounded blocks and lenses of thick-bedded (up to 1 m) fossiliferous phosphatic limestone, siltstone, sandy limestone, and limy conglomerate occur within the argillite, chert, and sandstone unit. These bodies range in size from about 50 m to over a kilometer in length. Early Jurassic ammonites and bivalves which were found at five localities (locs. 37 through 41, pl. 1), were identified by R.W. Imlay (written commun., 1976) as follows:

*Locality 37 (USGS Mesozoic loc. 31260)*
*Arnioceras* cf. *A. densicosta* (Quenstedt)
*Weyla* sp.

*Locality 38 (USGS Mesozoic loc. 31263)*[1]
*Arnioceras* cf. *A. densicosta* (Quenstedt)
*Weyla* sp.
*Pleuromya* sp.

*Locality 39 (USGS Mesozoic loc. 31264)*
Arietitid ammonite
*Badouxia canadense* (Frebold)
*B. columbiae* (Frebold)

*Locality 40 (USGS Mesozoic loc. 31265)*
*Arnioceras* cf. *A. densicosta* (Quenstedt)
*Lytoceras*? sp.
belemnite fragment
*Pleuromya* sp.

*Locality 41 (USGS Mesozoic loc. 31262)*
*Arnioceras* cf. *A. densicosta* (Quenstedt)
*Pleuromya* sp.

Fossils from all these localities are indicative of an early Sinemurian (Early Jurassic) age. Hence, rocks of Early and Late Jurassic age are juxtaposed without any apparent stratigraphic order. In places, as at locality 41, the undeformed Lower Jurassic sandstone contrasts markedly with that of the enclosing highly sheared, recrystallized phyllitic argillite.

A lens or fault block of red conglomeratic sandstone was found near the southwest end of the map area (pl. 1). Ammonite-bearing phosphatic limestone occurs nearby, but the relation between the two are obscure. These redbeds differ from the redbeds of the Chulitna terrane in that they lack abundant fragments of mafic volcanic rocks. Instead, their dominant clasts are of greenish-gray very fine grained siliceous crystal tuff similar to that of the adjoining massive tuff unit (see below). Another thin conglomeratic bed near the north end of the map area contains abundant pebbles of crystal tuff in a crystal-lithic tuff matrix.

The phosphatic limestone is an unusual occurrence, as rocks of this type have not been previously reported from the central Alaska Range and because it represents slow deposition in a basin without sources of abundant clastic detritus. X-ray analysis of the phosphatic limestone by R. A. Gulbrandsen shows the presence of kaolinite, a little chlorite, and carbonate fluorapatite with a $CO_2$ content of about 1.2 percent. According to Gulbrandsen (1970), $CO_2$ content of comparable value is characteristic of phosphate deposition in offshore areas in association with abundant chert and argillite and little or no carbonate, as in the Per-

[1]Fossils from this locality, collected by Hawley and Clark (1974, p. B5, loc. 4), were originally determined to be bivalves of late Paleozoic age. However, we found no evidence for fossils older than Early Jurassic at this locality, and we assume that the bivalves were misidentified. This change in age is significant for the structural interpretation of the rocks above and below the ophiolite of the Chulitna terrane.

| Series | Stage | Zone | Subzone | Numbered "shorthand" for zones | |
|---|---|---|---|---|---|
| Lower Cretaceous (part) | Berriasian (part) | *Parvicingula altissima* — — *Mirifusus* sp. | | 5 (Part) | |
| | Upper Tithonian | | | | |
| Upper Jurassic | Middle Tithonian | *Parvicingula altissima* | | 4 | |
| | Lower Tithonian | *Trilonche ordinaria* — — *Parvicingula hsui* | | 3 | |
| | | *Emiluvia hopsoni* | *Mirifusus baileyi* | 2 | 2B |
| | Lower Tithonian to Callovian | | *Mirifusus guadalupensis* | | 2A |
| | | *Parvicingula* s. s. — — *Emiluvia hopsoni* | | 1 | |
| | | *Eucyrtidium* (?) *ptyctum* — — *Parvicingula* s.s. | | 0 | |

FIGURE 5.—Radiolarian zonation for the Upper Jurassic Series of the California Coast Ranges (modified from Pessagno, 1977).

mian Phosphoria Formation. This suggests that the Upper Jurassic chert and argillite of the West Fork terrane and the lenses of blocks of Lower Jurassic phosphatic limestone originally may have formed a coherent stratigraphic sequence, which is now disrupted by folding and faulting. The coeval Lower Jurassic limy siltstone of the Chulitna terrane (loc. 8) has no detectable phosphate.

### MASSIVE TUFF

A very thick unit of massive cliff-forming dark-grayish-green crystal tuff with minor fossiliferous sandstone and conglomerate lies in fault contact immediately southeast of the argillite, chert, and sandstone unit. Original relations between these two units are obscure, but several lines of evidence suggest that the massive tuff unit now structurally underlies the argillite, chert, and sandstone unit and may, in part, be the older of the two. Superposition is suggested in the large overturned syncline in the southwestern part of the belt, which contains argillite and sandstone in the center and massive tuff on the limbs. Fragments and pebbles of crystal tuff occurring in the argillite, chert, and sandstone unit suggest that they were derived from the massive tuff.

The massive tuff unit has faint bedding features, including irregular lamination and color banding that ranges from light cream to dark green, but these features characteristically are obscured by a heavy cover of lichens and also by the fact that the rock seldom splits along bedding planes. Hence, joints and fractures are emphasized on outcrop surfaces rather than stratification planes.

Relatively coarse-grained patches and layers of the tuff consist mostly of calcitized plagioclase crystals up to 0.5 mm in size along with mafic volcanic and indeterminate lithic grains set in a cryptocrystalline impure siliceous matrix. Finer grained layers are mostly cherty matrix with sporadic crystals up to about 0.1 mm in size. Radiolarians are occasionally seen as ghosts, but they are not well enough preserved for identification. In contrast, the Paleozoic cherty tuff in the Chulitna terrane and the adjoining Upper Jurassic chert of the West Fork terrane contain abundant siliceous skeletal material, including sponge spicules and well-preserved radiolarians.

Fossils were found at one place (loc. 42, USGS Mesozoic loc. 31261) within the massive tuff unit in 2- to 3-m-thick beds of conglomeratic sandstone that contain phosphatic pellets. These coarse clastic rocks are overlain by 30 m or more of dark-gray siltstone with minor beds of conglomerate, which are in turn overlain by fine-grained crystal tuff similar to that forming the bulk of the unit. Fossils from sandstone were identified by R. W. Imlay (written commun., 1976) as follows:

*Arctoasteroceras jeletskyi* Frebold
*Paltechioceras* (*Orthechioceras*?) sp.
*Weyla* sp.

Imlay believes that these fossils indicate a late Sinemurian (Early Jurassic) age. Hence, they are younger than the lenses or blocks of ammonite-bearing phosphatic rock of early Sinemurian age that occur in the argillite, chert, and sandstone unit. This difference in age indicates that the two units are not now in normal stratigraphic sequence. Perhaps they represent partly coeval facies that have been tectonically juxtaposed. Radiolarians obtained from chert clasts in a thin conglomerate bed about 20 m above the ammonite-bearing sandstone are of late Paleozoic, probably Mississippian, age.

The base of the massive tuff unit is unknown, as is the internal structure and the age of the bulk of the formation. The Jurassic ammonites cited above occur at the western contact in beds that are right side up and which dip steeply to the west. Hence, these appear to be among the youngest exposed beds of a unit which may be several thousand meters thick. Because of this great thickness, we assume that some of the rocks may be of Triassic age, but no fossils are available to prove this.

## BROAD PASS TERRANE

The west side of the Chulitna River valley is underlain by rocks of the Broad Pass terrane. These rocks are a poorly exposed, complexly deformed assemblage of chert, cherty tuff, black argillite, phyllite, volcanic graywacke, and lenses and pods of limestone. This terrane can be traced northeastward to beyond the Cantwell (fig. 6) where it appears to terminate against the Denali fault (Hickman and others, 1977). Because of poor exposures, difficulty of access in deep, narrow canyons, and pervasive shearing, the internal structure and stratigraphic relations of the various rock types remain unknown. The dominant rock types are interbedded cherty tuff, chert, and argillite. The cherty tuff is greenish gray, green, and black, and well bedded in beds up to 10 cm thick that exhibit slight grading from silt-size clasts at the base to black argillite at the top. Vitroclastic textures are well developed, indicating explosive volcanic activity as a main source of clastic material (fig. 7).

The presence of a large lens of massive volcanic (andesitic?) graywacke south of Long Creek is additional evidence for volcanism, as is the large block of andesitic flows and volcanic sedimentary rocks exposed due west of Cantwell. These later rocks, considered by Hickman, Craddock, and Sherwood (1977) to be of Triassic age, are undated and are separated from the main belt of the Broad Pass terrane by the Cantwell fault.

Two large belts of gray phyllite that contain no volcanogenic detritus crop out southwest of Long Creek and east of Cantwell (fig. 6). In addition, five blocks or lenses of limestone are known. The best known and most readily accessible (loc. 48, fig. 6) is exposed along the Denali highway 4–5 km east of Cantwell. This massive gray-weathering limestone contains abundant corals which W. A. Oliver (written commun., 1976) has identified as:

*Alveolites* sp.
Auloporoid related to *Romingeria* sp.
*Lyrielasma* (s.l.) sp.
cf. *Microplasma* sp.

Oliver considers this assemblage to be of pre-Late Devonian and probably Early or Middle Devonian age. Blodgett (1977) reports the brachiopods *Leiorhynchus* spp., *Emanuella* sp., and *Ladjia* sp. from this locality, together with the trilobite *Dechenella* (*Dechenella*) sp. He considers this assemblage to be indicative of a Givetian (late Middle Devonian) age.

Other fossils were found in small pods of folded limestone on Long Creek (locs. 45 and 46, pl. 1). Locality 45 yielded a massive stromatoporoid and *Dendrostella*(?) sp., and locality 46 contains *Labechia* sp. and *Favosites* sp. W. A. Oliver (written commun., 1977) considers these fossils indicative of a Middle Devonian or older age. Conodonts from locality 47 (pl. 1) are assigned by A. G. Harris (oral commun., 1978) a Late Silurian or earliest Devonian age. A small collection of poorly preserved fossils was obtained from a limestone locality northeast of Cantwell by Hickman and Craddock (1975), who report the presence of unidentified corals, stromatoporoids, *Astraeospongia* sp., and other fossils to which they assign a Silurian(?) or Middle or Late Devonian age. All the limestone bodies thus appear to be older than the latest Devonian ophiolite of the Chulitna terrane.

Radiolarians obtained from cherty tuff at several localities within the Broad Pass terrane seem to be distinctly younger than the limestone blocks and lenses. The best preserved radiolarians were found at localities 49 and 50 (fig. 6). Locality 49 contains spheroids with large complexly bladed spines similar to forms known from Upper Devonian and lower Carboniferous rocks, as well as fragments of *Paronaella*(?) that may be post-Devonian in age. Locality 50 contains abundant *Paronaella* similar to *P. impella* and *P. turgida* described by Ormiston and Lane (1976) from Osagean (Mississippian) rocks of Oklahoma. Forms like these are not known in nearby rich radiolarian assemblages of Late Devonian (Fammenian) age, so a Mississippian age seems likely. Other radiolarian-bearing localities (locs. 43 and 44) yield poorly preserved faunas of late Paleozoic aspect.

The mixture of older shallow-water coral-bearing limestone with much younger deep-water volcaniclastic sedimentary rocks implies a major juxtaposition of unlike assemblages within the Broad Pass terrane. At locality 47 on Copeland Creek the limestone is bounded

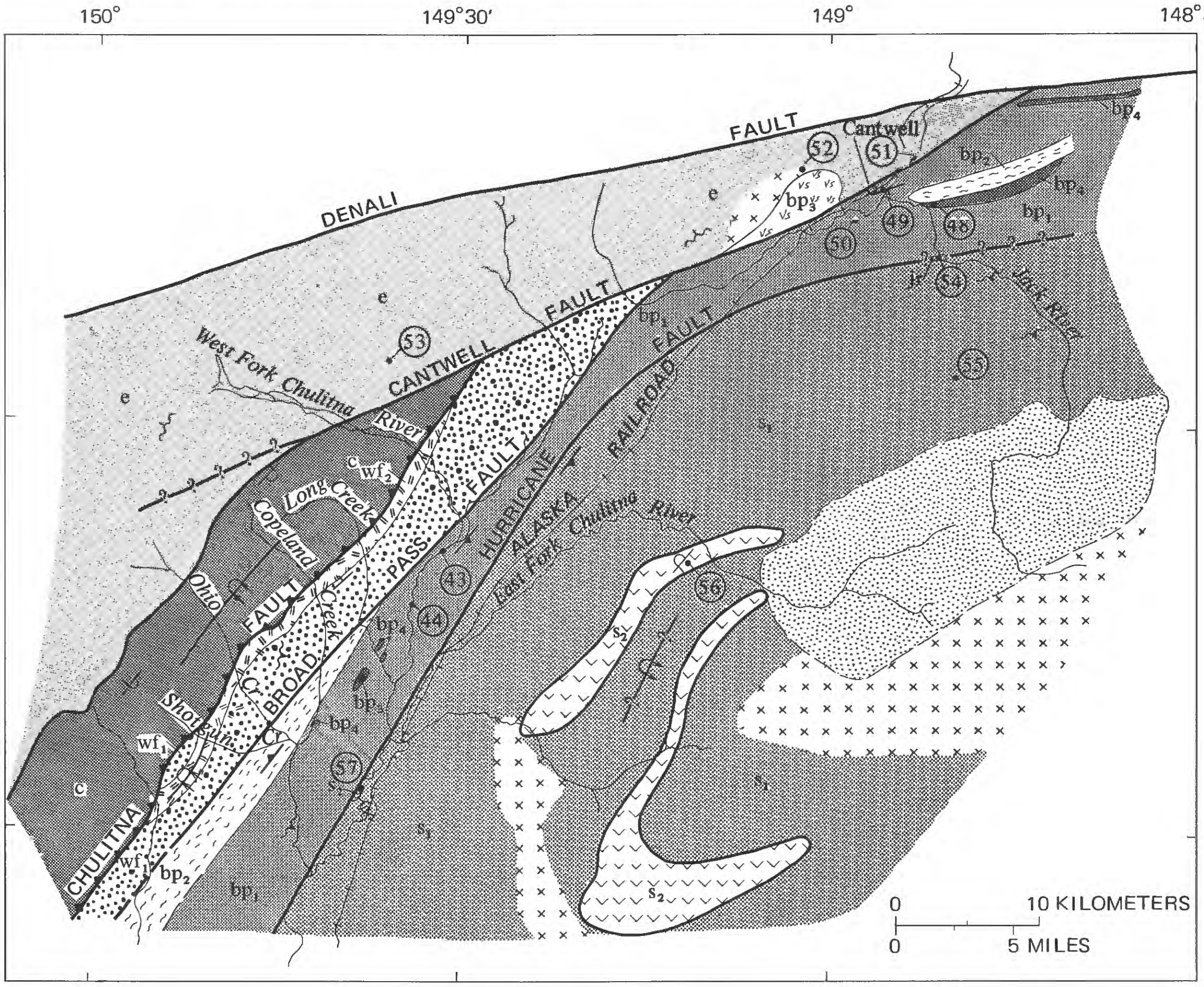



FIGURE 6.—Regional geologic sketch map of Upper Chulitna district and adjacent areas showing distribution of terranes and fossil localities.

on one side by serpentinite. The limestone blocks may represent either infolded remnants of a once continuous thrust sheet, emplaced on top of the younger volcanogenic suite, or they may represent slide blocks (olistoliths) emplaced during deposition. The large tracts of gray phyllite may also be allochthonous with respect to the volcanogenic rocks and may have been emplaced along with the limestone.

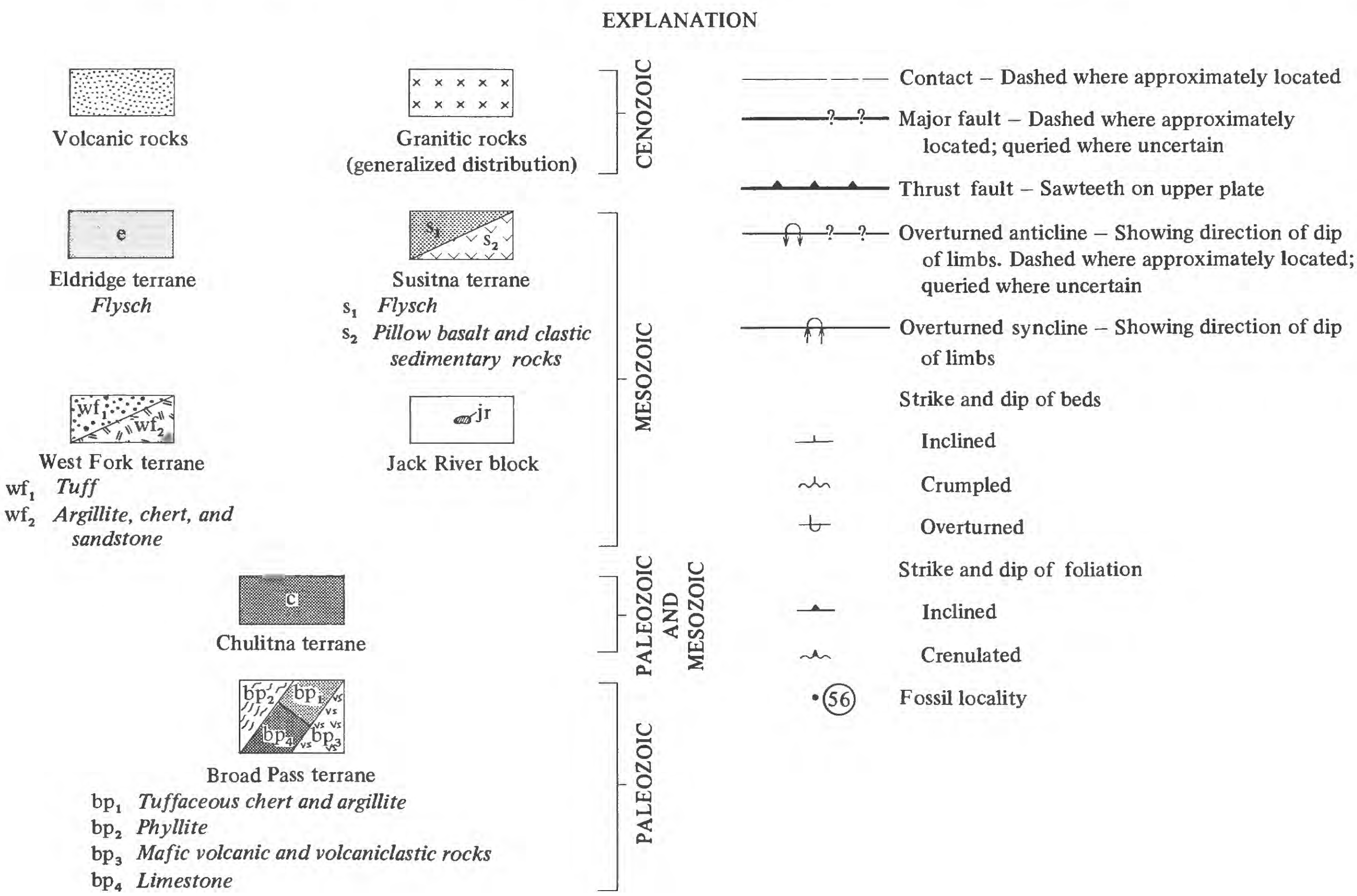
In view of the poorly established age of the volcanogenic cherts and tuff, detailed corrections are unwarranted, except to point out that comparable lower Carboniferous rocks are unknown elsewhere in southern Alaska. Lower Carboniferous rocks do occur in southeastern Alaska, but are nonvolcanic chert and fossiliferous limestone.

Paleozoic limestones comparable in age to those of the Broad Pass terrane are rare south of the Denali fault and are known only from southeastern Alaska (see Churkin and Eberlein, 1977) and in the Alaska Range to the west (Reed and Nelson, 1977). In none of these areas, however, is the geologic setting similar to that of the Broad Pass area, and a specific correlation of terranes is not implied.

The Broad Pass terrane is bounded on the northwest by the Broad Pass fault and on the southeast by the Hurricane fault. Both these faults appear to have very young (Holocene?) vertical displacements of at least 1,000 m or more with the southeast side up in each case. However, these movements probably represent reactivation of older, more fundamental faults along which the Broad Pass, West Fork, and Susitna terranes were juxtaposed. Whether these older movements were fundamentally of a strike-slip or thrust nature is undetermined.

## JACK RIVER BLOCK

Rocks exposed (loc. 54) within an area of about 2½ square kilometers on and east of Jack River, 6 km southeast of Cantwell, may be somehow associated with but are lithologically and temporally different from the rocks of the Broad Pass terrane. These




DESCRIPTION OF FOSSIL LOCALITIES

| Map No. | Field Number | Description |
|---|---|---|
| 48 | -- | Middle Devonian corals, brachiopods and a trilobite (W. Oliver, written commun., 1977; and Blodgett, 1977) |
| 49 | 77-J-3 | Carboniferous radiolarians (identified by Brian Holdsworth, 1977) |
| 50 | 77-J-5 | Do. |
| 51 | Ctw-4 (=USGS Mesozoic loc. M5789) | *Inoceramus* fragments and belemnites (*Acroteuthis*? sp.) of Hauterivian to Barremian (Early Cretaceous) age. Collected by Robert Hickman. |
| 52 | 77-J-6 | *Buchia sublaevis* of Valanginian (Early Cretaceous) age. |
| 53 | Fx9 of Hawley and Clark (1974) | *Buchia sublaevis* of Valanginian (Early Cretaceous) age. |
| 54 | 77-J-9 | *Heterastridium* of late Norian (Late Triassic) age in matrix and Permian radiolarians from clasts of red chert in conglomerate. |
| 55 | -- | Thin-bedded limestone with abundant *Buchia sublaevis* of Valanginian (Early Cretaceous) age interbedded with flysch. Collected by Bruce Castle. |
| 56 | -- | *Monotis subcircularis* and *Heterastridium* sp. of late Norian (Late Triassic) age interbedded with basalt. |
| 57 | -- | *Monotis subcircularis* and *Heterastridium* of late Norian (Late Triassic) age. |

FIGURE 6.—Continued.

anomalous rocks, informally named the Jack River block, consist of three units that dip steeply to the north. The lower unit comprises 40–50 m of cobble to boulder conglomerate composed of green volcanic rocks and well-rounded red radiolarian chert. Some chert clasts are 30 cm in diameter and are similar in appear-

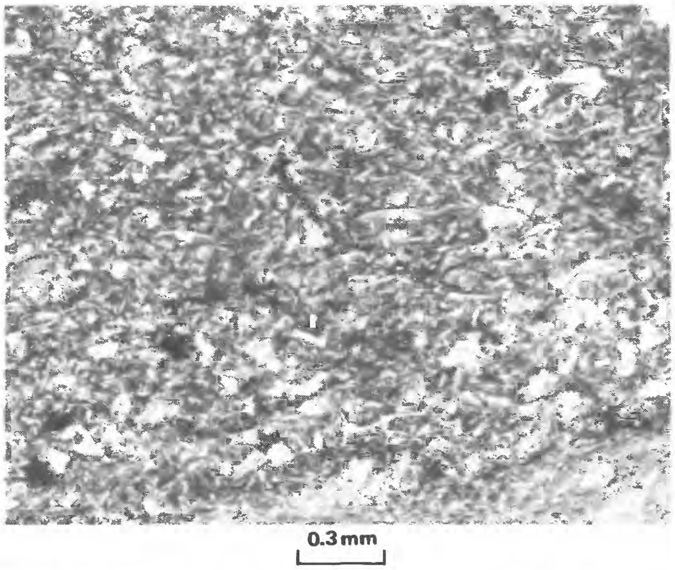



FIGURE 7.—Vitroclastic texture of cherty tuff from Broad Pass terrane, near locality 49 (see fig. 6 for location).

ance to Upper Devonian red chert from the ophiolite of the Chulitna terrane. Radiolarians extracted from these clasts, however, are different from those in the ophiolite, and are, instead, similar to unnamed forms known elsewhere to be of Permian age (unpub. data of D. L. Jones and B. K. Holdsworth). Permian rocks of similar composition are not known to crop out nearby, so the source terrane is cryptic.

The middle unit comprises a comparable thickness of finer grained volcanogenic (andesitic?) conglomerate in which red chert clasts are rare or absent, but in which the Late Triassic (late Norian) fossil *Heterastridium* sp. is locally abundant. The upper unit consists of about 50 m of massive volcanic sandstone.

*Heterastridium* occurs in totally different lithic assemblages in both the Chulitna terrane and the Susitna terrane (as described in the following section). The Jack River block thus appears to record a geologic history different from that of the adjoining areas; it received coarse sedimentary material from a once nearby provenance that has now disappeared.

We interpret the Jack River block to be a displaced fragment, possibly lying in the Hurricane fault zone. Its original site of deposition and the nature and amount of movement to its present locale are unknown.

## SUSITNA AND ELDRIDGE TERRANES

Large areas dominated by deformed upper Mesozoic flyschlike argillite, graywacke, conglomerate, and minor limestone (and their weakly metamorphosed equivalents) lie to the north and northwest of the Chulitna terrane and to the south and southeast of the Broad Pass terrane. The northern rocks are informally named the Eldridge terrane and the southern rocks the Susitna terrane. These named terranes are merely small parts of a vast region of highly deformed, dark-gray to black, dominantly fine grained clastic rocks that underlie 50,000 or more square kilometers in south-central Alaska (Beikman, 1974). Internal stratigraphy within this enormous body of rocks is unknown owing to a paucity of fossils, absence of marker beds, complex structure, and lack of any detailed studies. Insofar as is known, the Susitna terrane differs from the Eldridge terrane mainly in containing large thrust sheets, or nappes, composed of Upper Triassic pillow basalt.

### SUSITNA TERRANE

The Susitna terrane consists of two mappable units : a Cretaceous flysch unit and an Upper Triassic pillow basalt and clastic sedimentary rock unit (fig. 6). The flyschlike rocks of the Susitna terrane are not known in detail. They are dominantly fine grained with local interbeds of fine- to medium-grained graywacke. Bedding and slaty cleavage dip dominantly to the southeast, and many of the strata are overturned to the northwest. The vergence of folds in this terrane thus appears to be northward and is opposed to the southeast vergence of major folds within the Chulitna and West Fork terranes.

Fossils are known from only two localities within the flysch. One poor specimen of *Inoceramus* of probable Cretaceous age was found by Csejtey between the Chulitna and the Susitna Rivers southwest of the area shown in figure 6. At locality 55, *Buchia*-bearing limestone of Valanginian age was found by Mr. Bruce Castle. Rocks of similar age and lithology occur on the northwest side of the Chulitna River valley, so this occurrence substantiates an age equivalency of parts of the Susitna, Eldridge, and Chulitna terranes.

Two large sheets of basalt (some pillowed) with intercalated tuffaceous sedimentary rocks are structurally interleaved with the upper Mesozoic flysch (fig. 6). The Late Triassic (late Norian) fossils *Monotis subcircularis* and *Heterastridium* were found at a locality on the East Fork of the Chulitna River (loc. 56, fig. 6) and on the Chulitna River (loc. 57, fig. 6). Specimens of *Heterastridium* illustrated by Smith (1927, p. 118, figs. 7–9) are probably from locality 56. The Triassic rocks are best observed at locality 56 where they are overturned to the northwest and comprise two parts: a stratigraphically lower part of pillow basalt several hundred or more meters thick, and an upper part of intercalated massive basalt flows, tuff, sandstone, and siltstone 300–400 m thick. The fossils were obtained from the upper part of this unit. In the past, these rocks have been loosely correlated with the Middle and (or) Upper Triassic Nikolai Greenstone of the Wrangell Mountains (for example, Jones and others, 1977), but the presence of the late Norian fossils indicates that these two basaltic units are dissimilar in age.

Upper Mesozoic flysch occurs both above and below this inverted slab of Triassic basalt. Original depositional superposition of the flysch upon the Triassic basalt is possible, but the original nature of their contact is not known. The mapped distribution of the Triassic rocks suggests the presence of a large thrust sheet or nappe that is isoclinally folded and overturned to the northwest; however, facing data from all limbs are inadequate to substantiate this geometry. In any case, the Triassic rocks clearly are at least partly in thrust contact with the upper Mesozoic flysch and have been stripped off their own basement substratum, whatever and wherever that might be.

### ELDRIDGE TERRANE

The Eldridge terrane, a large tract of flyschlike rocks lying northwest of the Chulitna terrane, was not studied in detail during our investigations. In the adjoining area to the west, Reed and Nelson (1977) report that these rocks reach a probable thickness of more than 3,000 m and consist of medium- to dark-gray, isoclinally folded lithic graywacke, phyllite, and shale with local lenses of quartz-chert conglomerate. Also present are lenses and blocks of limestone composed mainly of *Inoceramus* prisms; radiolarian chert, and red ferruginous sandstone and siltstone. No detritus from the Chulitna terrane has been recognized.

Fossils are rare throughout the flysch, but the most abundant dated forms are of Valanginian and Hauterivian (Early Cretaceous) ages. Three fossil localities are known within the area of figure 6. Locality 51, found by Hickman and Craddock (1975), is along Parks Highway about 5 km northeast of Cantwell. There, a folded and faulted flysch sequence contains a limestone bed about 10 m thick composed of comminuted *Inoceramus* shells and fragments of belemnites (*Acroteuthis*?). This assemblage elsewhere in southern Alaska is common in rocks of Hauterivian and Barremian age (Jones, 1973). Localities 52 and 53 farther to the west contain *Buchia sublaevis* and related species of late Valanginian age in thin lenses of limestone.

Within our study area, a depositional contact of the upper Mesozoic strata on older rocks was not observed. Hickman, Craddock, and Sherwood (1977, p. 1225) state that these rocks in the western Reindeer Hills northeast of Cantwell lie depositionally on chert and argillite that we include in the Broad Pass terrane. We could not substantiate this relation, and believe that structural overriding of the Eldridge terrane by the Broad Pass is equally plausible (see next section).

## STRUCTURAL RELATIONS

The terranes briefly described above are all bounded by major faults. Similar Cretaceous rocks occur in the Eldridge, Chulitna, and Susitna terranes, but pre-Cretaceous rocks in four of the terranes each have differing internal stratigraphy and structure despite the fact that they are in part coeval. Furthermore, extensions of the Chulitna and West Fork terranes beyond that shown in figure 6 are unknown, and even the Broad Pass terrane is known to extend only a few tens of kilometers to the east. The Jack River block is totally anomalous with respect to the surrounding terranes, and its small size precludes ever attaining an adequate knowledge of its original character. These facts imply that large-scale tectonic dislocations occurred to achieve the present juxtapositions. However, the nature, timing, and amount of movement along the various faults have not been established. Some faults appear to have a complex history involving several periods of movements, and this greatly complicates analysis of the structural history. A further complication is introduced by proximity to the Denali fault, which is currently active with dextral strike-slip motion. Distributed shear related to this fault probably has affected all the terranes to some degree.

Despite these uncertainties, the dominant structural style seems to be that of compression and attendant thrust faulting that has juxtaposed fragments of what were once parts of extensive coherent terranes that are now mostly obliterated or obscured. The Chulitna terrane seems best interpreted as an internally thrusted and folded rootless nappe that lies both on Cretaceous flysch of the Eldridge terrane and on the chert, argillite, and tuff of the West Fork terrane. The high structural level of this nappe is confirmed by gravity data collected by Robert Moran and interpreted by David Barnes. These data show the lack of dense rock underlying the ophiolite of the Chulitna terrane; this lack indicates that these subcrustal rocks are not now rooted at depth in the mantle.

The original relations of the West Fork and Broad Pass terranes are unknown. In terms of age it is possible that the Broad Pass terrane formed the basement on which the West Fork accumulated, and this is supported by the presence of clasts of upper Paleozoic, probably Mississippian, radiolarian chert in the West Fork Terrane. No depositional contacts of the two terranes have been seen, and they could equally well be separated by major strike-slip or thrust displacements.

The relations of three terranes—Chulitna, West Fork, and Broad Pass—to the Cretaceous flysch of the Susitna and Eldridge terranes pose the most enigmatic and fundamental problems regarding the structural evolution of this part of south-central Alaska. Two hypotheses are possible. (1) The three terranes (plus the folded nappe of Triassic basalt found within the Susitna terrane) were juxtaposed elsewhere and emplaced on top of Cretaceous flysch from the south as a great complex nappe that has been subsequently refolded and broken by younger faults. This interpretation is preferred by Csejtey and others (1978). (2) The terranes were assembled nearly in their present position in pre-Cretaceous time through a complex combination of strike-slip and thrust movements and were then covered by the Cretaceous flysch. Slivers of this already deformed basement could have been structurally mixed with the flysch by later faulting. Several facts militate against this hypothesis: (1) lack of recognizable detritus within the flysch derived from the three terranes; (2) lack of depositional contacts of the flysch on the three terranes; and (3) deformation of the flysch is comparable to, or even exceeds, that found in some of the terranes, particularly in the Chulitna. This suggests a lower structural level for the flysch, although Hickman, Craddock, and Sherwood (1977) point out that some of the older rocks of the Broad Pass terrane are more deformed than the Cretaceous rocks.

## REGIONAL RELATIONS

As summarized above, the Chulitna, West Fork, Broad Pass, and Susitna terranes, and the Jack River block constitute different but partly coeval packages of rocks that have been juxtaposed by movements of large magnitude. Their relations are further complicated by the fact that none of the assemblages is present in the surrounding mountain ranges where other coeval but unlike rocks are well developed. This implies that these terranes were transported, not only with respect to each other, but also in respect to all surrounding rocks. In other words, they seem to represent fragments of allochthonous terranes that probably formed far from their present site. A comparison of the Chulitna terrane with rocks to the southeast that constitute Wrangellia has recently been published by Jones, Silberling, and Hillhouse (1977) and is summarized in figure 8. Wrangellia is regarded as an allochthonous terrane on the basis of geologic and geophysical data and its northward displacement for several thousand kilometers is evidently required (Hillhouse, 1977).

A southern origin for the Chulitna terrane also seems likely. The strongest arguments of this conjecture are: (1) The thick sequence of redbeds lying above carbonate rocks that exhibit warm-water characteristics suggests deposition at low paleolatitudes. Thick redbed sequences occur mainly in southern Canada and the western interior of the United States. The redbeds of the Chulitna terrane are the northernmost Triassic redbeds known in North America. Although thin redbeds are known from latitudes as high as 60° N. in Alberta, Canada, there they generally are thin and constitute only a small part of the stratigraphic section. (2) The presence of massive heads of colonial scleractinian corals in marine sandstone within and above the redbeds of the Chulitna terrane and of probable megalodontid bivalves in the limestone and pillow basalt unit suggests deposition in warm, tropical waters. Such fossils are unknown in northern Alaska, the Arctic Islands of Canada, and in Upper Triassic deposits of northern British Columbia (Tozer, 1970). (3) The Early Triassic ammonite fauna from the Chulitna terrane closely matches coeval faunas from California and Idaho from low paleolatitudes (Kathryn Nichols, unpub. data). It is distinctly different from Early Triassic faunas of northern Alaska, northern Canada, and British Columbia. The very presence of Lower Triassic rocks is anomalous, as they are unknown elsewhere in southern Alaska.

While none of these arguments alone is sufficiently compelling to demand a large amount of horizontal displacement for the Chulitna terrane, when taken in context with its unique occurrence and tectonic style, a displacement history comparable to that of Wrangellia seems reasonable.

The regional relations of the West Fork terrane are likewise enigmatic, in part because of uncertainties in the age of the massive tuff unit. We presume that this unit represents ash that blew downwind and accumulated in deep water and thus probably was derived from an andesitic arc. A possible candidate for the volcanic source is the Talkeetna arc to the south, extending from the Talkeetna Mountains on the east to the Alaska Peninsula and perhaps beyond, on the southwest. Arc-related volcanism started there in Late Triassic time (Moore and Connelly, 1977) and extended into Toarcian (late Early Jurassic) time. Comagmatic granitic plutons ranging in age from about 175 to about 155 m.y. (Reed and Lanphere, 1969, 1973) intrude these volcanic rocks. This plutono-volcanic activity was contemporaneous with deposition of at least

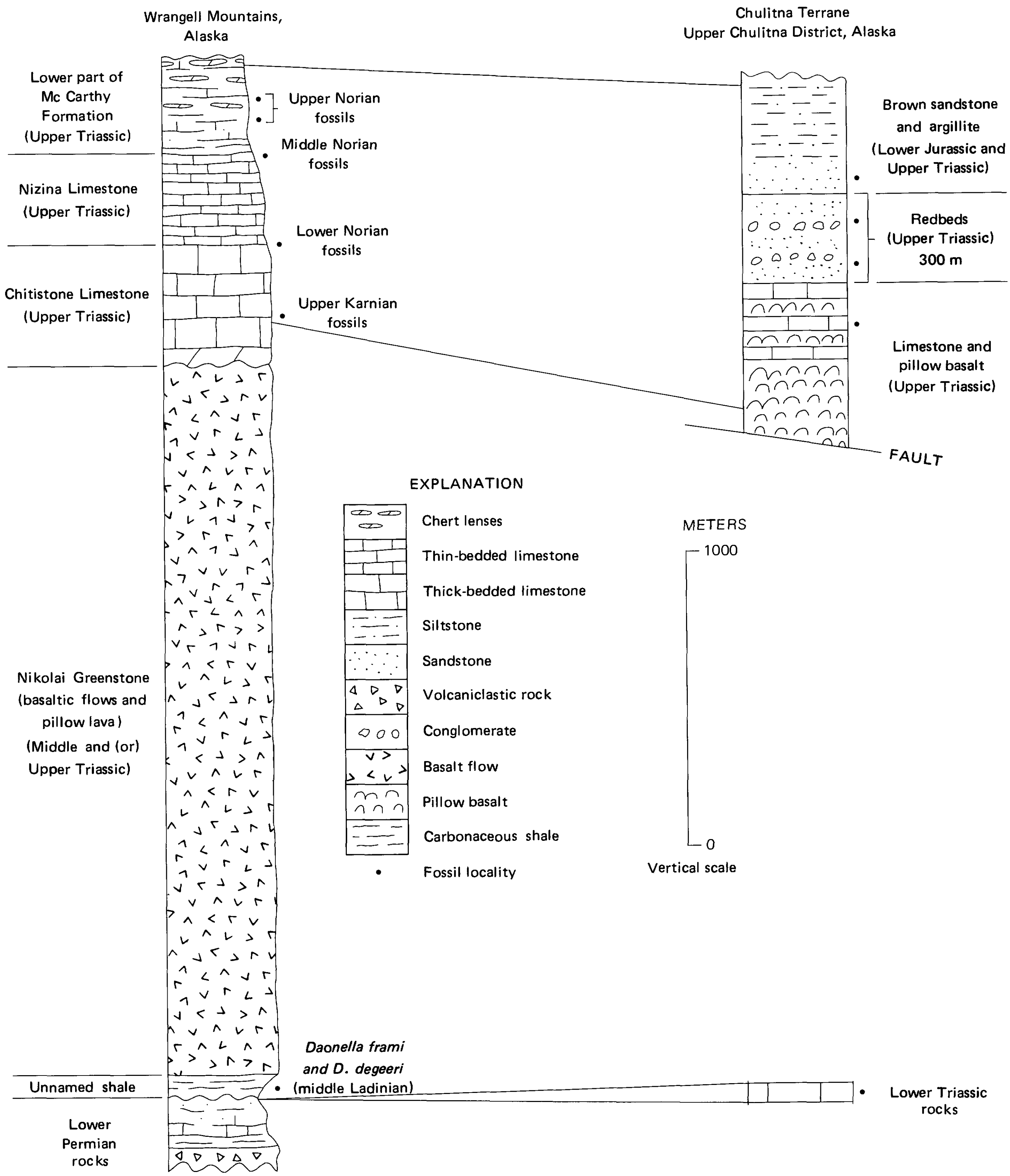



FIGURE 8.—Columnar sections comparing Triassic rocks of the Wrangell Mountains, Alaska, with those of the Chulitna terrane.

part of the massive tuff unit—that part that contains late Sinemurian ammonites, but whether or not the bulk of the unit falls in this age range is undetermined.

Inexplicably, the lower Sinemurian ammonite-bearing blocks or lenses of phosphatic limestone that occur with the Jurassic argillite, chert, and sandstone unit of the West Fork terrane to the northwest of the massive tuff unit are nonvolcanogenic except for a small amount of chlorite and kaolinite that may be volcanic derived. On the other hand, volcanogenic debris similar to the massive tuff unit is definitely present as silt- to pebble-size clasts within the argillite, chert, and sandstone unit, so it seems there was some original stratigraphic relation between the two.

Despite the equivalency in age of part of the West Fork terrane and the Talkeetna arc, it should be stressed that the West Fork rocks are very different lithologically from the Lower Jurassic Talkeetna Formation, which is dominantly shallow-water (and some nonmarine) tuff, agglomerate, flows, and breccia, with intercalated volcanogenic fossiliferous sandstone and siltstone (see Imlay and Detterman, 1973, for summary). Paleomagnetic data (Packer and Stone, 1974) indicate that the Jurassic rocks associated with the Talkeetna arc were formed at paleolatitudes comparable to present-day Oregon or northern California. Because these rocks appear to be allochthonous with respect to the other Jurassic rocks in Alaska, it is unwarranted to speculate further as to original relations until more paleomagnetic data are in hand.

Other volcanic terranes in the southern part of Alaska also could be considered as possible equivalents of the West Fork assemblage. For example, part of the Gemuk Group of southwestern Alaska includes thick units of greenish-gray, radiolarian-bearing andesitic tuff that ranges in age from Late Triassic to Early Cretaceous (unpublished date of J. M. Hoare, W. L. Coonrad, and D. L. Jones). Some of this tuff is lithologically similar to that of the West Fork terrane. Again, no direct connection of these disjunct terranes is implied by this comparison.

The Susitna terrane differs from the Eldridge terrane in containing large sheets of pillow basalt and associated deep-water marine sedimentary rocks of late Norian age. Triassic marine basalt of this age is known in several other places in southern and southeastern Alaska. For example, it occurs on the Alaskan Peninsula (see Jones and others, 1977), in Keku Strait (Muffler, 1967), and on Gravina Island (Berg, 1973). Norian fossils and older Triassic fossils are reported in dominantly basaltic sequences of the Amphitheatre Basalt of Rose and Saunders (1965) farther east in the southern Alaska Range (Smith and Lanphere, 1972). However, these fossils occur in faulted blocks of limestone and cannot be used to date the basalt. In the absence of a more complete stratigraphic section of pre-Cretaceous rocks in the Susitna terrane, genetic comparison among these Upper Triassic basalts has little basis. Nevertheless, the Triassic pillow lavas and associated deep marine rocks of the Susitna terrane are in strong lithologic contrast with the correlative strata nearby in the Chulitna terrane where the upper Norian is represented by redbeds and shallow-water marine sedimentary rocks.

A synthesis of the structural history that would explain how the pre-Cretaceous rocks of the Chulitna, West Fork, Broad Pass, and Susitna terranes arrived in their present positions is not now possible and may never be achieved in any detail. Nonetheless, a major amount of displacement of at least some of these rocks is required by the contrasts between them, and a generally northward direction of displacement with respect to North America is implied (Jones and others, 1978).

This is not the case for the upper Mesozoic flyschlike strata, which are structually mixed with older rocks in the Chulitna and Susitna terranes discussed herein and which form all of a third terrane (the Eldridge). These strata are generally similar in kind and all three contain coquinoid accumulations of *Buchia sublaevis*. This species of *Buchia* and mode of occurrence is common in other Lower Cretaceous rocks deposited in high paleolatitudes and may place a northern stamp on the enclosing rocks.

Thus, although the exact mode of emplacement of the pre-Tertiary rocks in the various terranes and their relations to one another may remain cryptic, our conclusion is that they were transported by plate-tectonic and other mechanisms mainly from original positions farther south. They then were structurally mixed or remixed with extensive upper Mesozoic continental rise or slope deposits shed onto an oceanic site not far from the present exposures of these flyschlike rocks in southern Alaska. The result is a mosaic of pre-Cretaceous fragments, representing more than one lithosphere plate, set in a matrix of upper Mesozoic flysch.

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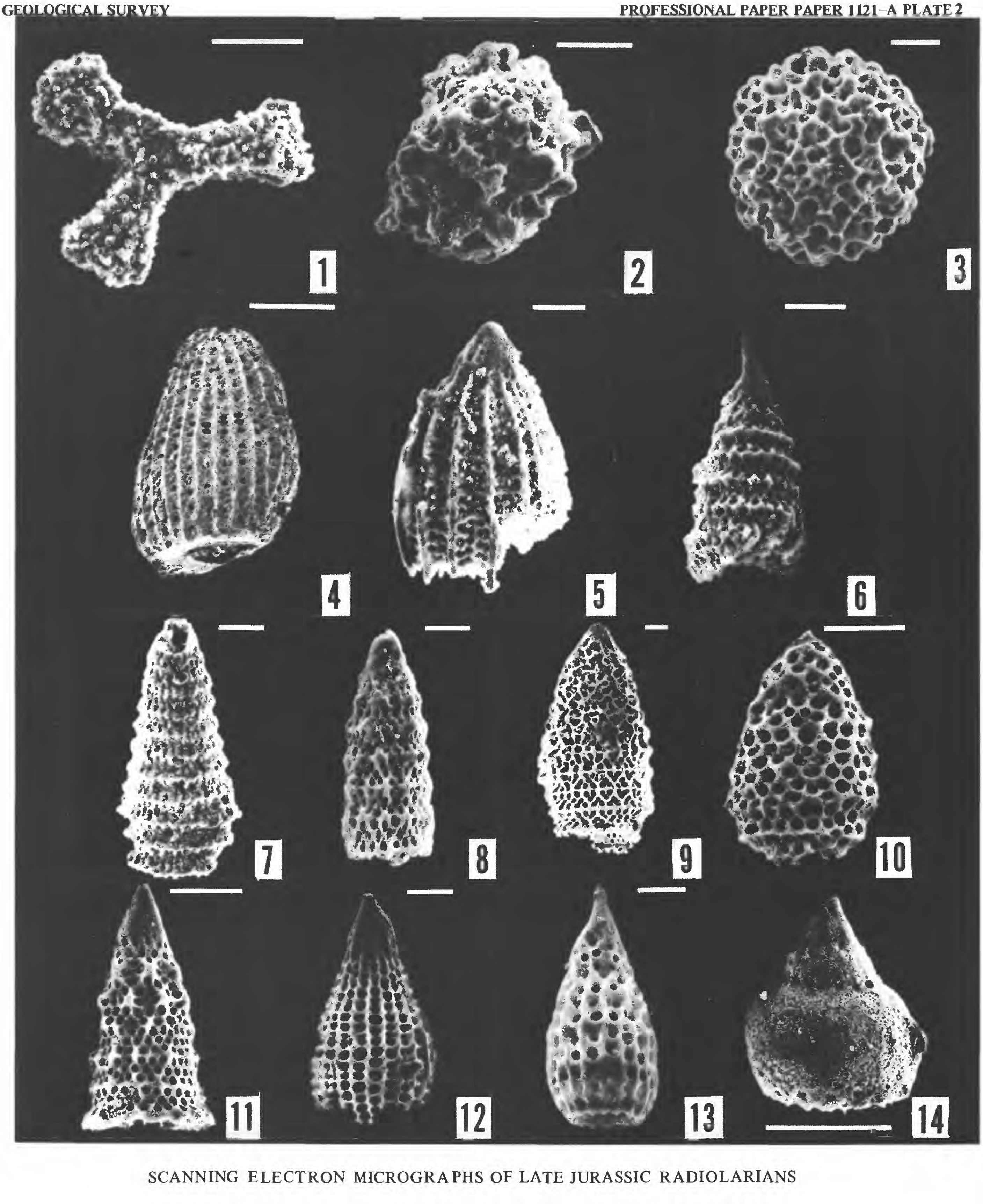
# PLATE 2

[Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225]

## PLATE 2

FIGURES 1–14. Scanning electron micrographs of Late Jurassic radiolarians. Length of scale on all illustrations = 50 μm. See plate 1 for fossil locations.

1. *Paronaella* sp. A. 500×; loc. 35.
2. *Praeconocaryomma magnimamma* (Rüst). 500×; loc. 26.
3. *Praeconocaryomma mamillaria* (Rüst). 320×; loc. 36.
4. *Archaeodictyomitra* cf. *A. rigida* Pessagno. Differs from *A. rigida* in having fewer and wider spaced costae and a less symmetrical test. 550× loc. 36.
5. *Hsuum*(?) sp. Lacks well-developed horn typical of *Hsuum*. 350×; loc. 35.
6. *Parvicingula* aff. *P. khabakovi* Zhamoyda. 400×; loc. 35.
7. *Parvicingula* sp. A. 300×; loc. 35.
8. *Xitus*(?) sp. Lacks well-developed horn and tubular extension on postabdominal chamber typical of *Xitus*. 300×; loc. 36.
9. Unnamed nassellariinid A. 140×; loc. 36.
10. Unnamed nassellariinid B. 540×; loc. 35.
11. Unnamed nassellariinid C. 475×; loc. 35.
12. Unnamed nassellariinid D. 300×; loc. 36.
13. Unnamed nassellariinid E. 320×; loc. 36.
14. Unnamed nassellariinid F. 800×; loc. 35.




SCANNING ELECTRON MICROGRAPHS OF LATE JURASSIC RADIOLARIANS