Six New Paleozoic and Mesozoic Formations in East-Central Alaska

By EARL E. BRABB

CONTRIBUTIONS TO STRATIGRAPHY

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Definition and description of some sedimentary rocks in the Kandik basin

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CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO STRATIGRAPHY

SIX NEW PALEOZOIC AND MESOZOIC FORMATIONS IN EAST-CENTRAL ALASKA

By EARL E. BRABB

ABSTRACT

Six of 25 new map units established by regional geologic mapping in the Charley River and Eagle quadrangles are formally defined and named as follows: Ford Lake Shale (Upper Devonian to Upper Mississippian), Step Conglomerate (Permian), Glenn Shale (Middle Triassic to Lower Cretaceous), and the Keenan Quartzite, Biederman Argillite, and Kathul Graywacke—three formations within the Lower Cretaceous Kandik Group.

INTRODUCTION

Regional geologic mapping by the author from 1960 to 1963 and by Michael Churkin, Jr., from 1962 to 1963 in the Charley River (1:250,000) and Eagle D–1 (1:63,360) quadrangles has established approximately 25 new rock-stratigraphic units of Precambrian, Paleozoic, and Mesozoic age. Most of these units are shown on preliminary geologic maps of these quadrangles by Brabb and Churkin (1964, 1965) released in open files of the U.S. Geological Survey. Five of the units have already been named, and a sixth has been identified with a unit in the Yukon Territory for which a name has already been published (Churkin and Brabb, 1965; Brabb, 1967). The purpose of this report is to define six additional names for formations that have extensive geographic distribution, so that the formations can be readily identified on published versions of the geologic maps and in subsequent geologic reports. Additional mapping in greater detail is desirable before formal names can be proposed for the remaining dozen or more units. The six new formations are described from oldest to youngest.

ACKNOWLEDGMENTS

In addition to mapping part of the regional geology, Michael Churkin, Jr., assisted by Arne Aadland, worked out the sequence of for-

mations in the Step Mountains that led to the naming of the Step Conglomerate in this report. Michael Churkin and N. J. Silberling, U.S. Geological Survey and Stanford University, measured one of the Triassic sequences that formed part of the data for Silberling's summary in table 2. R. N. Passero and H. L. Roepke, in 1960, J. C. Melik and R. L. Taylor, in 1961, Arne Aadland, in 1962, and D. L. Giles and R. H. Rohrbacher, in 1963, assisted in the regional geologic mapping. D. L. Jones identified the mollusks of Cretaceous age, and R. E. Grant identified the fossils given in table 1. R. W. Imlay identified one fauna of probable Jurassic age. R. A. Scott identified spores and pollen of late Mesozoic and Cenozoic age. J. A. Wolfe identified plants of Cretaceous age, and S. H. Mamay identified plants of Paleozoic age. Geologists of British Petroleum Co., Ltd. and Mobile Oil Co. kindly contributed several fossil collections and other material that helped date some of the formations discussed in this report.

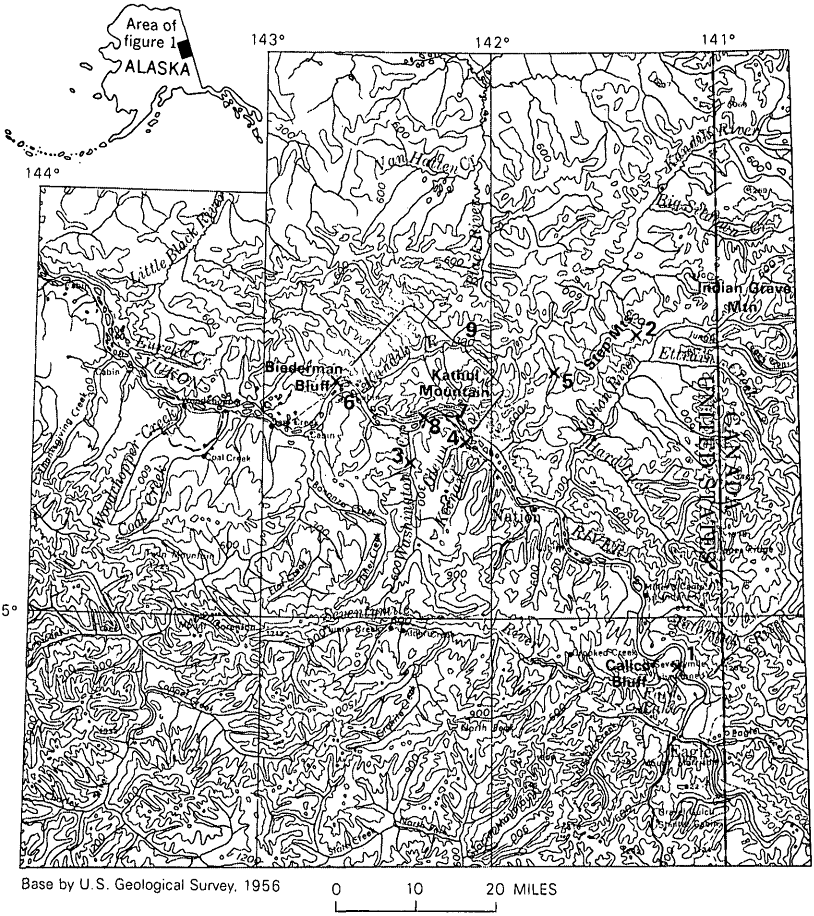
UPPER DEVONIAN TO UPPER MISSISSIPPIAN ROCKS

FORD LAKE SHALE

The Ford Lake Shale is here named for exposures in the type section—the east and west banks of the Yukon River (fig. 1) from about 2 miles east of Ford Lake to about 2 miles northeast of Ford Lake, Eagle D-1 quadrangle (1:63,360). The basal part of the formation in the type section and the top of the underlying Nation River Formation of Late Devonian age are concealed beneath alluvium at the mouth of Shade Creek. The top of the Ford Lake Shale is exposed at Calico Bluff (fig. 2), where it grades vertically upward into limestone of the overlying Calico Bluff Formation of Late Mississippian age. In the Step Mountains, the Ford Lake Shale is overlain unconformably by the Step Conglomerate of Permian age. The stratigraphic relationships of these formations are shown in figure 3.

The Ford Lake Shale consists predominantly of grayish-black siliceous shale and laminated grayish-black chert that splits with a slabby parting (fig. 4). Yellow sulfate minerals are common along weathered surfaces and give many outcrops of the shale and chert a distinctive bronze tinge. Brownish-black phosphate concretions, some as large as 4 inches in maximum dimension, and very pale orange carbonate concretions a few feet in length are common. Several limestone and dolomite beds and lenses occur in the upper part of the formation.

A section of the Ford Lake Shale about 1,000 feet thick is exposed on the west bank of the Yukon River near Calico Bluff, and several



1. Type section for the Ford Lake Shale.
2. Type section for the Step Conglomerate.
3. Type section for the Glenn Shale.
4. Type section for the Keenan Quartzite.
5. Reference section for the Keenan Quartzite.
6. Type section for the Biederman Argillite.
7. Reference section for the Biederman Argillite.
8. Type section for the Kathul Graywacke.
9. Type locality for the Kandik Group.

FIGURE 1.—Locations of sections discussed in text.

hundred feet of an additional(?) section are exposed on the east bank from ½ to 1½ miles downstream from the mouth of Shade Creek. The presence of several folds and the difficulty of correlating across the Yukon River make it impossible to determine the exact thickness of the formation in its type section. In the vicinity of Adams Peak, however, about 4 miles north of Ford Lake, the attitudes and the outcrop width of a homoclinal but more poorly exposed sequence indicate that the Ford Lake Shale is about 2,000 feet thick.

Few fossils have been found in the lower part of the Ford Lake Shale, and fossils from the upper part of the formation have not yet

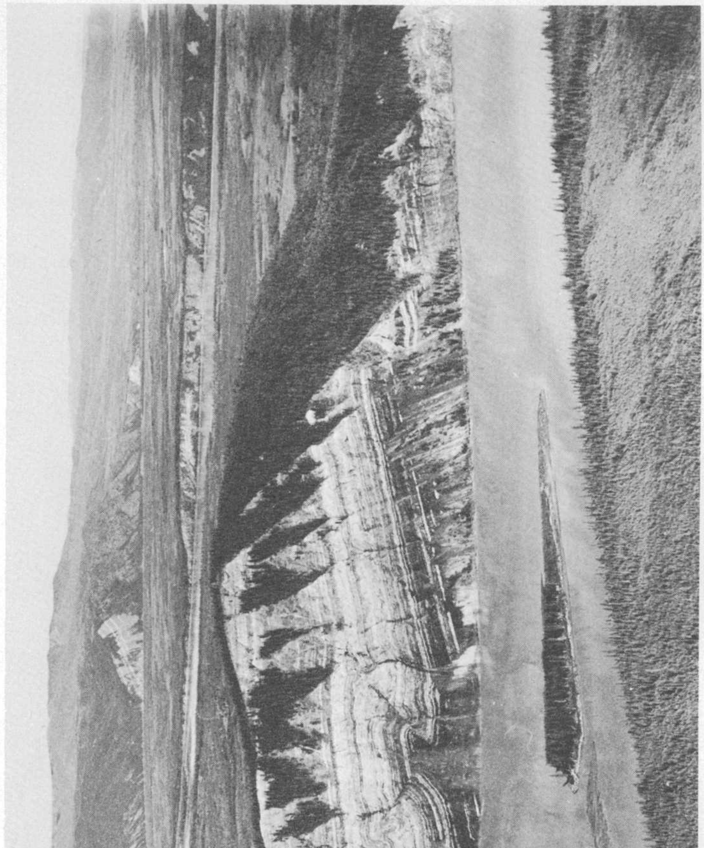


FIGURE 2.—Contact between the Ford Lake Shale and the overlying Calico Bluff Formation at Calico Bluff. A thin but persistent limestone bed (arrow) is considered to be the base of the Calico Bluff Formation. Faulting is clearly evident in the center of the photograph. The top of the bluff is about 1,000 feet above the Yukon River.

SYSTEM	SERIES	ROCK UNIT		
TERTIARY		Unnamed nonmarine sandstone, mudstone and conglomerate 3000± ft		
CRETACEOUS	Upper	Unnamed nonmarine sandstone, mudstone and conglomerate 3000± ft		
		?		UNCONFORMITY
CRETACEOUS	Lower	Unnamed nonmarine rocks near Seventymile River	Kandik Group	Kathul Graywacke 1500 + ft
				LOCAL UNCONFORMITY
CRETACEOUS	Lower	Missing	Kandik Group	Biederman Argillite 5000 + ft
CRETACEOUS	Lower	Missing	Kandik Group	Keenan Quartzite 1000 ft max
	?			
JURASSIC		Glenn Shale 5000± ft		
	?			
TRIASSIC	Upper	Glenn Shale 5000± ft		
TRIASSIC	Middle	Glenn Shale 5000± ft		
	?	UNCONFORMITY(?)		
PERMIAN		Step Conglomerate 2000± ft		Tahkandit Limestone 350 ft
		MAJOR UNCONFORMITY		
MISSISSIPPIAN	Upper	Calico Bluff Formation 1500± ft		
MISSISSIPPIAN	Lower	Ford Lake Shale 2000± ft		
DEVONIAN	Upper	Nation River Formation 4000± ft		

FIGURE 3.—Stratigraphic relations of the new formations named and described in this report.

been examined. Brachiopods and wood of Late Devonian or Early Mississippian age from the lower part of the formation in its type section were reported by Brabb and Churkin (1967, p. D9) from locality 60ABa 322. Plants from the Ford Lake Shale near the Tatonduk River (fig. 1) were discussed at length by David White (see Mertie, 1933, p. 419), who considered them to be of Devonian or, at latest, Early Mississippian age.

FIGURE 4.—Part of the type section of the Ford Lake Shale along the west bank of the Yukon River about 2 miles northeast of Ford Lake. The shale and chert beds at this locality are laminated, but they split with a slabby parting. The cliff is about 100 feet in height and is capped with river-terrace deposits.

Plant collections from the Ford Lake Shale in the Step Mountains (fig. 1) were made by Michael Churkin, Jr., and Arne Aadland in 1962 from shale in the Charley River B–2 quadrangle (Field No. 62ACn 1114, lat 65°28.6′ N., long 141°32.8′ W.) and from siltstone in the Charley River B–2 quadrangle (Field No. 62ACn 1116, lat 65°27.9′ N., long 141°33.6′ W.). The following statements were made by Sergius H. Mamay (written commun., 1962), who examined the plants:

Collection 1114 contains a very poorly preserved small plant axis with coarse longitudinal striations and the basal part of a lateral appendage. The striations suggest sphenopsid affinity but no nodal structure is present. Generic identification is impossible.

Collection 1116 contains (1) Several surface impressions of a fairly large stem with broad longitudinal ribs. This is obviously of calamarian origin but the nodal organization is not shown in this fragment, so that a generic identification cannot be made. (2) Several nondescript stem compressions. (3) A few specimens of dichotomizing axes, one of which has several lateral appendages attached. These are probably the bases of pinnule stalks, but are not diagnostic without foliar laminae.

The few fossils found in the lower part of the Ford Lake Shale and the gradational relations of the Ford Lake to its underlying and overlying units indicate that the Ford Lake is Late Devonian to Late Mississippian in age.

PERMIAN ROCKS

STEP CONGLOMERATE

TYPE SECTION AND AREAL DISTRIBUTION

The Step Conglomerate is here named after the Step Mountains (fig. 1), which lie between the Kandik and Nation Rivers at about lat 65°30′ N., Charley River C–1, C–2, B–1, and B–2 quadrangles (1:63,360). The formation forms part of the flanks of a doubly plunging anticline and consists mainly of chert-pebble conglomerate and sandstone and a few thin interbeds of bioclastic limestone. A section examined about 2½ miles northeast of bench mark 3977 (Nat) in the B–2 quadrangle extends from the NE¼ sec. 20, T. 8 N., R. 31 E., in the C–1 quadrangle, where the contact with the uppermost shale and limestone beds of the underlying Ford Lake Shale is exposed, to the SE¼ sec. 28 in the B–1 quadrangle, where the contact with an overlying grayish-black argillite, tentatively mapped as the Biederman Argillite, crops out. This section seems to have the best exposures of the Step Conglomerate and is designated the type section. The outcrop width and the attitudes indicate that the formation there is approximately 2,000 feet thick.

The Step Conglomerate is exposed over a wide area between the Yukon, Black, and Little Black Rivers (fig. 1). It has not as yet been recognized south of lat 65°25′ N.; in this area rocks of the same age are mainly limestone.

LITHOLOGY AND DISTINGUISHING FEATURES

Most of the clasts in the Step Conglomerate are rounded chert pebbles 4–20 millimeters in maximum dimension. A few pebble-size clasts of sandstone were also observed in polished sections of the conglomerate. Most of the chert pebbles are various shades of gray, ranging from white to black; a few are green or red. Most of the pebbles are in a matrix of sand-size chert and quartz grains, and a few are in a matrix of light-gray chert or calcite. The chert-pebble conglomerate grades upward into a very light gray sandstone and quartzite composed of chert and quartz grains. This quartzite is difficult to distinguish from the younger Keenan Quartzite of Early Cretaceous age without fossils or stratigraphic control.

There are at least two limestones in the lower part of the Step Conglomerate. One limestone is about 30 feet thick; it is light gray, thinly bedded, bioclastic, and resembles the Tahkandit Limestone of Permian age. The other limestone is about 20 feet thick; it is light brown and has many sand- and pebble-size rounded clasts of chert.

AGE AND STRATIGRAPHIC RELATIONS

Brachiopods are abundant in the limestone, less common in the quartzite, and rare in the conglomerate. Fossils from the Step Conglomerate, identified by Richard E. Grant (written commun., 1965), are given in table 1. Grant believed that the fossils are of Permian age and are quite similar to faunas from the type Tahkandit Limestone of Permian age. Collections 22352–PC, 22359–PC, and 22360–PC are significant in dating large areas of rocks exposed in the headwaters of the Little Black River, 40–60 miles west and 10 miles east of the Step Mountains; the rocks in that area are now mapped as Step Conglomerate.

The occurrence of limestone in the Step Conglomerate similar to the Tahkandit Limestone, the occurrence of a 75-foot-thick chert-pebble conglomerate at the base of the Tahkandit Limestone (Brabb and Churkin, 1967, p. D12), and the similarity of the faunas in the two formations indicate that the Step Conglomerate and Tahkandit Limestone are lateral facies. Extension of the name Tahkandit to the Step Mountains area and designation of the Step Conglomerate as a member of the Tahkandit were considered but rejected inasmuch as the Step is a distinctive mappable conglomerate unit about six times as thick as the Tahkandit. Moreover, the conglomerate at the base of the Tahkandit has not been observed outside the type section, so the name Tahkandit is most closely associated with a limestone formation.

The absence of the Mississippian Calico Bluff Formation and of Pennsylvanian rocks beneath the Step Conglomerate indicates that the Step Conglomerate rests unconformably on the Ford Lake Shale. A similar major unconformity at the base of the Tahkandit has only recently been recognized (Brabb and Churkin, 1967, p. D12–D14). The Step Conglomerate in the headwaters of the Little Black River area seems to rest unconformably on unnamed sedimentary and volcanic rocks of Paleozoic and probable Precambrian age. The rocks

TABLE 1.—*Fossils from the Step Conglomerate*

[Identified by R. E. Grant]

Fossils	USGS locality[1]							
	21790–PC	21701–PC	21792–PC	21789–PC	22333–PC	22352–PC	22359–PC	22360–PC
Antiquatonia sp							?	
Calliprotonia sp								?
Cancrinella sp			×					
Derbyia sp						?		
Horridonia sp								×
Kochiproductus sp		×		×	?			
Krotovia sp			?					
Licharewia sp						×		
Linoproductus				×				
Liosotella sp						×		?
Liosotella pseudohorrida (Wiman)			×					
Lissochonetes sp			?					
Megousia			×			×		
Muirwoodia sp			×					
Neophricadothyris sp			×					
Neospirifer sp							?	
Orthotichia sp						×		
Pterospirifer sp						×		
Rhynchopora sp			×					
Stenoscisma sp			×					
Streptorhynchus sp						×		
Waagenoconcha sp			×					
trilobite			×					
bryozoa	×	×			×		×	×
crinoid columnals	×				×		×	×
pelecypod	×							

[1] See following table for collection localities.

USGS No.	*Field No.*	*Locality*
21789–PC	63ACn 1563	From sandy limestone in lower part of Step Conglomerate; Charley River B–1 quadrangle, lat 65°28.4′ N., long 141°28.6′ W. Collector, Michael Churkin, Jr., 1963.
21790–PC	63ACn 1641	From sandstone in the lower part of the Step Conglomerate; Charley River B–1 quadrangle, lat 65°29.5′ N., long 141°24.8′ W. Collector, Michael Churkin, Jr., 1963.
21701–PC	63ABa 4087	From quartzite in the Step Conglomerate; Charley River B–2 quadrangle, lat 65°28.9′ N., long 141°33.5′ W. Collector, Earl E. Brabb, 1963.
21792–PC	63ABa 4083	From quartzite in lower part of Step Conglomerate; Charley River C–1 quadrangle, lat 65°31.2′ N., long 141°26.9′ W. Collector, Earl E. Brabb, 1963.
22333–PC	62ACn 1113	From bioclastic limestone in lower part of Step Conglomerate; Charley River B–2 quadrangle, lat 65°28.7′ N., long 141°33.0′ W. Collector, Michael Churkin, Jr., 1962.
22352–PC	63ABa 4121	From quartzite within the Step Conglomerate; about 3 miles east of Takoma Bluff and 60 miles west of the Step Mountains, Charley River B–6 quadrangle, lat 65°29.4′ N., long 143°34.3′ W. Collector Earl E. Brabb, 1963.
22359–PC	63ABa 4042	From Step Conglomerate; about 12 miles east of the Step Mountains. Charley River C–1 quadrangle, lat 65°31.9′ N., long 141°00.4′ W. Collector, Earl E. Brabb, 1963.
22360–PC	63ABa 4112	From crinoidal limestone float presumably within Step Conglomerate; about 3 miles east of Takoma Bluff and 60 miles west of Step Mountains, Charley River C–6 quadrangle, lat 65°30.2′ N., long 143°34.6′ W. Collector, Earl E. Brabb, 1963.

overlying the Step Conglomerate are the Glenn Shale of Middle Triassic to Early Cretaceous age and in some places the Biederman Argillite of Early Cretaceous age. These relations suggest that the top of the formation is also bounded by an unconformity.

MIDDLE TRIASSIC TO LOWER CRETACEOUS ROCKS

GLENN SHALE

TYPE SECTION AND AREAL DISTRIBUTION

Shale exposed along the banks and in the bed of Washington Creek (fig. 1) from 2 to 4 miles northwest of bench mark 2452

(Glenn) in the Charley River A–3 quadrangle (1:63,360) is here named the Glenn Shale. The type section extends from a fault in the NW¼ sec. 24, T. 5 N., R. 26 E., where the lower part of the formation is in contact with volcanic rocks of presumed Precambrian age, to the Keenan Quartzite of Early Cretaceous age in the NW¼ sec. 12, T. 5 N., R. 26 E., in the Charley River B–3 quadrangle (1:63,360).

The Glenn Shale has been recognized over an area of more than 2,000 square miles from Glenn Creek (fig. 1), for which it is named, to the headwaters of the Black River near the Alaska-Yukon Territory boundary, and westward as far as Eureka Creek. Phyllite and quartz-chlorite semischist overlying the Step Conglomerate in the vicinity of Indian Grave Mountain are thought to be a local metamorphic facies and are tentatively included in the Glenn Shale.

LITHOLOGY

The Glenn Shale in its type section along Washington Creek consists predominantly of grayish-black fissile carbonaceous shale, which grades upward into grayish-black massive argillite and siltstone containing carbonate "cannonball" concretions a few inches in diameter. There is a 50-foot-thick dark-gray fossiliferous limestone at the base of the formation along Washington Creek; at other localities, such as along Trout Creek, this limestone is several hundred feet thick and is a conspicuous part of the formation. Unusually fossiliferous limestone beds in the lower part of the Glenn Shale, about half a mile northeast of the mouth of the Nation River, are shown in figure 5. Well-known but relatively thin oil shales (see Mertie, 1930, p. 131–132) occur within this limestone and a few tens of feet above it about half a mile southwest of the mouth of the Nation River and along Trout Creek.

THICKNESS

The type section has not been accurately measured, but judging from attitudes and outcrop width, the formation seems about 5,000 feet thick. Repetition of fossil-bearing strata and steep attitudes, however, indicate that the Glenn Shale is tightly folded in some areas, so the thickness of the formation in its type section could be less. In the Step Mountains, the Glenn Shale is only a few hundred feet thick.

AGE AND STRATIGRAPHIC RELATIONS

Shale and limestone in the lower part of the Glenn Shale near the mouth of the Nation River (fig. 1) contain abundant pelecypods, many ammonites, and a few brachiopods; these fossils have long been

FIGURE 5.—Limestone in the Glenn Shale, consisting largely of cephalopods. Locality is about half a mile northeast of the mouth of Nation River.

correlated with the Karnian and Norian Stages of the Upper Triassic (see Martin, 1916, 1926; Smith, 1927; Mertie, 1930). Unfortunately, the diagnostic faunas are from different localities or from extensively folded and faulted sections, so the faunal sequence is in doubt. A schematic summary of the inferred faunal sequence pieced together from isolated localities by N. J. Silberling is given in table 2. The principal difference in this scheme from those previously published is Silberling's recognition of faunas of Middle Triassic (Ladinian) age. This age is based on the discovery of *Daonella* cf. *D. degeeri* at the following locality:

USGS M2138 (Field No. 63ACn 1776), Charley River A–1 quadrangle, lat 65° 14.4′ N., long 141°23.9′ W., from calcareous shale on the west bank of Hard Luck Creek. Collected by Michael Churkin, Jr., 1963.

The following fossils were collected from the stratigraphically lowest exposures of the Glenn Shale in its type section, about 100 feet stratigraphically above the highest exposures of volcanic rocks of the Tinder Group of Precambrian age:

USGS M2155 (Field No. 63 ABa 4061), Charley River A–3 quadrangle, lat 65° 14.9′ N., long 142°18.3′ W.

Monotis cf. *M. subcircularis*
Heterastridium? sp.
Age: late Norian (according to Silberling).

TABLE 2.—*Schematic summary of the Triassic faunal sequence in the vicinity of Nation*

[The sequence is inferred, in part, from faunas collected at separate localities. Prepared by N. J. Silberling]

Substage	*Diagnostic fossils*	*Stratigraphic thicknesses*
?	?	?
Upper Norian	*Monotis subcircularis* Gabb; *Heterastridium* sp.	?
?	?	?
Middle Norian	*Monotis scutiformis pinensis* Westermann; *Halobia* cf. *H. fallax* Mojsisovics; *Himavatites*? sp.	Few tens of feet.
Upper Karnian to middle Norian.	*Halobia* spp.	Few hundreds of feet at most.
Upper Karnian to middle Norian.	*Halobia cordillerana* Smith; *Monotis scutiformis typica* Kiparisova.	Few feet.
?	?	20 to 30 feet.
Uppermost Ladinian or lower Karnian.	*Nathorstites* aff. *N. gibbosus* Stolley; "*Cladiscites*" *martini* Smith; *Discophyllites* sp; *Proclydonautilus* sp; *Germanonautilus brooksi* Smith; all of the pelecypods and brachiopods described by Smith (1927) from the upper Yukon except *Halobia cordillerana*.	About 10 feet.
?	?	?
Lower Ladinian	*Daonella* cf. *D. degeeri* Böhm	Several feet.
?	?	Few tens of feet.

(Tahkandit Limestone of Permian age)

These fossils and the sequence worked out by Silberling (table 2) suggest that a few hundred feet of section ranging in age from Ladinian to early Norian have been faulted out along Washington Creek.

The prolific pelecypod and ammonite faunas of Triassic age in the Glenn Shale have been found only in the area south of lat 65°25′ N., from the Alaska-Yukon boundary to the Coal Creek area (fig. 1).

Otapiria sp. and *Pentacrinus subangularis* var. *alaska* of probable Jurassic age were reported by Imlay (1967, p. B7–B8) from an unknown stratigraphic position within the Glenn Shale about 3 miles southwest of the mouth of the Nation River (fig. 1). No fossils of certain Jurassic age have as yet been found within the area shown in figure 1.

Buchia okensis of Early Cretaceous (Berriasian) age has been identified by D. L. Jones from argillite in the middle part of the Glenn Shale along Washington Creek. This fossil was originally identified as *Aucella crassicollis* by T. W. Stanton (see Mertie, 1930, p. 139, USGS collection 2674).

No fossils were found in the upper part of the Glenn Shale in its type section, but the following fossils, identified by D. L. Jones, were collected from argillite and shale in the upper part of the formation on the west bank of the Nation River (fig. 1) near the mouth of Tindir Creek:

M1026 (Field No. 60 ABa 552), Charley River B–1 quadrangle, lat 65°25′ N., long 141°23.7′ W. Collected by Earl E. Babb, 1960.
Polyptychites sp.
Buchia cf. *B. crassicollis*
Age: Early Cretaceous (probably Valanginian).

M1027 (Field No. 60 ABa 553), Charley River B–1 quadrangle, lat 65°24.9′ N., long 141° 24.2′ W. Collected by Earl E. Babb, 1960.
Buchia cf. *B. crassicollis*
Age: Early Cretaceous (probably Valanginian).

In summary, fossils indicate that the Glenn Shale ranges in age from Middle Triassic (Ladinian) to Early Cretaceous (probably Valanginian). All of the diagnostic fossils have been found south of lat 65°25′ N.

The Glenn Shale rests on the Tahkandit Limestone or the Step Conglomerate, but the contact is not exposed. Presumably, beds of Early Triassic age are missing, and thus the contact between the Glenn Shale and the Tahkandit Limestone or the Step Conglomerate is considered to be an unconformity. The Glenn Shale is overlain, apparently conformably, by the Keenan Quartzite of Early Cretaceous (Valanginian) age and locally, unconformably, by unnamed nonmarine sedimentary rocks of Late Cretaceous and Tertiary age.

LOWER CRETACEOUS ROCKS

KANDIK GROUP

The name Kandik Formation was formally proposed by Mertie (1930) for several thousand feet of predominantly shale and sandstone exposed in the valleys of the Kandik and Yukon Rivers (fig. 1). The Kandik Formation, of Early Cretaceous age, is herein raised to group status and is subdivided into three newly named formations—in ascending order, the Keenan Quartzite, the Biederman Argillite, and the Kathul Graywacke. The type locality for the Kandik Group is in the vicinity of the Kandik River and is herein considered to be along the valley of the Yukon River from the vicinity of the mouth of Glenn Creek to the top of Biederman Bluff.

KEENAN QUARTZITE

TYPE SECTION AND AREAL DISTRIBUTION

The Keenan Quartzite is best exposed along the west bank of the Yukon River half a mile downstream from the mouth of Glenn Creek (fig. 1), Charley River B–3 quadrangle (1:63,360). Keenan Creek, for which the formation is named, is a small tributary of Glenn Creek. The formation at the Yukon River locality, which is the type section, consists of about 150 feet of light- to dark-gray fine-grained massive quartzite which is overlain, apparently conformably, by tightly folded siltstone and argillite of the lower part of the Biederman Argillite. It is underlain, apparently conformably, by siltstone beds of the upper part of the Glenn Shale. When the Yukon River is at low stage, the Keenan Quartzite is also exposed on the east bank of the Yukon River about half a mile northeast of the mouth of Glenn Creek. From there northeastward it forms resistant ridges between the Kandik and Nation Rivers.

A supplementary reference section is well exposed along an unnamed tributary of the Kandik River (fig. 1) in the E½ sec. 23, T. 7 N., R. 29 E., in the Charley River B–2 quadrangle. Here the Keenan Quartzite is several hundred feet thick and has interbeds of black shale and argillite. The formation is thickest (approx. 1,000 feet) in the areas about 5 miles east and 15 miles southwest of the mouth of Van Hatten Creek in the Charley River D–2 and C–3 quadrangles. Figure 6 shows a typical exposure of the formation east of Van Hatten Creek. The Keenan Quartzite is also exposed at many other localities in a 2,000-square-mile area extending from the Alaska-Yukon boundary to tributaries of the Yukon River near the abandoned settlements of Woodchopper and Coal Creek.

LITHOLOGY AND DISTINGUISHING FEATURES

At most localities, the Keenan Quartzite is light gray on fresh surfaces and white or very pale orange on weathered surfaces. With increasing iron oxide content, it takes on shades of red and brown, and with increasing carbon content, it takes on darker shades of gray and black. In thin section, the rock consists of rounded and well-sorted fine or very fine quartz grains with secondary overgrowths of quartz filling the interstices between the grains. Many of the quartz grains are rimmed by chlorite. At a few localities the cement is cal-

FIGURE 6.—Blocky rubble characteristic of the Keenan Quartzite along ridges a few miles east of the mouth of Van Hatten Creek (see fig. 1). Partings in the quartzite are probably along joints inasmuch as there are no other indications of bedding.

cite or iron oxide. Rounded sand-size chert grains are a minor constituent; some samples contain microcline, muscovite, hornblende, and epidote. That no chert-pebble conglomerate has as yet been found in the Keenan Quartzite is useful in distinguishing it from the quartzite beds in the Step Conglomerate. Glauconite occurs in the lower part of the Keenan Quartzite about 5 miles south of the Step Mountains.

AGE AND STRATIGRAPHIC RELATIONS

The pelecypod *Buchia* "*sublaevis*" of Early Cretaceous (Valanginian) age, according to D. L. Jones (written communs., 1960, 1963), has been found in the Keenan Quartzite at the following localities:

USGS M2057 (Field No. 63ABa 3882), Charley River C–3 quadrangle, lat 65° 38.7′ N., long 142°23.1′ W. Collected by Earl E. Brabb, 1963.

USGS M2059, Charley River B–2 quadrangle, lat 65°29.7′ N., long 141°34′ W. Collected by geologists of Mobil Oil Co., 1962.

USGS M2060 (Field No. 63ACn 2505), Charley River C–4 quadrangle, lat 65° 34′ N., long 142°44.8′ W. Collected by Michael Churkin, Jr., 1963.

USGS M2061 (Field No. 63ACn 2541), Charley River C–4 quadrangle, lat 65° 33.8′ N., long 142°47.9′ W. Collected by Michael Churkin, Jr., 1963.

USGS M2062 (Field No. 63ACn 2623), Charley River C–4 quadrangle, lat 65° 33.3′ N., long 142°37.3′ W. Collected by Michael Churkin, Jr., 1963.

USGS M2063 (Field No. 63ACn 2822), Charley River B–3 quadrangle, lat 65° 18.3′ N., long 142°03.6′ W. Collected by Michael Churkin, Jr., 1963.

USGS M1764 (Field No. 62ABa 2601), Charley River D–1 quadrangle, lat 65° 46.6′ N., long 141°00′ W. Collected by Earl E. Brabb, 1962.

USGS M1765 (Field No. 62ABa 2632), Charley River D–3 quadrangle, lat 65° 46.9′ N., long 142°07.1′ W. Collected by Earl E. Brabb, 1962.

USGS M1766 (Field No. 62ABa 2646), Charley River C–4 quadrangle, lat 65° 34′ N., long 142°44.8′ W. Collected by Earl E. Brabb, 1962.

In addition, D. L. Jones identified a belemnite at M2059 and *Buchia* cf. *B. crassicollis* of Valanginian age at the following locality:

M1022 (Field No. ABa 797), Charley River D–1 quadrangle, lat 65°45.2′ N., 141°15.3′ W. Collected by Earl E. Brabb, 1960.

Collection M9389 (Field No. 1509A) contains an *Inoceramus*? sp. (see Mertie, 1930, p. 139) collected by Eliot Blackwelder in 1915 from the middle part of the Keenan Quartzite in its type section.

In summary, fossils indicate that the Keenan Quartzite is of Early Cretaceous (Valanginian) age.

The Keenan Quartzite apparently represents an interruption in the deposition of the argillaceous sediments that constitute the underlying Glenn Shale and the overlying Biederman Argillite. Though it seems conformable with these formations at most localities, the occurrence of glauconite in the lower part of the Keenan Quartzite near the Step Mountains and the thinness of the Glenn Shale in that area could be interpreted as indicating an unconformity. The thinness of the Glenn Shale could be due to faulting, however. Additional geologic mapping in greater detail in the Step Mountains is needed before the problem can be solved.

In the headwaters of the Black River near the Alaska-Yukon Territory boundary, the Keenan Quartzite seems to be overlain unconformably by the Kathul Graywacke of Early Cretaceous (Albian) age; here the intervening Biederman Argillite is missing.

BIEDERMAN ARGILLITE

TYPE SECTION AND AREAL DISTRIBUTION

The Biederman Argillite is here named for the excellent exposures in its type section along Biederman Bluff (fig. 7), a newly named geographic feature on the west side of the Yukon River about 4 miles northwest of the mouth of the Kandik River (fig. 1) in the Charley River B–4 quadrangle. The type section extends from the banks of the Yukon River to the top of the bluff in the NW¼ sec. 32, T. 7 N., R. 25 E. Additional exposures are present along the Yukon River both upstream and downstream from the type section, but folds,

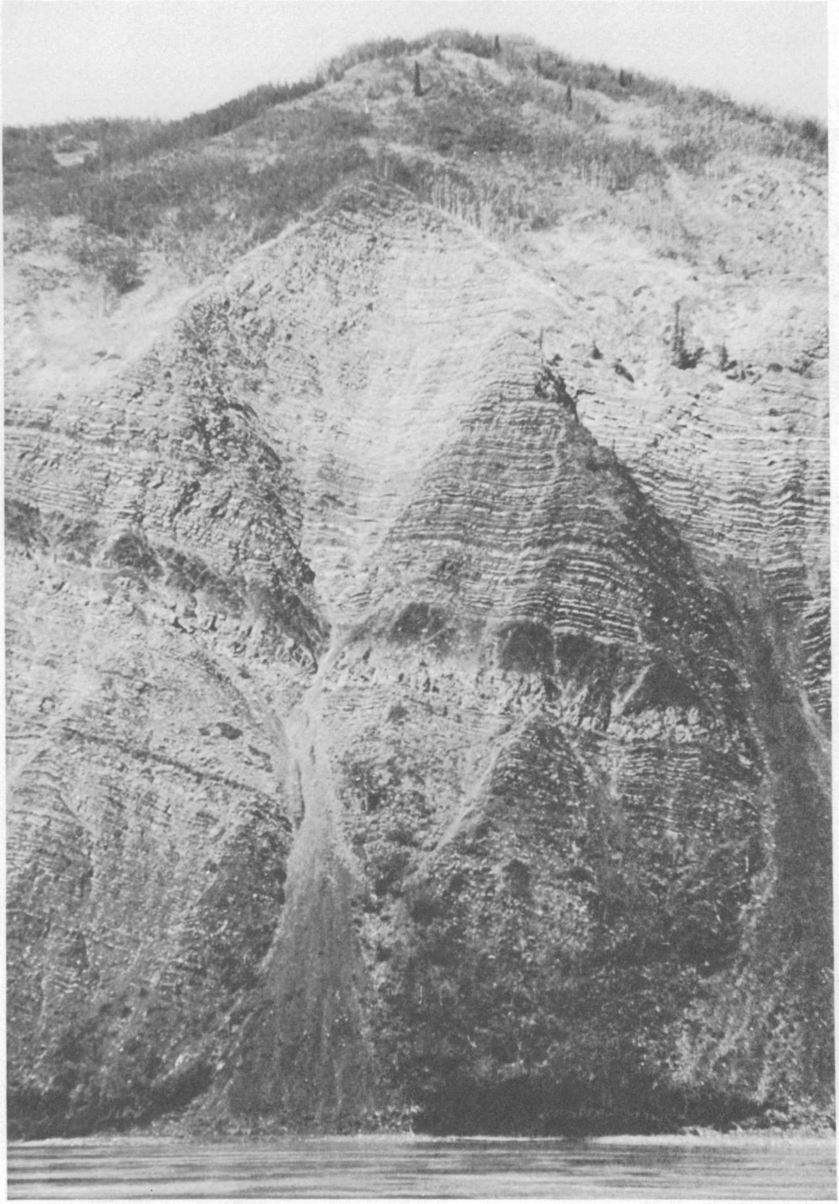


FIGURE 7.—Type section of the Biederman Argillite at Biederman Bluff. The peak at the top of the photograph is about 1,000 feet above the level of the Yukon River (at the bottom of the picture). The dark band in the center of the photograph is massive argillite; the other rocks are argillite with many interbeds of siltstone and sandstone.

faults, landslides, covered areas, and the scarcity of fossils for stratigraphic control make it difficult to establish the sequence of rocks beyond the type section. Inasmuch as neither the top nor the base of the formation are exposed in the type section, a supplementary reference section is herein established. It extends from the top of the Keenan Quartzite in its type section on the Yukon River half a mile downstream from the mouth of Glenn Creek to the base of the Kathul Graywacke in its type section about 1 mile southeast of bench mark 3122 (Nat) on Kathul Mountain. This reference section is 12–18 miles southeast of Biederman Bluff (fig. 1).

The Biederman Argillite underlies an area of more than 2,000 square miles from Coal Creek (fig. 1) to the Alaska-Yukon Territory boundary.

LITHOLOGY AND DISTINGUISHING FEATURES

In its type section and at most other localities, the Biederman Argillite is mainly dark-gray or grayish-black argillite in beds a few inches to a few feet thick. The argillite has many thin interbeds of fairly well sorted medium-gray siltstone and light-gray fine-grained sandstone and quartzite, which give outcrops of the formation a rhythmically bedded appearance (fig. 8). The siltstone and sandstone beds characteristically have small-scale cross-laminations, graded beds, convolute bedding, and other sedimentary structures that sug-

FIGURE 8.—Rhythmic interbedding of argillite, siltstone, and sandstone—a characteristic of the Biederman Argillite at Biederman Bluff.

gest current action and instability of the basin floor during deposition of the sediment.

At many localities the siltstone and sandstone are sparse and the Biederman Argillite has a massive appearance. The argillite commonly weathers to needlelike forms a few inches long. Many of the samples will "ring" when struck with a hammer. Axial-plane cleavage is well developed at many localities; the formation as a whole is extensively folded and faulted.

Greenish-gray chert, siliceous shale, grayish-black argillite, and chert-limestone breccia exposed along the lower reaches of the Kandik River and its tributaries about 5 miles north of Kathul Mountain have been included in the Biederman Argillite, but they could be upfolded rocks of Paleozoic age. A few thin beds of chert-pebble conglomerate definitely occur in the Biederman Argillite on the southwest bank of the Yukon River about 4 miles downstream from the mouth of the Charley River; however, unlike the Step Conglomerate, this conglomerate in the Biederman Argillite has a matrix of grayish-black argillite.

THICKNESS

The type section was not measured in detail, but it is estimated to be approximately 1,000 feet thick. The entire formation is at least 5,000 feet thick, but probably does not exceed 10,000 feet.

AGE AND STRATIGRAPHIC RELATIONS

Fossils are scarce in the Biederman Argillite. No fossils have been found in the type section, and only the following fossils, identified by D. L. Jones, were found in the reference section:

USGS M3783 (Field No. lot 18) from lower part of Biederman Argillite, within a few hundred feet stratigraphically above the Keenan Quartzite, Charley River B–3 quadrangle, lat 65°18.4′ N., long 142°05.7′ W. Collected by E. M. Kindle, 1906.

Inoceramus sp.
Pinna sp.
Polyptychites sp.
Age: Early Cretaceous (Valanginian).

USGS M13428 (Field No. 25AMt 207) probably very close to, or at, M3783. Collected by J. B. Mertie, Jr., 1925.

Inoceramus sp. fragments and a belemnite.

USGS M2064 (Field No. 63ACn 2825) probably very close to, or at, M3783. Collected by Michael Churkin, Jr., 1963.

Inoceramus sp.

USGS M3785 (Field No. lot 19) from float near the top of the Biederman Argillite, on the north bank of the Yukon River near Kathul Mountain, Charley River B–3 quadrangle, approximate lat 65°20′ N., long 142°16′ W. Collected by E. M. Kindle, 1906.

Buchia "*sublaevis*" of Valanginian age.

Unfortunately, collection M3785 may well have been from rocks washed a few miles downstream from the richly fossiliferous localities near the mouth of Glenn Creek; it is here discounted in determining the age of the upper part of the Biederman Argillite.

E. M. Kindle, in 1906, collected *Inoceramus* sp. and *Buchia* sp. (formerly *Aucella*) from an unknown stratigraphic position within the Biederman Argillite on the south bank of the Yukon River about 4 miles downstream from the mouth of the Charley River (see Mertie, 1930, p. 139, collection M3784), and Eliot Blackwelder found a plant identified by F. H. Knowlton as *Chondrites heeri* Eichwald, from an unknown position with the Biederman Argillite on the south bank of the Yukon River about 1½ miles upstream from the mouth of the Kandik River (see Mertie, 1930, p. 140). The following collections identified by D. L. Jones are from rocks questionably assigned to the Biederman Argillite in an area of extensively folded and faulted rocks along Woodchopper and Coal Creeks (fig. 1), about 20 miles west of Biederman Bluff:

USGS M1763 (Field No. 62ABa 2353) from carbonaceous shale along an old meander of Coal Creek, Charley River B–5 quadrangle, lat 65°20.4′ N., long 143°06.2′ W. Collected by Earl E. Brabb, 1962.
Buchia sp., possibly *B. "sublaevis."*

USGS M13429 (Field No. 25AMt 227) from argillite on the east bank of Woodchopper Creek, Charley River B–5 quadrangle, lat 65°20.2′ N., long 143°19′ W. Collected by J. B. Mertie, Jr., 1925; re-collected by Earl E. Brabb, 1960 (USGS M1023, Field No. 60ABa 1206).
Buchia "sublaevis" of Valanginian age.

USGS M1025 (Field No. 60ABa 1203), from limestone talus at the base of a massive limestone exposed on the west valley slope of Woodchopper Creek, Charley River B–5 quadrangle, lat 65°19.5′ N., long 143°20.2′ W. Collected by R. N. Passero and Earl E. Brabb, 1960.
Inoceramus sp. of Jurassic or Cretaceous age.

An extensive pelecypod and brachiopod fauna of Jurassic or Cretaceous age from this limestone at locality M1025 was reported by Mertie (1938, p. 220). The stratigraphic positon of this limestone within the Mesozoic sequence could not be determined, but the limestone is most closely associated geographically with the Biederman Argillite.

The Biederman Argillite has been examined at more than 100 localities over a 2,000-square-mile area, but no additional fossils have been found. Ten samples of the argillite and siltstone at widely separated localities were processed by Richard A. Scott for spores or pollen, but all samples were barren.

In conclusion, fossils and stratigraphic relations indicate that the lower part of the Biederman Argillite is Early Cretaceous (Valanginian). The type section and most of the formation are in general undated; however, the few fossils that have been found are consistent with an Early Cretaceous age. The great thickness of the formation, in contrast to thinner formations in the area that include several series or even two systems, suggests that additional stages of the Cretaceous may be represented in the Biederman Argillite. Pending paleontologic documentation, however, the formation is considered to be Early Cretaceous (Valanginian).

At most localities the Biederman Argillite rests conformably on the Keenan Quartzite and is overlain unconformably by the Kathul Graywacke. On the northeastern flank of the large anticline in the Step Mountains, however, the Biederman Argillite seems to rest directly on the Step Conglomerate. Although an unconformable relationship is possible, it should be noted that exposures are poor in the area between the Step Mountains and the Nation River; thus the Keenan Quartzite may have been overlooked, and the argillite above the Step Conglomerate may be the Glenn Shale rather than the Biederman.

KATHUL GRAYWACKE

TYPE SECTION AND AREAL DISTRIBUTION

Conglomerate and sandstone of graywacke type exposed on Kathul Mountain (fig. 1) is here named the Kathul Graywacke. The type section extends from grassy slopes (fig. 9) about a mile southeast of bench mark 3122 (Kat) in the Charley River B–3 quadrangle (1:63,360), where medium- to coarse-grained graywacke of the Kathul Graywacke in contact with shale of the underlying Biederman Argillite is exposed, to the upper slopes of Kathul Mountain about half a mile southeast of bench mark 3122, where the youngest beds of the Kathul Graywacke crop out along the trough of a northeast-trending syncline.

The Kathul Graywacke extends continuously from Kathul Mountain to the middle and upper reaches of the Kandik River and the Alaska-Yukon border, underlying an area of about 275 square miles. The formation underlies an additional 40 square miles in an area adjoining the border between the Kandik River and tributaries of the Black River, at about lat 65°50′ N. The formation is fairly well exposed along most of the Kandik River and its tributaries; its conglomerate boulders are one of the principal hazards in traveling along the Kandik River by boat.

LITHOLOGY AND DISTINGUISHING FEATURES

In the type section, the Kathul Graywacke consists of beds of pebble-conglomerate and sandstone a few inches to as much as 50

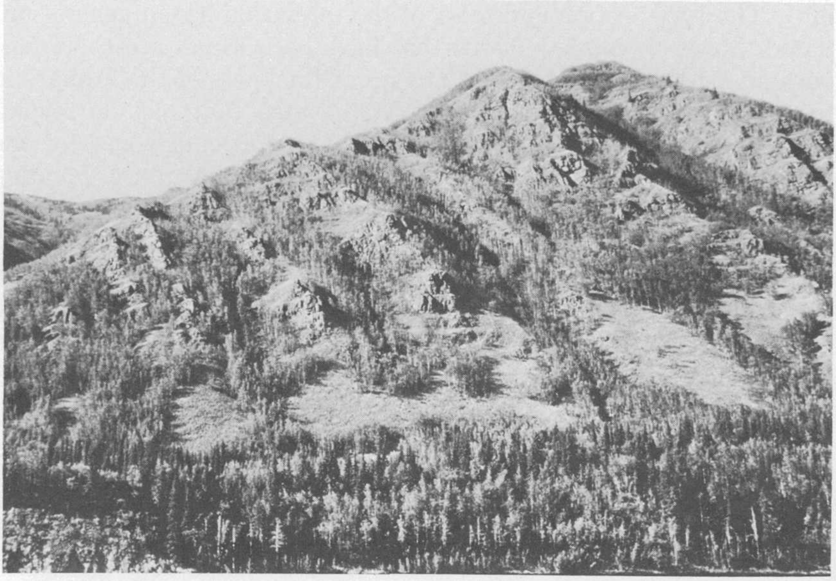


FIGURE 9.—Type section of the Kathul Graywacke on Kathul Mountain. The blocky outcrops between the grassy slopes and the crest of the mountain are chiefly conglomerate and sandstone of graywacke type. The Biederman Argillite underlies the grassy slopes in the middle foreground.

feet thick that grade upward to thin beds of siltstone and argillite. The conglomerate and sandstone is greenish gray on fresh surfaces and light olive gray on weathered surfaces. The argillite is dark gray or grayish black. Grayish-green, gray, and black rounded chert pebbles and grains are conspicuous but not the major constituents of the conglomerate and coarse-grained sandstone. The clasts are mainly a poorly sorted mixture of reworked sandstone, argillite, and limestone; quartz, plagioclase, and potash feldspar grains; volcanic, granitic(?), and metamorphic rocks; and detrital chlorite, epidote, hornblende, muscovite, and biotite. The clasts and grains are in a matrix of more than 10 percent by volume of argillaceous material, most of which has been altered to chlorite and (or) epidote. The surface of many quartz grains and extensive parts of chert and feldspar grains seem in thin section also to have been replaced by chlorite. The green color of the volcanic and some metamorphic clasts and the green detrital and secondary epidote and chlorite, in combination with poor sorting and an abundant matrix, serve to distinguish these graywackes from all other sedimentary formations in the region.

The graded sets of conglomerate, sandstone, and argillite are common throughout the formation, but outside the type section—which

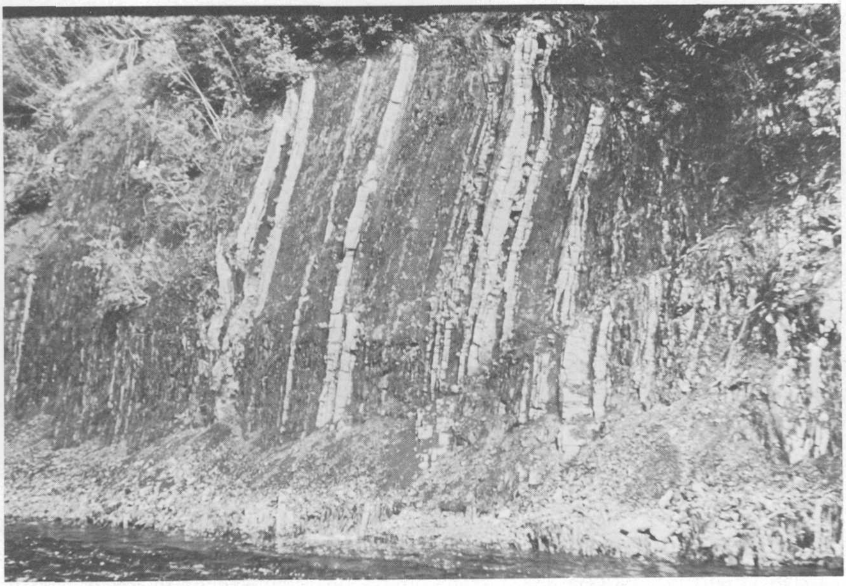


FIGURE 10.—Faulted beds of the Kathul Graywacke along the Kandik River near the mouth of Big Sitdown Creek (fig. 1). These beds are similar in appearance to those in the Biederman Argillite, but the occurrence of poorly sorted greenish graywacke beds near these rocks led us to map them as Kathul Graywacke.

probably has less than 10 percent argillite—massive argillite and rhymically bedded argillite, siltstone, and sandstone (fig. 10) similar in appearance to the Biederman Argillite make up a substantial and possibly even a major part of the Kathul Graywacke. The poorly sorted greenish graywacke beds in or near these rhythmically bedded rocks were used to distinguish them from the Biederman Argillite. The widespread occurrence of potash feldspar on stained slabs of the Kathul Graywacke was a useful laboratory technique for confirming the field identifications.

Pebble- and boulder-size clasts of argillite are common in sandstones of the Kathul Graywacke exposed along the Kandik River. These clasts appear to have been eroded from nearly contemporaneous argillaceous beds. Convolute structures also suggest instability of the basin floor during deposition of the sediment. Small-scale cross-laminations are common, and measurements at four localities along the upper part of the Kandik River suggest that the basin currents flowed from east to west. An eastern source for the sediments is not in accord with the composition of the clasts, however. The only reasonable source for the volcanic, metamorphic, and granitic(?) clasts, and the chlorite and epidote, is in the terrain south and west of Kathul Mountain, not in Canada.

THICKNESS

The Kathul Graywacke is about 1,500 feet thick in its type section on Kathul Mountain, and it seems to be several thousand feet thick in the middle and upper reaches of the Kandik River in Alaska.

AGE AND STRATIGRAPHIC RELATIONS

Nondiagnostic plant fragments are fairly common in the Kathul Graywacke, but six samples of argillaceous rocks from the formation examined by Richard A. Scott for spores or pollen were all barren. Invertebrate fossils are exceedingly rare. The following collections were identified by David L. Jones:

M1021 (Field No. 60ABa 791) from sandstone (graywacke) in lower part of Kathul Graywacke, on west bank of Kandik River, Charley River D–1 quadrangle, lat 65°48.8′ N., long 141°07.3′ W. Collected by Earl E. Brabb, 1960.
Poorly preserved pelecypods and gastropods. No age determination.

M2058 (Field No. 63ABa 3933) from sandstone (graywacke) in lower part of Kathul Graywacke, Charley River D–1 quadrangle, lat 65°55.4′ N., long 141° 00.1′ W. Collected by Earl E. Brabb, 1963.
Pholadomya sp. No age significance.

Field No. KPO 2043, from olive-green siltstone near the crest of Kathul Mountain, Charley River B–3 quadrangle, lat 65°21.4′ N., long 142°16.2′ W. Collected by geologists of British Petroleum Co., 1962.
Poorly preserved pelecypods. No age determination.

Stratigraphic relations of the Kathul Graywacke are somewhat uncertain because of the scarcity of fossils for stratigraphic control, poor exposures, structural complications, and difficulties in distinguishing the formation from the Biederman Argillite. The Kathul Graywacke rests conformably on the Biederman Argillite in the vicinity of Kathul Mountain (fig. 1), but in the Step Mountains and in the headwaters of the Black River the formation apparently rests unconformably on the Biederman Argillite, Keenan Quartzite, or Step Conglomerate. The Kathul Graywacke is overlain unconformably by unnamed and poorly consolidated conglomerate, sandstone, mudstone, and thin coal seams near the Alaska-Yukon Territory boundary at lat 65°45′. Pollen from the shale is late Tertiary, according to R. A. Scott (written commun., 1962). At other localities, Scott has found pollen ranging in age from Late Cretaceous to late Tertiary in this unnamed formation (see fig. 3).

Fossils indicate that the Kathul Graywacke is marine, and Mesozoic or younger. Stratigraphic relations indicate that the formation is (1) Early Cretaceous (Valanginian) or younger, (2) older than late Tertiary, and (3) probably older than Late Cretaceous. The Kathul Graywacke is here provisionally considered to be of Early Cretaceous (Albian) age on the basis of the following evidence. The formation is most similar, lithologically, to unnamed nonmarine conglomerate, sandstone, and mudstone exposed along the Yukon River in the vicinity of the mouth of the Seventymile River (figs. 1, 3). Like Kathul Graywacke, this unnamed formation has clasts of chert, quartz, volcanic rock, plagioclase and potash feldspar, chlorite, and biotite. Like the Kathul Graywacke, this unnamed formation marks an abrupt change in the regimen—a change from terrains contributing mainly chert, quartz, and argillaceous material to terrains contributing these materials plus metamorphic, granitic(?), and volcanic rocks and their mineral constituents, such as chlorite, plagioclase, and potash feldspar. Both the Kathul Graywacke and the unnamed formation seem to rest unconformably on older units, possibly reflecting the Aptian orogeny which affected many areas in Alaska (Gates and Gryc, 1963). The unnamed formation contains plants of probable Early Cretaceous (Albian) age, according to J. A. Wolfe (written commun., 1963), and thus, if the two formations are correlative, the Kathul Graywacke may also be Albian.

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