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United States
Department of the Interior
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Geological Investigations
Naval Petroleum Reserve No. 4
Alaska

Special Report 33

THE STRATIGRAPHY AND PALEONTOLOGY OF
THE NOATAK AND ASSOCIATED FORMATIONS
BROOKS RANGE, ALASKA

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STRATIGRAPHY AND PALEONTOLOGY OF THE NOATAK AND ASSOCIATED FORMATIONS, BROOKS RANGE, ALASKA

by

J. Thomas Dutro, Jr.

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STRATIGRAPHY AND PALEONTOLOGY OF THE NOATAK AND ASSOCIATED FORMATIONS, BROOKS RANGE, ALASKA

by

J. Thomas Dutro, Jr.

ABSTRACT

A thick complex sequence of clastic rocks, formerly named the Noatak formation, underlies the Lisburne formation (Mississippian) in the Brooks Range, northern Alaska. Five formations have been recognized as a result of recent investigations by the author and other geologists of the Navy Oil Unit, U. S. Geological Survey. In the western Brooks Range, the three formations present below the Lisburne formation are: Utukok formation (Upper Tournaisian to Lower Visean), Noatak formation (restricted) (Upper Devonian to Lower Tournaisian (?)) and Hunt Fork (?) formation (Upper Devonian). In the central Brooks Range the Kayak formation (Lower to Upper Tournaisian), Kanayut formation (Upper Devonian to Lower Tournaisian (?)), and Hunt Fork formation (Upper Devonian) lie below the Lisburne formation.

Lithologic and faunal characteristics of these sedimentary units reveal the regional pattern of sedimentation and suggest specific paleoecologic environments. The chert conglomerates in the Kanayut and Noatak formations are thought to have formed in a belt characterized by fluctuating marine and nonmarine conditions, the chert source being a mid-Devonian regolith.

Analysis of faunules suggests certain correlations with the European, Siberian, and western Cordilleran sections.

Described faunas of the Utukok and Kayak formations include 40 brachiopod species and varieties, 9 echinoderm species, 2 bryozoan species, 8 molluscan species, and 1 trilobite species, of which 13 are new.

INTRODUCTION

One of the most distinctive lithologic units in northern Alaska is the Lisburne formation (Mississippian), which crops out along the north flank of the Brooks Range for more than 600 miles and is easily recognized by its light-gray color and cliff-forming habit. Beneath this well-defined unit is a thick and variable complex of chiefly detrital rocks to which the name Noatak formation has been applied. The present study indicates that in its type area, the western Noatak district, this complex is nearly 4,000 feet thick and is devisible into three lithologic units as indicated in figure 1.

In the Anaktuvuk Pass-Kanayut Lake region, 9,000-10,000 feet of beds in an equivalent stratigraphic position has also been divided into three major units. These lithologic units are given the rank of independent formations and, for reasons explained later, the name Noatak is restricted to the middle unit of the western Noatak district; new names are proposed for the other units.

The Noatak formation, restudied in its type area, is here redefined and more fully described. Detailed examination of sections in the western Noatak district, Alaska (see fig. 2), was made during the summer of 1950. Additional field work in 1949 near Kanayut Lake and in 1951 at Cape Thompson and south of Lake Noluk has added considerable data regarding regional relationships. Faunal studies were initiated at Yale University in the winter of 1949-50 and were continued at the U. S. National Museum during the winters of 1950-51 and 1951-52.

Acknowledgments

Several geologists of the Navy Oil Unit, U. S. Geological Survey, aided the author in the preparation of this paper. Arthur H. Lachenbruch and Milton C. Lachenbruch, Jr. helped with field mapping in the type Noatak area; William P. Brosgé, Marvin D. Mangus, William W. Patton, Jr., and Edward G. Sable kindly made available supplementary data, especially for the type Utukok section and the pre-Kanayut strata of the central Brooks Range; Wenonah Eckstein provided invaluable editorial assistance; Frances Kline did final drafting on maps and diagrams; typing was done by Irene Keller. Arthur L. Bowsher of the U. S. National Museum, in charge of the 1949 work in the Kanayut Lake area, provided many sound suggestions, especially with regard to faunal identifications and correlations.

James Steele Williams, who helped make possible the whole program of field and laboratory work, and other members of the Paleontology and Stratigraphy Branch of the U. S. Geological Survey, provided valuable information concerning lower Mississippian faunas.

Dr. Carl O. Dunbar offered encouragement and guidance in all phases of the work and critically read the manuscript.

Finally, thanks are due my wife for her encouragement and assistance throughout the writing of this paper.

Previous work

The Noatak sandstone was first described by Philip S. Smith (1913, p. 70) from exposures along the Noatak River between the junctions of the Nimiuktuk and Kugururok Rivers:

"In the most typical exposures seen from a point near the camp of August 11 to the canyon the rocks are dominantly sandstones, medium fine grained and rather massive, but containing layers of shale that accentuate the bedding.

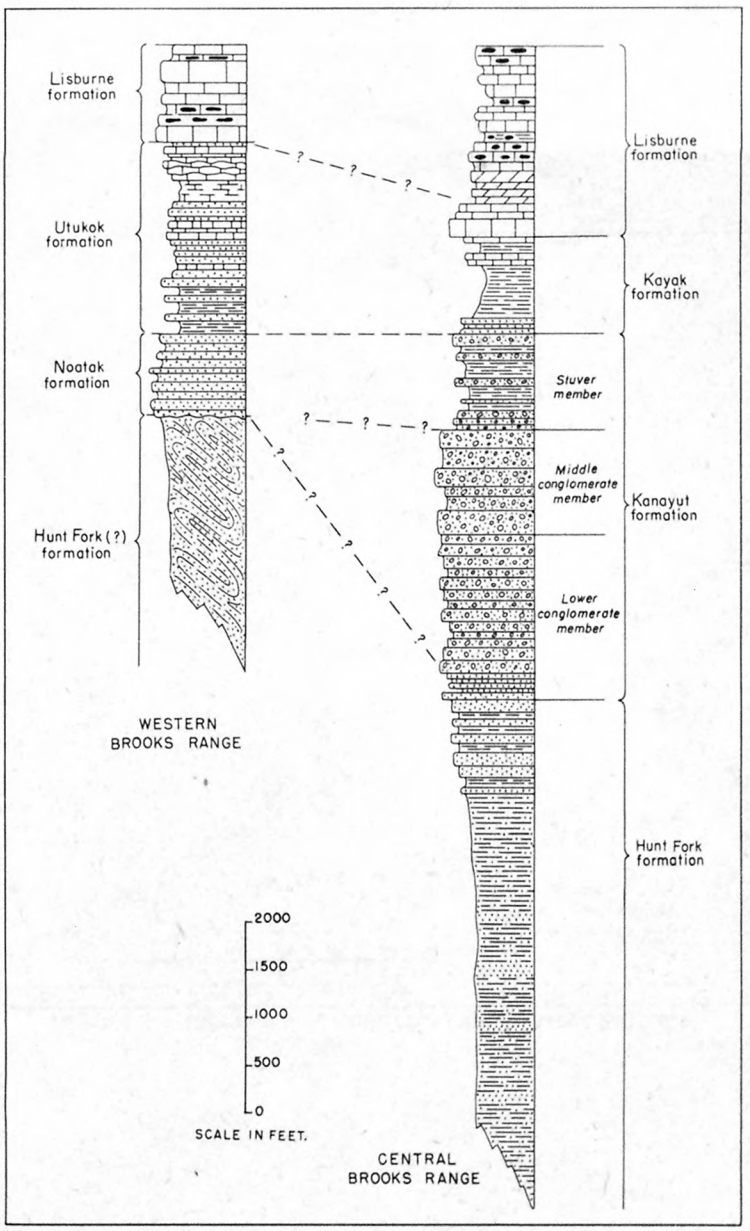

FIGURE 1. — GENERALIZED STRATIGRAPHIC COLUMNAR SECTIONS

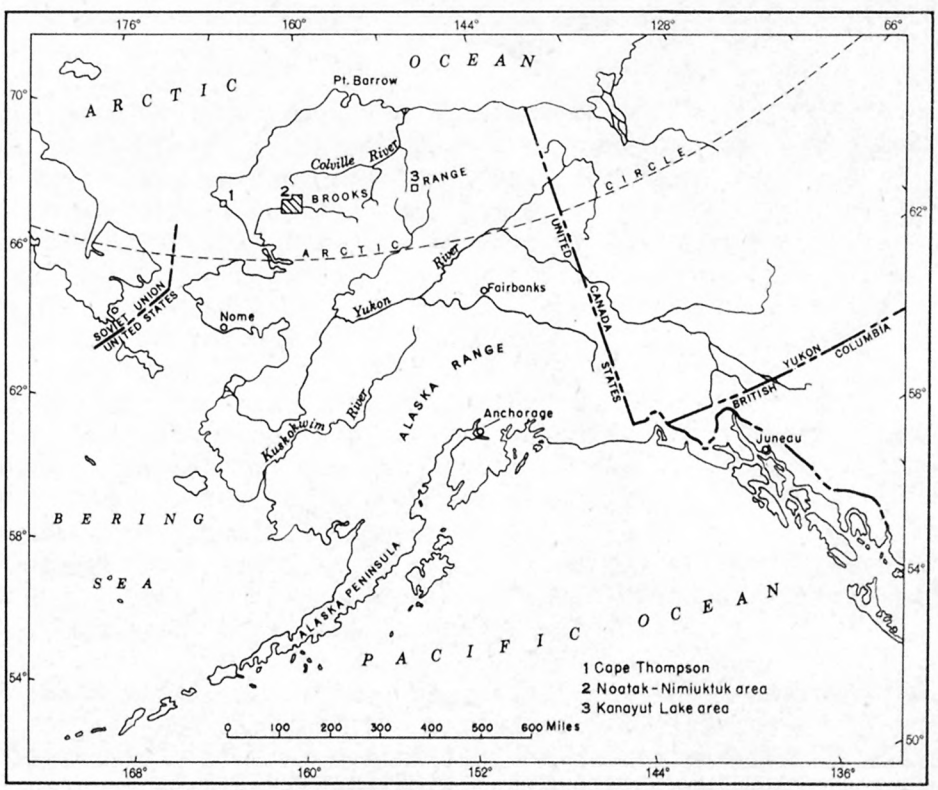

FIGURE 2. — INDEX MAP SHOWING LOCATION OF AREAS STUDIED 19829

n exposed surfaces the rocks are usually rusty brown to brownish green, but n fresh fracture they are dark gray or greenish. The component minerals are sually not distinguishable microscopically with the exception of quartz and lakes of mica. When treated with acid many of the sandstones effervesce lightly, showing the presence of calcite. Under the microscope the sand- tone is seen to be composed mainly of quartz and some sericite, with limon- tic and carbonaceous material filling the interstices.

"Some slightly conglomeratic beds are associated with the sandstones and ertain of these show flattened masses of indurated shale or quartzite which re of pebble-like form, but which may represent contemporaneous accumulations f mud. Mica has been developed parallel with the surface of these nodules, ut the material within is unsheared. Many of these accumulations closely imulate fossils and can be distinguished from them only by careful examina- ion.

"Some thin beds of limestone, few over a foot thick, are interbedded ith the sandstones. These limestone beds show considerable variation in olor, some being dark gray whereas others have weathered to light yellow. ll the limestones are semi-crystalline, but exhibit only slight signs of ovement. Fossils are fairly numerous in some of these beds and are entirely ndeformed. In places the rocks are cut by small local calcite veins and ave been intruded by basic intrusive rocks. The limestone beds become more rominent toward the top of the formation ....

"Shales and slaty beds are interlaminated with the other members of his formation. Generally they exhibit both bedding and cleavage, but not uch metamorphism. The slates contain little clayey material but seem to be ormed mainly of fine-grained quartz and some calcite. As a rule the rock s too fine grained to permit its component minerals to be distinguished. nder the microscope it is seen to be composed mainly of quartz, kaolin, or ericite, and a greenish, nearly amorphous, finely divided mineral, together ith magnetite, some sulphides, and limonitic material."

Although Smith and J. B. Mertie, Jr., (1930, p. 165) expanded the defin- tion to include "all the rocks of the region of pre-Lisburne age", they ealized the limitations of this definition, which was adopted for convenience nd necessitated by the scope of their report and the scale of the accompany- ng geologic map. After noting the extreme lithologic variation along strike ver a distance of more than 500 miles they state (1930, p. 158):

"These facts suggest strongly that the Noatak formation comprises a reat assemblage of rocks, which by more detailed mapping might well be plit up into smaller formational units."

The object of the present study is to split up that assemblage of rocks nd to describe the faunas of the various formations.

A brief comment on the organization of the paper seems advisable. I ave departed from the customary method of describing formations in order of heir geologic age, oldest first. The old Noatak formation is divided into hree lithologic units, of which the middle one is to retain the name Noatak ormation. This redefined unit is discussed first, followed by discussion

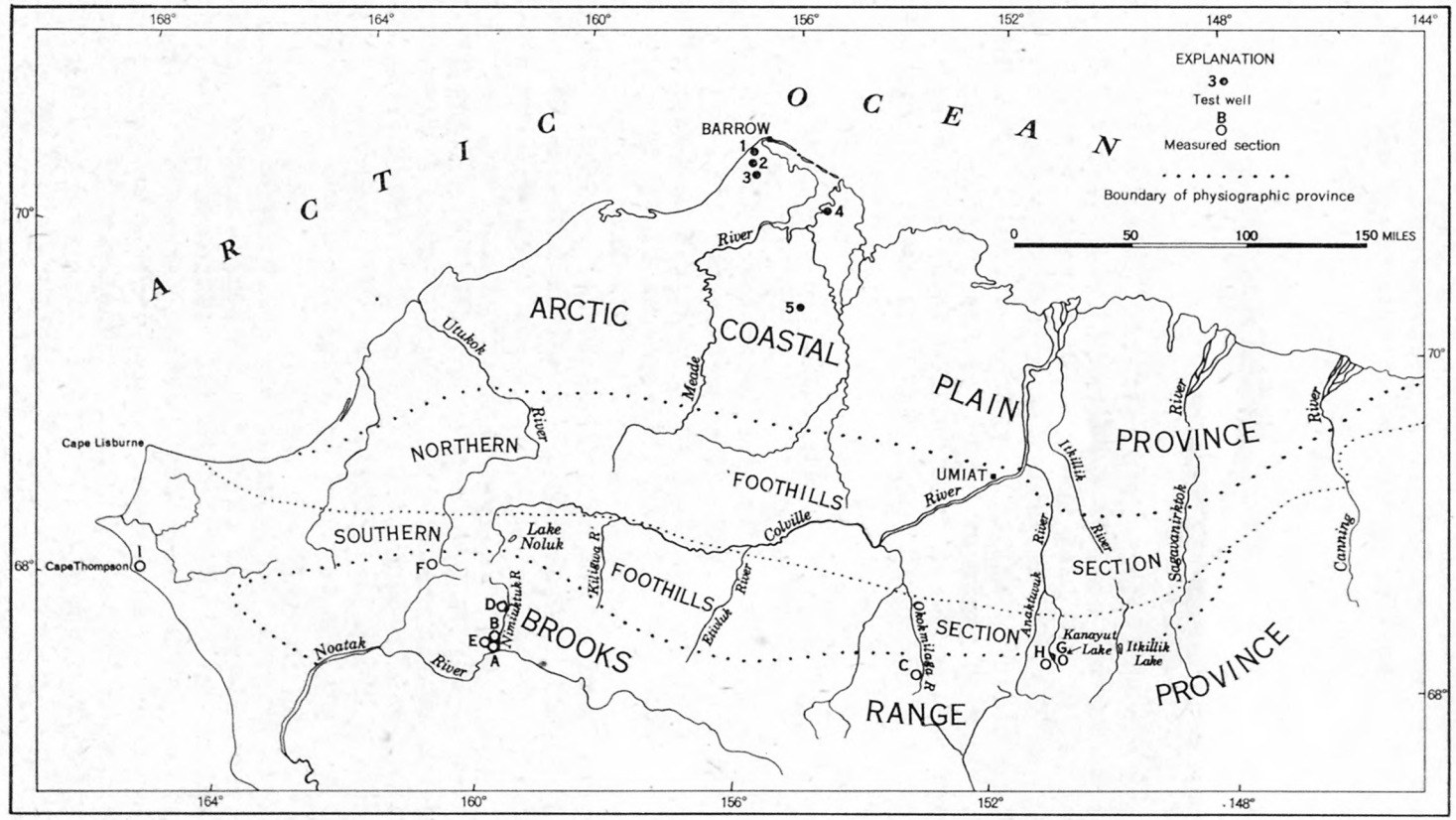

FIGURE 3.– INDEX MAP SHOWING PHYSIOGRAPHIC PROVINCES, GEOGRAPHIC FEATURES, LOCATION OF SECTIONS AND WELLS

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of the other two which were a part of the original formation. Finally, two formations, correlative in part with the first three but geographically separated, are described. I have divorced faunal and lithologic descriptions, the section on Stratigraphy presenting lithologic detail, whereas faunas are discussed under Stratigraphic Paleontology. Formal species descriptions comprise the Systematic Paleontology section.

STRATIGRAPHY

Noatak formation (restricted)

Type area

The type area of the Noatak formation (restricted) is the mountains immediately west of the Nimiuktuk River about 4 miles upstream from its confluence with the Noatak River, approximately lat. 68° 10' N. and long. 159° 58' W.; here the formation ranges in thickness from 700 to 1,000 feet (see pl. 4). Other typical Noatak exposures are in the hills south of the Noatak-Nimiuktuk River junction, and in cut banks along both sides of the Noatak River approximately 40 river miles downstream from that junction (see fig. 3). The name is taken from the Noatak River which flows through the type area.

Lithology

The formation is chiefly sandstone, with minor amounts of clay shale and conglomerate. Typically the sandstone is quartzose, very fine to medium-grained, light-medium bluish-gray to medium gray, and well-indurated, individual beds being one-tenth to three-tenths of a foot thick. The cement is mainly siliceous except near the top where it is partly calcareous. Scattered throughout, parallel to the bedding in many places, are fine grains of iron minerals. On weathered surfaces alteration to limonite has resulted in a characteristic reddish-brown color. Medium-dark gray streaks of clay- and silt-size material are alined parallel to bedding and, upon weathering, result in platy, flaggy slabs which constitute most of the talus. In a few places there are concentrations of reddish-brown ferruginous mudstone bodies which approximate oblate spheroids with the long axis of any planar section oriented parallel to bedding. They vary from medium pebble size to small cobble size. Both large-scale and small-scale cross bedding are common.

Associated clay shale is medium gray to medium-dark gray, fissile, and abundant mica flakes produce a lustrous sheen on bedding surfaces. At one place, cobble-size sandstone nodules lithologically similar to the main part of the formation occur within the shale. Surfaces of these nodules are covered with mica flakes which in cross section are oriented perpendicular to radii of the nodules. These facts, in addition to the observation that mica has an irregular vertical distribution through the formation, substantiate the hypothesis that the mica is a primary sedimentary constituent.

Plate 4. -Hills west of Nimiuktuk River near junction with Noatak River, type area of Noatak formation (restricted)

Conglomerate is rare but has been found locally at the base of units having large-scale cross bedding. The conglomerate matrix, 80 to 85 percent of the rock, is similar to the enclosing sandstone. The remainder is well-rounded small to medium-sized pebbles of which about 75 percent is vein quartz, 15 percent is medium-gray to dark-gray chert, and 10 percent is light greenish-gray or medium-gray slate and phyllite. Quartz veins are common in the underlying Devonian siltstone-slate-phyllite sequence and may well have been the source of the quartz in the conglomerate lenses. A source for the chert is not definitely known though Middle Devonian chert formations are present in the Yukon-Tanana region; further discussion of chert pebbles in rocks of this age is included in the description of the Kanayut formation (see pages 13 to 18).

In its type area, the Noatak formation (restricted) is about 90 percent sandstone, 2 percent conglomerate, and 8 percent shale. A detailed record of the type section (section A in the Appendix) is the most complete unfaulted sequence to be found in the type area. Relationships to younger formations are shown in supplementary section B; normal contacts with any older formation were not observed.

Relationship to other units

The Noatak formation (restricted) here defined is essentially the sandstone unit originally described by Smith. Lithologic units which he included in a single formation are the siltstone-slate-phyllite sequence below, the Noatak formation (restricted) next, and the Utukok formation above. These three units can be mapped separately on the basis of gross lithology. Fossils indicate that the lower unit is probably late Devonian, whereas the upper unit is early Mississippian. Because the contact between the middle and upper units is gradational, the top of the Noatak formation is arbitrarily placed at the top of the highest massive sandstone bed below a sequence of platy calcareous sandstone and clay shale. The Noatak formation is at least partly equivalent to the Kanayut formation which crops out along the crest of the Brooks Range 200 miles to the east. Although most similar to the Stuver member, it may be a westerly sandy phase of the entire Kanayut formation, including the thick lower conglomeratic sequence. For general correlations of these and subsequently described formations; see figure 1.

Hunt Fork (?) formation

Type area

The type section of the Hunt Fork formation, approximately 5,300 feet thick, is located at about lat. 68° 17' N. and long. 153° 20' W., and was measured by William W. Patton, Jr., of the U. S. Geological Survey, during the summer field season of 1951. A highly generalized section is included in the Appendix as section C.

The formation is named for the Hunt Fork of the John River, along which typical outcrops occur. More pertinent to the immediate problem are the outcrops in the Noatak Valley, considered to be the same formation.

Below the Noatak formation (restricted) lies a thick series of quartzitic siltstone, slate, and phyllite originally included as a metamorphic phase of the Noatak formation, but now designated as Hunt Fork (?) formation.

Lithology

Percentages of the different rock types vary; quartzitic siltstone beds predominate in some outcrops whereas others are almost entirely phyllite and clay slate.

Siltstone is medium gray to greenish gray, thin-bedded, micaceous, locally pyritized, and with siliceous cement in most places, though beds in the few fossiliferous localities have calcareous cement. Cleavage, understandably not as well developed in the siltstone as in the finer clastics, lies at varying angles to bedding.

The medium-gray, extremely micaceous phyllite and slate has well-developed cleavage, in places parallel to bedding and at acute angles elsewhere. Primary bedding is shown by color banding, the bands exhibiting subtle textural differences as well. In siltier beds ripple marks indicate the normal bedding attitude.

Joints seem to have developed after cleavage, both cleavage and primary stratification being offset by the joints. Quartz veins cut beds along cleavage planes in some places and along joints in others. Subsequent slippage along joint planes has in turn offset some of the veins which follow cleavage planes.

Relationship to other units

The structural complexity of the Hunt Fork (?) strata as compared to overlying units is striking. Tightly folded and faulted beds have well-developed cleavage and joint systems and are traversed by many quartz veins. The Noatak formation (restricted) and younger formations are almost completely unmetamorphosed; quartz veins, though not entirely absent, are rare. This does not seem explainable by any difference in competency. Beds of the equally competent Utukok formation, exposed in the vicinity of the Hunt Fork (?) strata, are unmetamorphosed, and the most competent Noatak strata are but gently folded. The contact between these two formations was seen at only one place where overturned Hunt Fork (?) strata are faulted over Noatak sandstone and conglomerate in what seems a reverse fault. Distribution of outcrops suggests an unconformity between these units

(see pl. 1). In its type area, the Hunt Fork formation is thought by W. W. Patton, Jr., M. D. Mangus, and W. P. Brosgé (1951, p. 5) to lie conformably beneath the Kanayut formation. The presence in the latter area of several thousand feet of conglomerate not found in the Noatak Valley may be additional evidence of a break in sedimentation in the western area.

Utukok formation

In the western Brooks Range the Utukok formation lies between the Noatak formation (restricted) and the Lisburne formation. Although the Utukok formation in the western Noatak district is not as thick as in its type area near the headwaters of the Utukok River, overall composition and faunas are quite similar.

Lithology

The 650-foot sequence exposed in the Nimiuktuk Valley is mainly sandstone and limestone. The sandstone in most places is quartzose, fine-grained, medium light gray to pale red, thin bedded, and orthoquartzitic. Weathered surfaces exhibit a waxy sheen and are pale-yellowish brown to moderate-yellowish brown. Some strata are slightly calcareous, others contain laminae of ferruginous mineral grains that weather to yellowish-brown limonite.

Limestone is fine-grained calcarenite, composed mainly of fragmental clastic calcite which grades laterally and vertically into coarser beds of recognizable fossil material. This comparatively impure limestone differs markedly from the overlying Lisburne limestones in that the latter are almost entirely composed of clastic calcite or fossil fragments, whereas the former has a considerable percentage of finer ferruginous, siliceous, and argillaceous clay-sized material. These beds are generally medium gray, thin, shaly, and weather a light brown. Marine invertebrate fossils were collected from several horizons (see pl. 3).

Dark-gray to grayish-black clay shale near the base contains zones of red-brown-weathering siltstone concretions that differ from the ferruginous bodies of the Noatak formation (restricted) both in grain size and in the presence of a definite concentric structure. Similar concretions are found in the Kayak formation of the central Brooks Range (see page 27).

In most exposed sequences the beds grade from sandstone and shale at the bottom through impure silty limestone to coarser clastic limestone at the top. Sections B, D, and E were measured in the lower Nimiuktuk Valley (see Appendix).

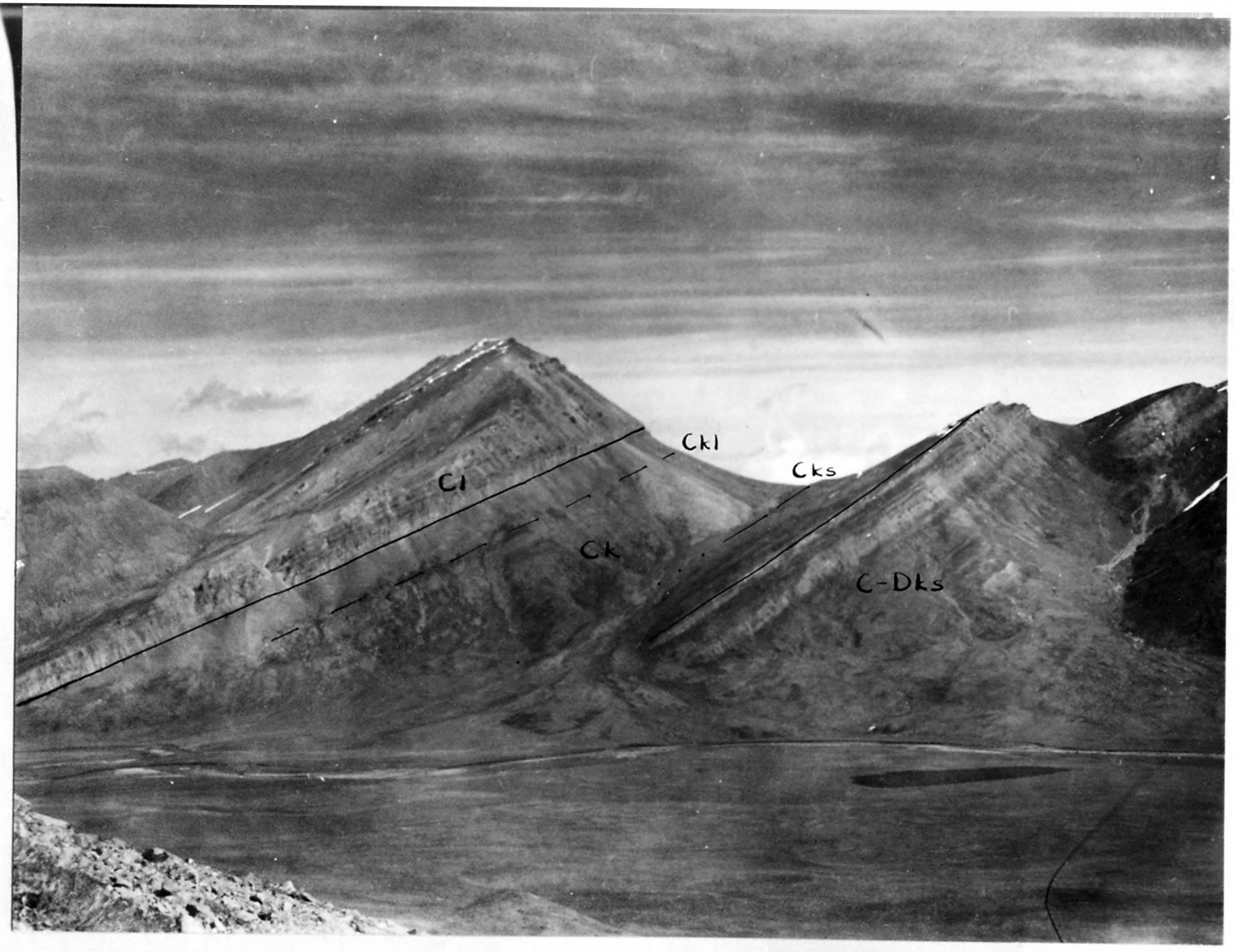

Plate 5. -East wall of Kanayut Valley, type sections of Kayak and Kanayut formations

Type area

The type section, located just west of the Utukok River near its headwaters (approximately lat. 68° 33' N. and long. 161° 10' W.), was measured by Edward G. Sable of the U. S. Geological Survey in 1950. The formation takes its name from the Utukok River. It is about 2,000 feet thick and is composed of rocks similar in lithologic detail to those described above. Vertically, the same progressive change from orthoquartzite through impure calcarenite to coarse clastic limestone occurs. Thin zones of shale are intercalated near the base of this and other sections measured in the vicinity; no contact with the Noatak formation (restricted) was seen. Farther west a thickness of over 4,000 feet has been measured, but stratigraphic detail and fossil collections are better for the thinner type section, included in the Appendix as section F.

Relationship to other units

This formation seems to be conformable with lithologic units above and below; the lower contact, as stated on page 9, is drawn at the top of the highest massive sandstone bed in the Noatak formation. The upper contact is the base of the lowest massive limestone cliff of the Wachsmuth member of the Lisburne formation, which in most places is a light brownish-gray to medium-gray clastic limestone that contains black to dark-brown chert nodules and weathers pale-bluish gray.

The Utukok formation thickens and becomes more calcareous and more fossiliferous north and west of the Nimiuktuk Valley. Eastward along the north front of the Brooks Range it thins; it has not been definitely recognized east of the Killigwa River, though it may be present as silty limestone and calcareous shale zones near the base of the Wachsmuth member farther east. The Utukok formation is equivalent to the lower part of the Wachsmuth member and may also be equivalent to the upper part of the Kayak formation (see fig. 1). Faunal evidence supports these correlations (see pages 35 to 38).

Kanayut formation

The Kanayut and Kayak formations crop out in the central Brooks Range and are correlative, in part, with the three formations discussed above and included in the original Noatak formation. Rocks of the Kanayut formation, first reported by Frank C. Schrader (1902, p. 240), were included in the expanded Noatak formation by Smith and Mertie (1930, p. 155). However, it is a perfectly good mappable unit and is herein reestablished as a formation, the name taken from Kanayut Valley where sections were measured in 1949 (see pl. 5).

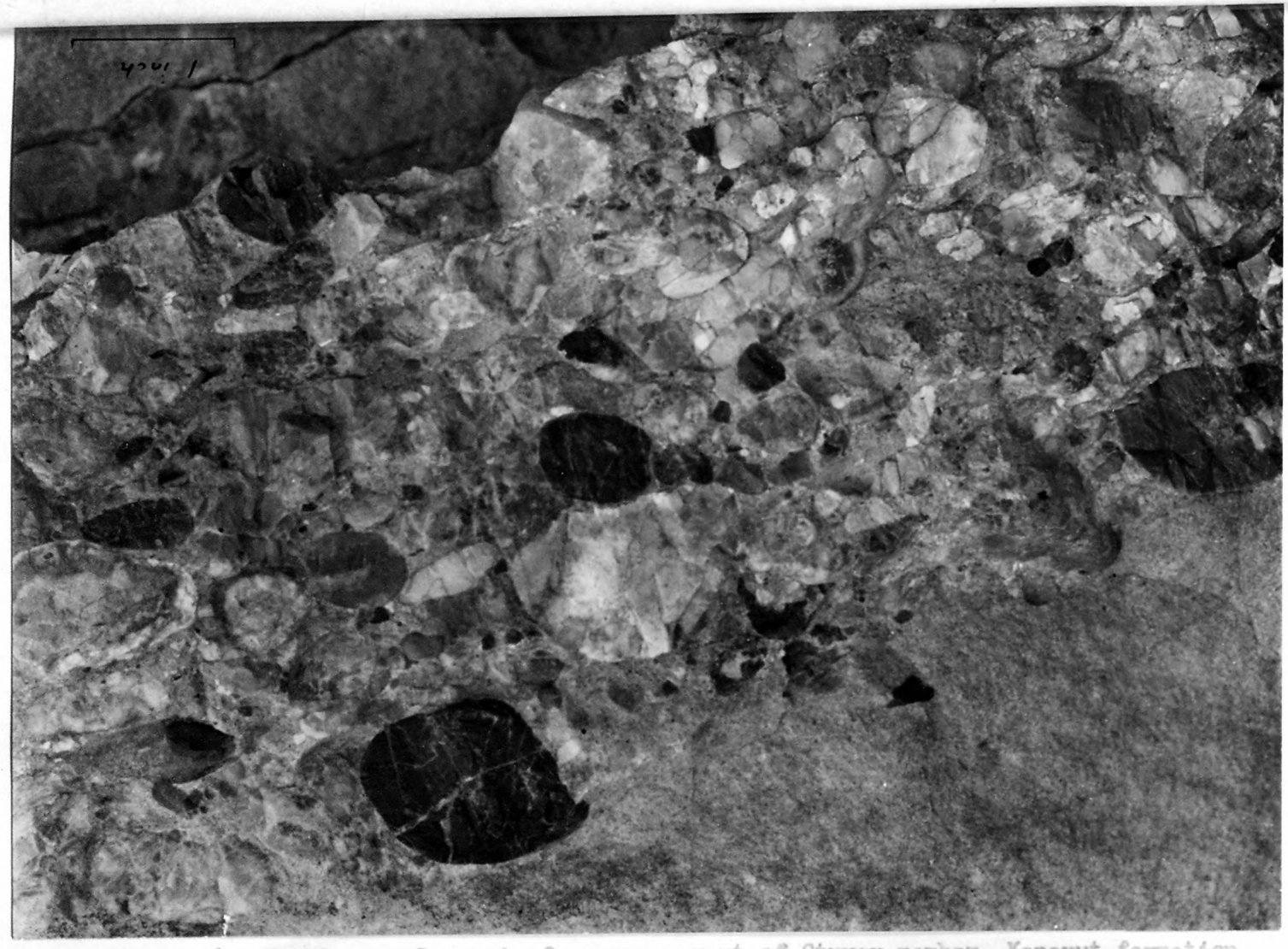

Plate 6. -Pebble conglomerate from upper part of Stuver member, Kanayut formation

Lithology

Schrader's fine description in a subsequent professional paper (1904, pp. 60-62) is here repeated in part:

"The rocks of this series are principally conglomerates, with interbedded layers of quartzite, which toward the top pass into slate and shale. The pebbles composing the conglomerate are practically all siliceous and consist of black, slate-colored, red, green and bluish flint and milky white quartz. They range in size from less than an inch in diameter to cobbles, and in a few instances approach bowlderets. The cement is siliceous, usually dense, and often contains grains of cryptocrystalline or aphanitic silica, undoubtedly derived from the same parent rock as the pebbles. Great force is required to break the rock with the hammer, and, when broken, the fracture plane is almost invariably found to take a direct course, traversing any pebbles, though perfectly sound, that may lie in its path; in fact, the cementation is so firm as to form of the conglomerate, as a whole, a rock substantially as hard as the hardest flint pebbles that are included in it . . . The interbedded quartzites in the Stuver series are medium grained and exceptionally hard and siliceous, and are usually of a gray or sometimes a pinkish or reddish color, while the slate is dark . . . The exposed portion shows a thickness of at least 2,000 feet."

This unit is exposed in the Anaktuvuk Pass region and in the mountains south of Kanayut, Nanushuk, and Itkillik Lakes (see pl. 2). During the summer of 1949, Arthur L. Bowsher of the U. S. National Museum and I examined a well-exposed sequence just east of the Kanayut River (approximately lat. 68° 20' N., long. 150° 47' W.). This section, included in the Appendix as section G, is at least 3,800 feet thick; a 4,800-foot section has been measured on the Okokmilaga River by Patton, Mangus, and Brosgé (1951, p. 5).

Type area

Schrader's original description can be supplemented by additional information gathered in 1949 and 1951. Three members are recognized though they are similar in composition and are believed to be genetically related.

Lower conglomerate member.--The lower conglomerate member is a thick sequence of conglomerate with thin beds of sandstone; pebbles and cobbles of chert and quartz are distributed at random in a matrix of quartzose sandstone. Beds are medium gray on fresh surfaces but weather reddish brown. An estimated thickness of 1,600 feet is exposed along the east side of Alapah Creek, though the base of the formation is concealed. It is probable that at least 1,800 feet is represented by this member in sections measured farther west in 1951. Along the Okokmilaga River the lower beds are alternating sandstone and shale with shale more predominant near the base. A similar sandy section, examined by Bowsher in 1950, occurs at the base of the formation along the west wall of the second valley east of Kanayut Valley.

Middle conglomerate member.--The middle conglomerate member, a nearly uninterrupted series of conglomeratic beds with chert pebbles and cobbles in a quartzose sandstone matrix, has individual beds from 4 to 8 feet thick (see pl. 7A). A few thin sandstone beds are scattered through a thickness of about 1,000 feet, which thickens westward to about 1,600 feet in sections along the Okokmilaga River.

The nature of the coarse constituents is extremely interesting. Pebbles and cobbles are mainly chert and quartz, varying in color from pure white through yellowish gray, olive gray, pale brown, olive green and pale yellowish-green to dark-reddish brown and grayish black. Some appear to be true chert while others seem to be silicified argillite, shale and limestone. All probably have come from an area of predominantly sedimentary rocks except for the quartz which may have had an igneous origin. As noted on page 10, however, quartz veins are common in the underlying Kurt Fork formation. The medium- to coarse-grained sandstone matrix is composed of quartz and chert grains; cementing materials seem to be iron oxides and silica with very little carbonate. Though quartzose, these strata (and those of the underlying member) are not orthoquartzitic as is the Stuver member or the Noatak formation (restricted).

Stuver member.--The upper 850 to 1,000 feet of the Kanayut formation is composed of interbedded orthoquartzite, conglomerate, and clay-silt shale. These are the actual beds described by Schrader as his Stuver series, the name being retained here for the member. Typical outcrops are about 6 miles east of Anaktuvuk Valley on Mt. Stuver from which the name was taken.

Conglomerate beds, similar to those of the lower two members but with an orthoquartzitic matrix, make up about 30 percent of the strata (see pl. 6); sandstones which comprise about 15 percent of the strata are fine- to medium-grained, light gray to medium gray, quartzose and orthoquartzitic; fissile clay-silt shales comprising about 60 percent of the section are generally grayish green or grayish black, though several reddish zones are present.

In the lower part, through a thickness of about 400 feet, a cyclic recurrence of beds is ideally developed as follows:

1. Basal massive-bedded pebble conglomerate.
2. Cross-bedded medium- to coarse-grained sandstone or conglomerate.
3. Thin-bedded fine- to medium-grained, noncross-bedded sandstone
4. Clay-silt shale which may contain thin sandstone lenses.

Four such units, from 50 to 100 feet thick, were measured. In each the conglomerate overlies the shale with apparent conformity. Some units contain thin lentils of fine-grained plant-bearing sandstone at irregular intervals. A part of the section showing these details is included as figure 4.

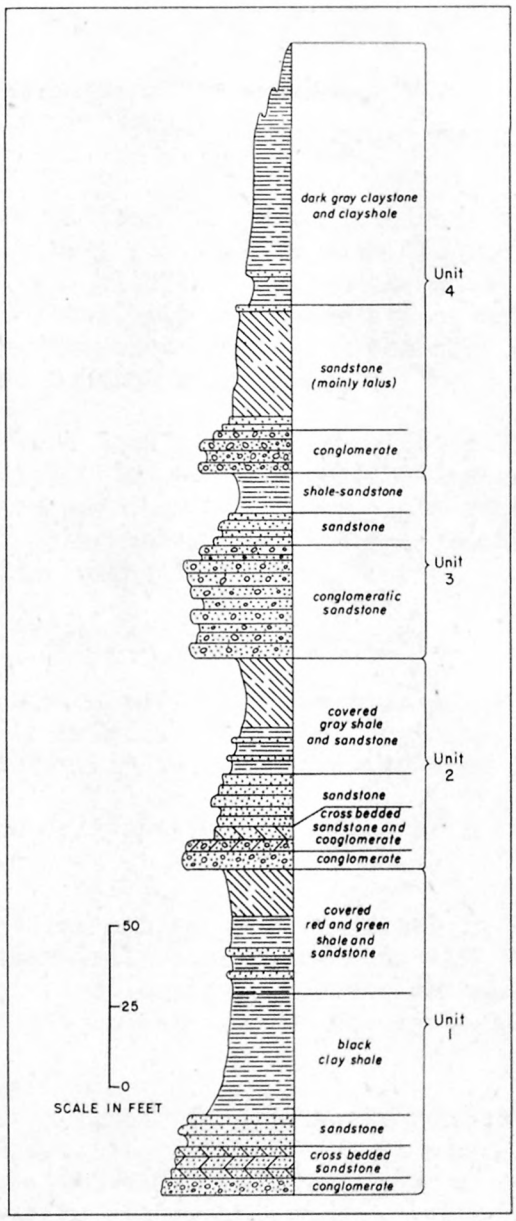

FIGURE 4.-CYCLIC SEDIMENTATION IN STUVER MEMBER

Relationship to other units

The Kanayut formation conformably underlies the Kayak formation and overlies the Hunt Fork formation with no noticeable unconformity. It has been suggested above that the Kanayut formation is at least partly equivalent to the Noatak formation (restricted). In the absence of good faunal correlations, three relationships are possible:

1. The two formations are exact equivalents, the Noatak formation being a thinner sandy westerly extension of the Kanayut formation.

2. The two formations are partly equivalent, the Noatak formation being most likely correlative with the Stuver member of the Kanayut formation, and with the lower members not represented in the west. General lithologic characteristics, thickness relationships, and the apparent unconformity at the base of the Noatak formation make this assumption reasonable.

3. The two formations are not correlative. General stratigraphic relationships rule out this possibility as the Kanayut and Noatak formations occupy about the same place in the stratigraphic column. Available paleontologic evidence indicates at least partial time equivalence (see pages 35 and 36).

Origin of the conglomerates

A thick sequence of conglomeratic beds generally gives rise to conjecture as to its origin. When the conglomerate is lithologically unique, as this one is, it is even more inviting for speculation.

Early ideas on origin were summarized by Smith and Mertie (1930, pp. 155-157):

"... the pebbles and angular fragments in the chert conglomerate and breccia are essentially contemporaneous with the formation of the primary chert matrix; not contemporaneous, perhaps, in the sense of secular time units but in relation to the geologic time units in the Paleozoic era."

Their discussion emphasizes weathering and deposition of fragments of primary chert. As chert is not abundant in pre-Upper Devonian rocks, they concluded that primary chert was being deposited in Devonian time essentially contemporaneous with the deposition of clastic chert conglomerate.

They consider concentration of cherty debris on an erosion surface but discard the idea on the following grounds (Smith and Mertie, 1930, p. 156):

"The weakness of this explanation (residual concentration at the surface) is that the early Paleozoic and pre-Paleozoic rocks that

formed the land mass back of the Mississippian ocean contained much vein quartz, which is as resistant to residual decomposition as chert, and therefore these conglomerates should contain as many pebbles of vein quartz as chert, if not more. But this, as is well known, is not the case."

It is apparent from the discussion in Bulletin 815 that the authors have assembled data from a study of exposures scattered over hundreds of square miles in northern Alaska. The Kanayut conglomerates crop out in a belt 10 to 15 miles wide that stretches approximately along the 68th parallel for 200 to 250 miles from long. 148° to 158° W. The most significant evidence cited by Smith and Mertie is the presence of chert breccia beds in the Tolovana district, 200 miles south of the known southern limit of Kanayut exposures; however, it is by no means proved that the formation in the Tolovana district is even partly equivalent to the Kanayut formation. Moreover, the Kanayut conglomerates are composed of strikingly well-rounded and well-sorted pebbles, subangular phenoclasts being exceedingly rare.

The data as now known are:

1. The Kanayut formation crops out in a relatively narrow linear belt near the northern margin of the Brooks Range.

2. The conglomerates are composed of pebbles and cobbles of vari-colored chert, vein quartz, and quartzite; the matrix is quartzose sandstone; cementing materials are silica, iron oxides, and some carbonate.

3. Most of the conglomerate beds are massive, non-crossbedded, and well-indurated; in the Stuver member, orthoquartzitic beds are common.

4. No marine faunas have been found above the basal few hundred feet, plant fragments are present in zones throughout the entire thickness.

5. Both contacts appear gradational; the underlying fine clastics of the Hunt Fork formation contain an Upper Devonian brachiopod and pelecypod assemblage; the overlying Kayak formation appears entirely marine and contains a Kinderhookian fauna near its top.

6. Red and green shale is present in the Stuver member.

7. Conglomeratic strata in the central Brooks Range appear partly equivalent to sandstones of the Noatak formation to the west.

8. A massive-bedded, medium-grained, medium-gray sandstone which crops out near Agak Lake (not shown on maps; about 12 to 15 miles south of the linear conglomerate belt) may also be equivalent to the Kanayut formation.

9. Other beds which may be equivalent to the Kanayut formation crop out in the foothills belt north of the Range and south-southwest of Lake Noluk (see fig. 3). These are moderate-brown clay shale and dark-gray siltstone and contain an Upper Devonian brachiopod fauna. A small amount of olive-gray limestone is present.

Certain inferences can be drawn from these data. The Kanayut formation is probably a series of alternating marine and nonmarine strata. The red and green shale in the Stuver member seems indicative of nonmarine origin, whereas the brachiopod-bearing sandstone in the lower member is certainly marine. The conglomerates may be either marine, nonmarine, or both. It is probable that deposition was in an area of fluctuating marine and nonmarine environments near the shore of a mid-Paleozoic seaway.

No profound break in sedimentation is implied, but it is assumed that chert pebbles originated as a regolith, being weathered products on a low-lying landmass in Devonian time. The pebbles probably are silicified fragments of older sedimentites (limestone and shale or argillite) as well as a considerable amount of chert. It is known that some sedimentary rocks, especially carbonates, exposed to present-day weathering develop silicified surfaces to a depth of several inches.

I have observed this phenomenon in Mississippian limestones just northeast of Itkillik Lake in northern Alaska. On cliff faces the limestone appears to be relatively pure with less than 10 percent black chert. The same beds, when traced to dip slopes, are almost completely chert, the silicification being due to ground water processes.

A well-documented account of this type of silicification was given by C. L. Dake (1930, p. 202). After describing occurrences of chert residues that mask the Van Buren-Gasconade and Potosi formations, Dake states:

"In road cuts, and quarries, it is a very common thing to see beds that are very cherty at the old erosion surface grade laterally into less cherty or even non-cherty beds, within a very few feet, or even inches, back into the fresh exposure. From this fact, it may be safely inferred that much of this concentration takes place as replacement in the limestone very close to the weathered surface, where the silica-bearing solutions evaporate."

The same type of silicification was reported by Josiah Bridge (1930, p. 89):

"The entire transition from dolomite to chert may be traced out along a hillside in any number of cases. An especially good example may be seen on Council Hill, a mile northwest of Eminence.

Here the southwest face of the hill contains practically no chert, while on the southeast face less than a quarter of a mile away there are practically no outcrops of dolomite at the same horizons, but cherts are abundant."

An example of this process in noncarbonate rocks has been reported from the Tuscaloosa gravels of Kentucky by P. P. Fox (1945, pp. 208-209):

"Ground water carrying dissolved silica has been effective in consolidating a small portion of the gravel in this locality to a cherty mass . . . several of the consolidated zones lie parallel to pure layers of sand from which a part of the silica may have been dissolved. The chert conglomerate exhibits varying degrees of cementation . . . the outside portion of many of the zones is only slightly cemented and the outline of the gravel can easily be recognized. However, the inside portion is completely replaced by a dense, glassy chert and the original gravel can no longer be recognized . . . it is assumed that normal ground waters were responsible for the dissolution and transportation and redeposition of the silica."

Such silicified material is accumulating as residuum today, as Dake indicates (1930, pp. 174-175):

"One is forced, from the above facts, to the conclusion that as the dolomites are leached away, the minutely disseminated silica is gradually dissolved, and reconcentrated in larger and larger masses, thus developing the very huge chert bowlders that are so common a feature of the chert residues of the area in question . . . to the writer, it seems proven beyond question of doubt, in spite of profound earlier conviction to the contrary that most of the large masses of chert strewn over the central Ozark area, where the Cambro-Ordovician formations outcrop, are secondary, and developed by segregation of formerly disseminated silica, as the formations weathered."

The arguments given by Smith and Mertie against the accumulation of chert as residuum in this fashion during Devonian time seem at least partly invalidated by Dake who states in a concluding paragraph of his discussion (1930, p. 202):

"It is known, then, with a high degree of certainty that these formations do not carry enough chert, as such, in thick beds and huge blocks, to begin to yield the large amount of chert residuum observed, and consequently, that in spite of the alleged insolubility of silica in cold waters, perfectly enormous quantities of that substance are dissolved during the weathering process by ordinary cold shallow ground water." (Italics are Dake's.)

It is interesting that Dake reflected a view which was unpopular among geologists at the time and which remained so for at least 15 years more, despite the fact that chemists had shown silica to be carried in solution rather than in the colloidal state, a favorite theory of geologists for years. This was pointed out by Chalmer J. Roy (1945, pp. 401-402):

"Chemical investigations, approaching the problem in a variety of ways, do not support the accepted concept that the dissolved silica in natural waters is colloidal. On the contrary, these investigators, to date, justify the following conclusions: 1. The dissolved silica in natural waters is in true solution or crystalloid rather than colloidal. 2. Although the molecular character of the dissolved silica has not been investigated directly, the evidence indicates that it is ionic."

In the light of these data it seems quite plausible that chert could have accumulated as a residual mantle in Devonian time, despite the fact that cherty formations, as such, are rare in the early Paleozoic rocks of northern Alaska. This chert residuum could have been the source of the chert pebbles which are found in the Kanayut formation.

As long as streams were near grade, great amounts of coarse sand and pebbles of silicified material would not be expected among sediments accumulating in adjacent sedimentary basins. The Hunt Fork formation, underlying the Kanayut formation, records just such a period when fine sand, silt, and clay particles were deposited in great thickness. No great change in conditions would be necessary to initiate conglomerate deposition. Epeirogenic movements may have altered land-sea relationships, steepened stream gradients, and resulted in removal of the silicified regolith with concurrent deposition in a linear shoreline belt.

It would seem that the offshore submarine slope must have been relatively steep to allow so great a thickness as 3,000 to 4,000 feet of conglomerate to accumulate in a zone of restricted width. Joseph Barrell (1925, pp. 311-312) analyzed this problem of conglomerate deposition and suggested:

". . . it has been seen that the most favorable conditions for the accumulation of thick marine conglomerates are those where the sea is transgressing (= rising) against a land of some relief. The conglomerates made in this way are rather readily recognizable, because they are basal conglomerates developed upon an erosion surface of an older rock formation."

It does not seem that the last sentence quoted above necessarily follows from the preceding discussion in his paper. Transgression against a shore with a steep slope seems necessary, however, as Barrell indicated.

This condition could have been fulfilled in either of two ways, or perhaps a combination of the two.

1. Upwarp of the landmass with accompanying basin subsidence in such a way that continued movement would provide a sufficiently steep offshore profile.

2. Block faulting with continued or intermittent movement to maintain necessary steepness along a faulted coastline.

No concrete evidence of such an ancient faulted coast has been found, but it is possible that a combination of the two processes may have taken place.

In this respect it should be kept in mind that these conglomerates are at least partly nonmarine and that thick accumulations of conglomerates deposited under deltaic and alluvial plain conditions are known to occur.

As shown in figures 5 and 6, the landmass which provided these late Devonian sediments probably lay to the north and northeast of present outcrop belts. A certain amount of direct evidence supports this view.

Five test wells have been drilled into Paleozoic or pre-Paleozoic rocks in northern Alaska. All yielded information indicating a northern landmass during the Paleozoic era, though only one of these has reached Devonian rocks which may be equivalent to the formations under consideration.

In Topagoruk Test Well No. 1 (well 5 in fig. 3) chert conglomerate beds were encountered at 10,040 feet and drilling was stopped in this unit at 10,503 feet. Plants of possible Middle Devonian age from the core at 10,441 feet have been identified by James Schopf of the U. S. Geological Survey. Above the conglomerate is 270 feet of red siltstone and shale which may be equivalent to the Mississippian Lisburne formation. If this is true, Mississippian strata thin northward and pass from marine limestone into nonmarine redbeds.

Three test wells near Point Barrow show that Triassic, Jurassic, and Cretaceous (Neocomian) strata pinch out northward against a pre-Mesozoic high.

In the Canning River region, evidence in outcrops supports this hypothesis of a northern landmass. Pre-Lisburne beds, similar to the Kayak formation (described on pages 27 to 30), lie unconformably on the Neruokpuk schist. The early Paleozoic or pre-Paleozoic age of this schist is open to question, but in any case the Canning River region seems to have been a high in late Devonian and early Mississippian time. In addition, the Lower Permian Sadlerochit formation coarsens northward from argillite and shale through sandstone to conglomerate in its northernmost exposures.

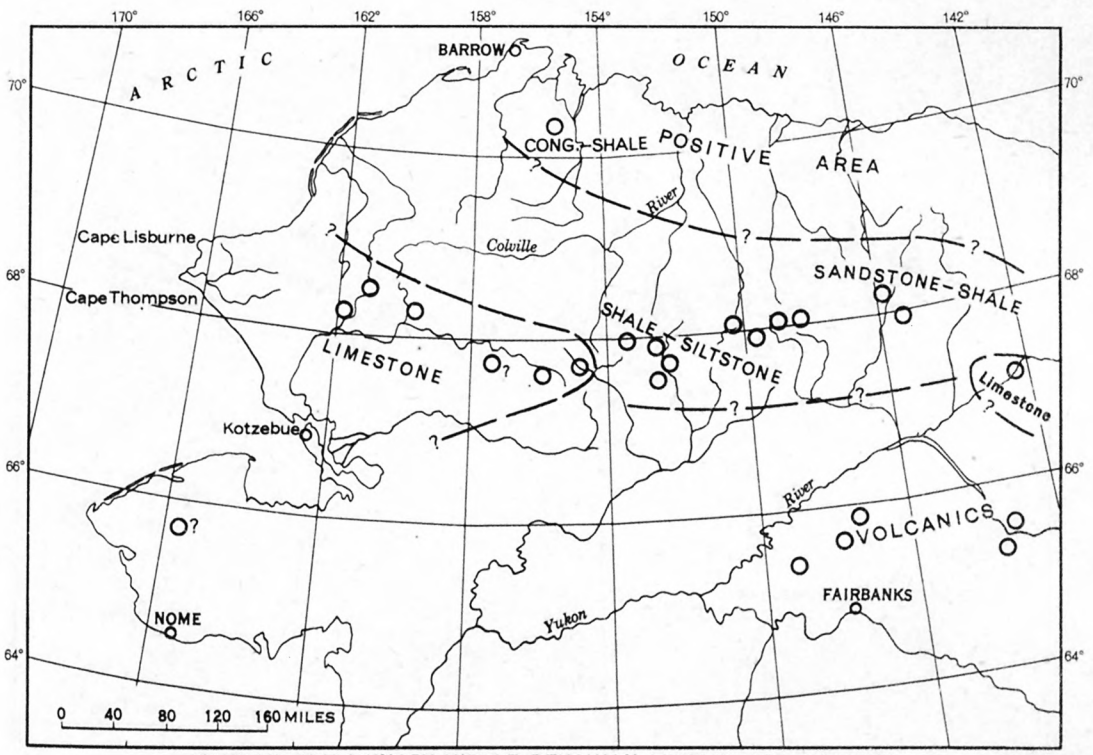

FIGURE 5. PRELIMINARY MIDDLE DEVONIAN LITHOFACIES DIAGRAM

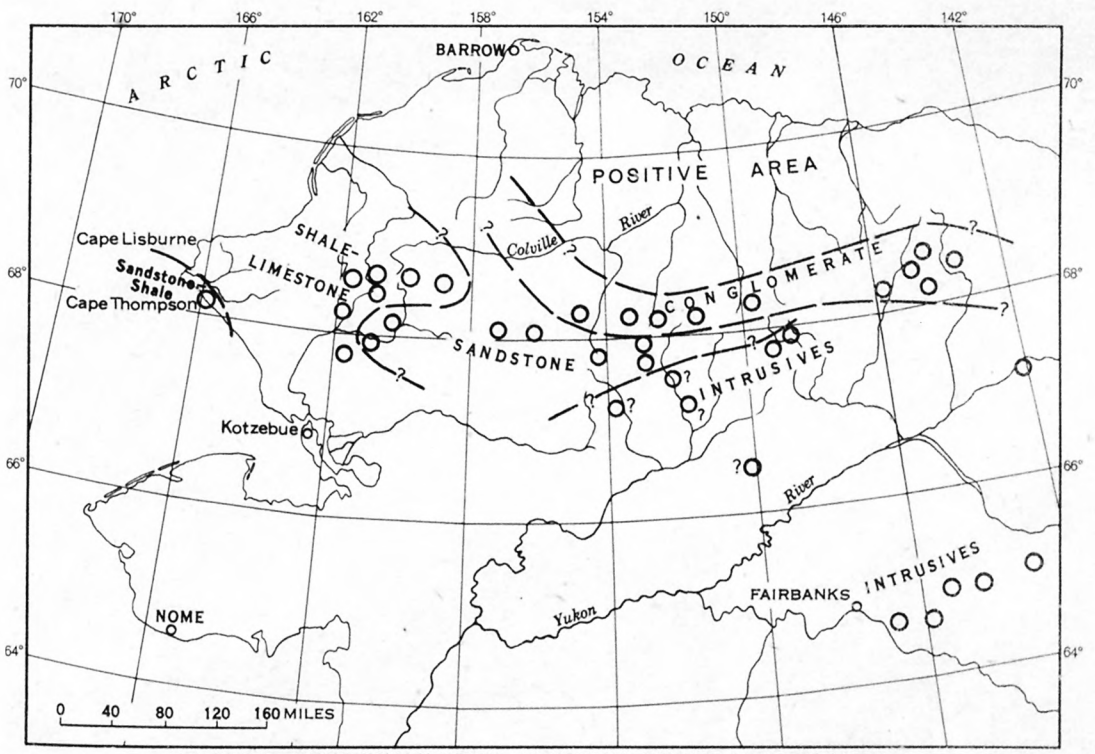

FIGURE 6. PRELIMINARY UPPER DEVONIAN LITHOFACIES DIAGRAM

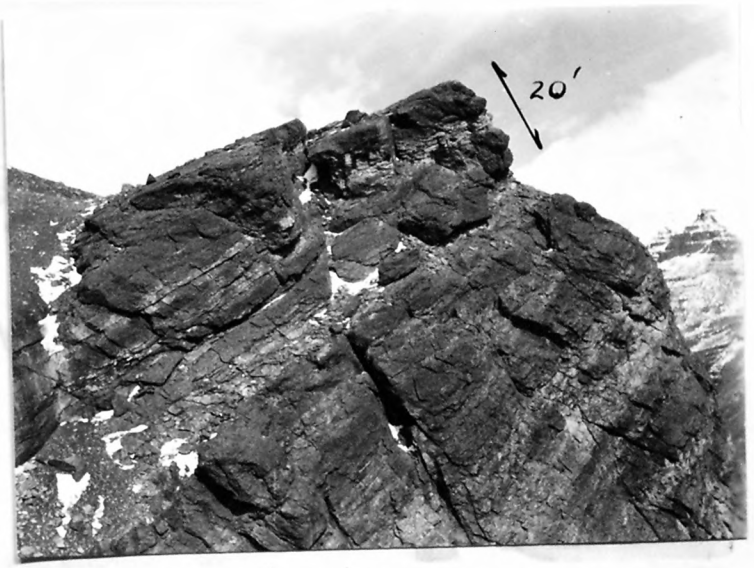

Plate 7A. - Conglomeratic cliff in upper part of middle conglomerate member, Kanayut formation, exposed along west wall of Alapah Creek

Plate 7B. - Argillaceous limestone member, Kayak formation, exposed along west wall of Kanayut Valley about one mile south of Kanayut Lake

On mainly theoretical grounds A. J. Eardley (1948, p. 427) suggested that such a Paleozoic landmass was present during the Paleozoic era:

"From the 1937 geologic map of the U.S.S.R., compiled and printed by the Soviets, it is surmised that the geology (of eastern Siberia) is somewhat similar to Alaska. This, together with Umbgrove's conception of the "Nucleus of Tschuktschen", has led me to show Carboniferous deposition along northeastern Siberia as well as land to the north. The land seems necessary to supply the mainland assemblage of sediments to the Cordilleran geosyncline in Alaska. This postulated land could have connected with the Canadian shield and not have been cut from it by the Archipelago basin as shown on the map."

Eardley has mistakenly placed Wrangell Island in an area of pre-Cambrian rocks and his interpretation is generalized, but the hypothesis of a northern landmass seems sound.

The lithofacies diagrams also suggest that normal marine miogeosynclinal sedimentation was not reestablished, following Late Silurian-Early Devonian diastrophism, until the beginning of the Mississippian. It is possible that a source of Middle and Late Devonian clastic rocks was a geanticlinal area to the south and southeast of the crest of the present Brooks Range, as well as the northern positive area.

Kayak formation

Along the north flank of the central Brooks Range, the marine Kayak formation lies between the Kanayut and Lisburne formations. It consists of approximately 1,000 feet of sandstone, gray-black shale, and argillaceous limestone.

Type area

In Kanayut Valley characteristic outcrops were selected for a type section by Arthur L. Bowsher and the author in 1949 (see pl. 5). The name Kayak is taken from Kayak Creek, the west fork of the Kanayut River which divides about 4.5 miles south of Kanayut Lake. Five members are recognized:

1. basal sandstone member;
2. lower black shale member;
3. argillaceous limestone member;
4. upper black shale member;
5. red limestone member.

Basal sandstone member.--The lowermost beds are medium-grained, even-bedded, ferruginous sandstone with interbedded clay shale and silt shale. Sand grains are of clear, angular to subrounded, slightly frosted quartz. Succeeding sandstone beds are uniformly four-tenths to six-tenths of a foot thick, each stratum sharply separable

cross lamination. Three and three-tenths miles S. 23° E. of Kanayut Lake the majority of these cross laminae are inclined to the northwest. Higher beds are commonly thinner, averaging from one-tenth to two-tenths foot thick, with interbeds of medium-gray to grayish-black clay shale and silt shale toward the top. The maximum known thickness of this member is 130 feet.

Lower black shale member.--About 600 feet of grayish-black, well-indurated, micaceous, fissile shale lies above the basal sandstone member. It weathers a moderate yellowish brown and contains pyrite as idiomorphic crystals; several zones of pebble-size ferruginous mudstone concretions are present in the upper part. Reddish-purple calcareous ferruginous nodules averaging four-tenths foot in diameter occur among the higher shales also.

This incompetent shale, lying as it does between more competent units, has taken up much of the thrust movement in the area. Many fault zones are of crumpled and faulted black shale in which blocks of the argillaceous limestone and the red limestone lie at all attitudes.

Argillaceous limestone member.--Eighty-five feet of predominantly calcareous strata comprise this unit, the oldest abundantly fossiliferous Mississippian strata in the central Brooks Range (see pls. 7B, 8A, 8B). The lower 30 feet is essentially a sequence of dark-gray, argillaceous, shaly, bioclastic limestone. Undulatory lensing strata alternate with thin regular beds, giving a banded appearance to outcrops. Near the middle of the member is 15 feet of medium-gray to dark bluish-gray, calcareous clay shale. The upper 40 feet is argillaceous shaly limestone with thin partings of calcareous clay shale, bioclastic limestone becoming more common near the top.

Upper black shale member.--This unit, 110 feet thick, is lithologically similar to the lower black shale member, except that it contains several thin limestone beds about 25 to 30 feet above its base. Near the top are bands of dark-gray, dense, very finely crystalline siderite concretions.

Red limestone member.--This upper unit of the Kayak formation, composed of 10 to 20 feet of gray to dark-gray, very argillaceous, ferruginous, medium-grained bioclastic limestone, weathers light brown or reddish brown.

Section H of the Appendix is the type section of the Kayak formation measured in Kanayut Valley. Sections measured by Bowsher in 1950 in Anaktuvuk Valley and near the headwaters of Alapah Creek, respectively, are included on plate 3 to show lithologic and thickness variations over a relatively short distance in the type region.

Plate 8A. - Lower (α) member of argillaceous limestone member, Kayak formation.

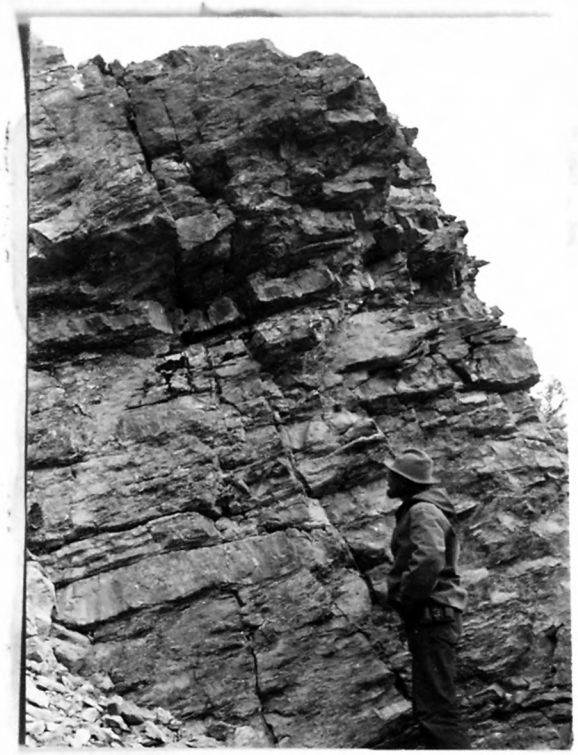

Plate 8B. - Upper (β) zone of argillaceous limestone member, Kayak formation.

Relationship to other units

The Kayak formation lies conformably above the Stuver member of the Kanayut formation (see pl. 2). The contact with the overlying Wachsmuth member of the Lisburne formation may be a disconformable one. Fish teeth and phosphatic pellets are concentrated near the top of the red limestone, the top surface of which is undulatory, with relief of less than a foot. Faunal evidence suggests a time break between uppermost Kayak and lowermost Lisburne strata, but this gap may be due to lack of preservation of faunas and/or to poor collecting conditions. Possible equivalence to lower shaly zones of the Utukok formation has been suggested on page 13.

Section at Cape Thompson

Far to the west on the Arctic coast, pre-Lisburne strata crop out along the beach in the vicinity of Cape Thompson (lat. 68° 08' N. and long. 166° W.). This section, examined by E. M. Kindle in August 1908, was revisited by the author during the summer of 1951.

Kindle described three units below the Lisburne formation. Lowest was 140 feet of lead-gray thin-bedded sandstone and shale with occasional bands of brown ferruginous chert and films of coal. It was overlain by 280 feet of bluish-gray to black fissile shale and was in turn succeeded by 380 feet of black and buff thin-bedded limestone.

Essentially the same zones were recognized in 1951, though more lithologic detail was secured and a greater thickness measured. Some beds seen in 1951 were probably obscured by beach gravels in 1908. The section at Cape Thompson is included in the Appendix as section I.

Lithology

About 850 feet of shale with thin sandstone beds is partly exposed along the beach northwest of the Cape proper and is overlain by about 125 feet of sandstone and interbedded shale. The sandstone is medium gray to brownish gray, fine-grained, siliceous, quartzitic and noncalcareous, with interbedded fine sand to silt-size, dark-gray, micaceous, noncalcareous shale and reddish-brown, ferruginous, siliceous, lenticular mudstones containing plant fragments. The latter are undoubtedly the "brown ferruginous chert" beds of Kindle's lower unit.

Overlying is 480 feet of dark-gray to grayish-black silt shale and clay shale with nodules of ferruginous mudstone as described above. This probably is Kindle's middle unit.

Uppermost beds are approximately 315 feet of grayish-black calcareous shale with lenses of medium dark-gray siltstone and beds of medium dark-gray to brownish-gray bioclastic calcarenite which weather a dark-yellowish orange. This is probably Kindle's highest pre-Lisburne unit.

Above these strata is approximately 550 feet of light-gray bioclastic limestone, nearly the thickness estimated by Kindle. A fault is probably present at the base of this limestone unit, however, the amount of displacement being unknown.

Relationship to other units

Although Cape Thompson is far removed from other localities referred to in this paper, tentative correlations can be made. The strata there compare better with the section from the central Brooks Range than with that of the western Brooks Range, about 200 miles nearer. The lithologic sequence, together with the lower Mississippian faunas collected from the upper calcareous shale and limestone unit, suggests rather close correlation with the Kayak formation. If this is the correct interpretation, depositional conditions in the two areas were probably similar in early Mississippian time. Transgressive overlap is suggested in both areas, where a basal sandstone, probably of litteral marine origin, is overlain by black shale succeeded by argillaceous fossiliferous limestone.

Evidence for geographic distribution of land and sea elements in lower Mississippian time is meager. Sound paleogeographic interpretations must await more information, but preliminary conclusions can be drawn, based partly on a possible correlation of the Kayak and Utukok formations. Figure 7 is a lithofacies diagram of northern Alaska in lower Mississippian time. Some of the evidence bearing on this interpretation has been presented in the earlier discussion of the Kanayut formation.

SUMMARY OF GEOLOGIC HISTORY

Distribution of sedimentary units in time and space suggests tentative conclusions regarding the geologic history of the Brooks Range during Late Devonian and early Mississippian times.

Figures 5 through 7 are based on field observations in the Brooks Range and an appraisal of the geologic literature for the region north of the Alaska Range. Similar preliminary studies have been made for all Paleozoic systems throughout Alaska, northwestern Canada, and eastern Siberia.

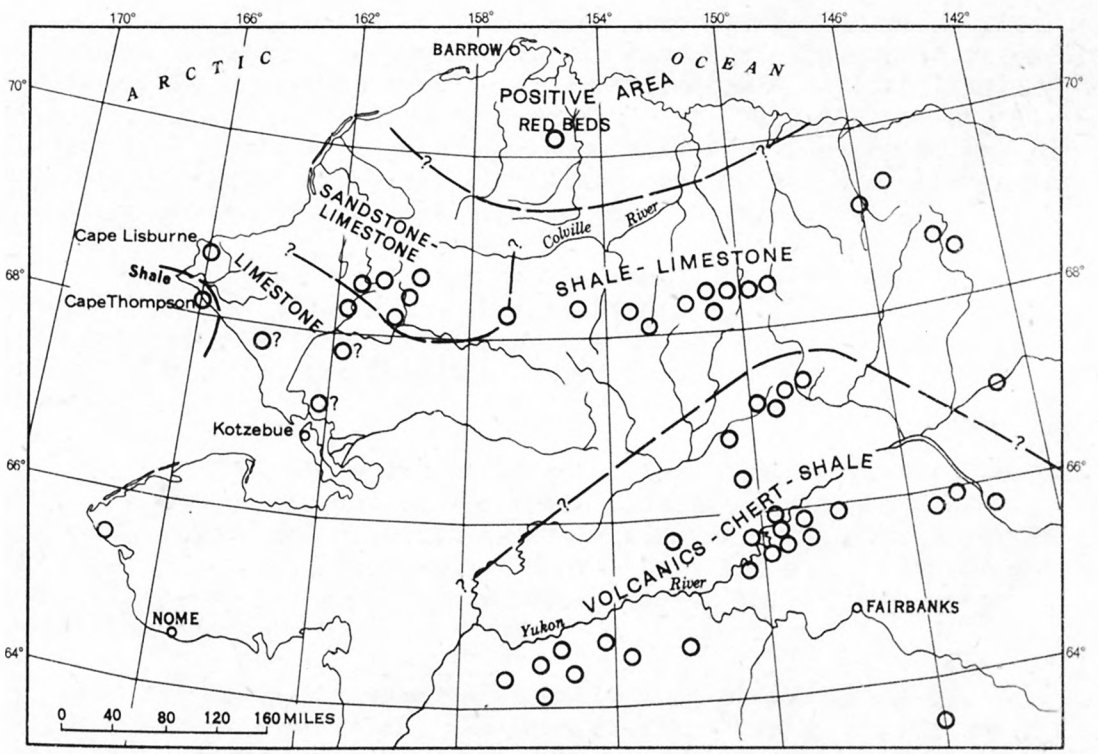

FIGURE 7. PRELIMINARY LOWER MISSISSIPPIAN LITHOFACIES DIAGRAM

The following generalizations have resulted:

1. An arcuate orthogeosynclinal belt extended across Alaska from west to east during the Paleozoic era. This was a northerly continuation of the Cordilleran trough and extended westward along the northern coast of Siberia, bifurcating on reaching the Siberian shield.

2. This geosynclinal belt contained two major lithologic suites in each system except the Cambrian and Pennsylvanian: a miogeosynclinal facies to the north and a eugeosynclinal facies to the south (the Millard and Fraser belts of Kay, 1947).

3. Because the boundary between these two facies moved progressively northward through Paleozoic time, late Paleozoic eugeosynclinal rocks tend to overlie early Paleozoic miogeosynclinal rocks. This was recognized by Cady (1949, pp. 137-138) in the Kuskokwim region and in general seems to be true for the entire geosynclinal belt. The axis of thickest accumulation of miogeosynclinal deposits shifted northward at the same time.

4. A positive craton lay to the north and provided clastic sediments to the geosynclines in late Devonian, late Mississippian, and Early Permian times, at least. It is not known whether this area was joined to the Canadian shield during part or all of the Paleozoic.

5. Major diastrophism occurred in late Silurian-Early Devonian time. No Lower Devonian or uppermost Silurian rocks are known in northern Alaska, and granitic intrusives may have been emplaced in the upper Chandalar River region during this interval. Pre-Devonian rocks are generally more highly metamorphosed than Middle Devonian and younger ones.

6. Epeirogenic movements probably took place during the late Devonian and Pennsylvanian. No Pennsylvanian marine strata are known from northern Alaska. The nonmarine Nation River formation, 3,700 to 6,000 feet thick, crops out along the upper Yukon River and is thought to be of Pennsylvanian age. In the Brooks Range Lower Permian rocks lie on upper Mississippian ones with no apparent angular unconformity.

Figure 7 gives a fairly good picture of the shape and extent of the Paleozoic geosynclines in northern Alaska, with the miogeosynclinal and eugeosynclinal belts well differentiated, and the positive area to the north.

It is probable that normal marine conditions were not reestablished along the entire length of the geosyncline, following Early Devonian orogeny, until early in the Mississippian period. Middle and Late Devonian marine limestones occur only at the western and eastern extremities of the belt, with clastics present in the central Brooks Range region. It is possible that a source of these clastics was to the south, perhaps in a geanticlinal belt resulting from diastrophism, as well as to the north in the craton.

Hunt Fork formation

Fossils have been collected from Hunt Fork beds at a few places in the western Noatak district; in the type locality none have yet been found, though outcrops a few miles away, thought to be the same formation, have yielded some fossils. These meager faunas, composed of pelecypods (Pterinopecten aff. P. princeps (Conrad)) and crinoid columnals, though not distinctive, are similar to those found in Upper Devonian strata in eastern North America and Russia. Brachiopods collected by Smith and Mertie (1930, p. 147) are of undoubted Late Devonian age, but they are from beds whose correlation with the Hunt Fork formation is doubtful.

Noatak formation (restricted)

Comminuted plant fragments from the upper sandy beds are too poorly preserved to permit specific identification but have been referred to the genera Lepidodendron, Sphenopteris, and Stigmaria, characteristic of Upper Devonian and Carboniferous floras. Brachiopod-bearing strata, thought to be quite low in the formation, contain Cyrtospirifer cf. C. whitneyi (Hall), indicative of Upper Devonian age.

Utukok formation

Abundant brachiopod-molluscan assemblages are related to upper Tournaisian and lower Visean faunas (upper Kinderhookian - lower Osagean) elsewhere in the world. Collections contain sturdy-shelled brachiopods along with pelecypods, gastropods, cephalopods and trilobites, suggestive of a shallow water marine environment. These forms are found in impure silty limestones, quartzose sandstones and shales which point to turbulent conditions of deposition. The scarcity of corals and bryozoans supports this interpretation. Characteristic faunal components: Leptaena analoga (Phillips), Schuchertella ampla Dutro, Schellwienella radialiformis (Demanet), Chonetes sp. A, Chonetes utukokensis Dutro, Setigerites sablei Dutro, Pustula sp. A, Spirifer cf. S. gregori Weller, Spirifer cf. S. grimesi Hall, Spirifer cf. S. rowleyi Weller, ? Imbrexia forbesi (Norwood and Pratten), Punctospirifer ? solidirostris (White), Edmondia burlingtonensis White and Whitfield, Naticopsis sp., Straparolus blairi Miller, Euomphalus sp., Mooreoceras ? sp. and Phillipsia sp.

Kanayut formation

Fossil evidence from this clastic unit is similar to that from the Noatak formation. Marine sandstones in the lower 600 feet contain casts and molds of Cyrtospirifer cf. C. whitneyi (Hall) of Upper Devonian age.

Floral evidence, no more definite than that from the Noatak formation, points to an Upper Devonian or Carboniferous age for the Stuver member, from which most of the plant fragments have been collected.

Kayak formation

The lower sandstone member, apparently of littoral marine origin, contains worm tubes and borings and scattered plant remains but is otherwise unfossiliferous. No fossils have been found in the lower black shale.

A varied and prolific marine invertebrate fauna has been collected from the argillaceous limestone member. Two faunal zones, designated as α and β, have been recognized.

Characteristic of the lower (α) zone: amplexoid, zaphrentoid and hapsiphylloid corals, Pentremites alaskensis Dutro, Pentremites ascitus Dutro, Actinocrinites accinctus Dutro, Ptylopora aff. P. acuta Ulrich, Rhipidomella michelini (Leveille), Leptaena analoga (Phillips), Chonetes sp. A, Spirifer cf. S. osagensis Swallow, Spirifer platynotus Weller, Punctospirifer cf. P. northviewensis (Branson) and Platyceras nasutum Miller. In this zone, corals, echinoderms and bryozoans are as abundant as brachiopods, but in higher beds this is not the case.

Zone β contains a varied brachiopod fauna including: Leptaena analoga (Phillips), Schuchertella ampla Dutro, Chonetes sp. A, Chonetes sp. B, Productella pyxidata (Hall), Spinulicosta cf. S. concentrica (Hall), Pustula cf. P. morbilliana (Winchell), Linoproductus ? cf. L. ? belliplicatus (Branson), Camarotoechia cf. C. chouteauensis Weller, Spirifer missouriensis Swallow, Spirifer cf. S. osagensis Swallow, Spirifer platynotus Weller, Spirifer striatiformis Meek, Punctospirifer cf. P. northviewensis (Branson), Syringothyris halli Winchell, Cleiothyradina glenparkensis Weller, and Dielasma cf. D. chouteauensis Weller. Other invertebrate phyla are represented by fewer individuals.

The red limestone fauna contains: Pentremites ascitus Dutro, Cryptoblastus sp. A, Setigerites ? truncicostis Dutro, Buxtonia ? parva Dutro, Spirifer missouriensis Swallow, Spirifer cf. S. osagensis Swallow, Spirifer platynotus Weller, Brachythyris aff. B. chouteauensis Weller, and Syringothyris halli Winchell.

These three faunules all appear to be of Tournaisian age, and may be age equivalents of the lower Utukok formation. As indicated previously, however, faunas in the latter formation range to a lower Visean age.

Absolute faunal comparisons can not be made with the Mississippi Valley section, but it is suggested that Kayak faunas are mainly Kinderhookian while Utukok faunas range from Kinderhookian through Osagian.

General discussion

It is known that all the faunas studied are of pre-Meramacian age. The lowest occurrence of lithostrotionid corals is nearly one thousand feet above the top of the Kayak formation and these corals are not present in the Utukok formation. The Gigantoproductus zone occurs still higher in the Lisburne formation.

Brachythyris is found in both the Kayak and Utukok formations though individuals are small (Brachythyris cf. B. chouteauensis Weller) and not of the Brachythyris subcardiformis (Hall) or Brachythyris suborbicularis (Hall) types. These latter species have been recognized in lower Lisburne faunas, higher in the stratigraphic column.

Of the 18 species and varieties in the α zone, seven also occur in Kinderhookian faunas, four are reported in Burlington faunas and four are new while two of the remaining forms are reported only from the Tournaisian of western Europe. Of the 20 forms in the β zone, 14 are present also in the Kinderhookian, one in the Burlington and two are new. Among the 9 species described from the red limestone member, five are Kinderhookian and the remaining four are new.

Of the 29 species and varieties listed among Utukok faunas, six occur only in Kinderhookian faunas, three only in Burlington faunas, three in both the Kinderhookian and Burlington, two in the Keokuk limestone, and seven are new.

Table 1 shows the distribution of these faunal elements and indicates comparisons with other described Lower Carboniferous faunas.

Brachiopods seem most useful for faunal zonation and they give the best indication of relative ages between the Kayak and Utukok formations. This is especially true of the spiriferids; none of the species occurs in both formations.

Spirifer cf. S. osagensis Swallow and Spirifer platynotus Weller are found in all three major faunal zones of the Kayak formation; Spirifer striatiformis Meek seems confined only to the β zone; Spirifer missouriensis Swallow is found in the β zone and in the red limestone member; Brachythyris aff. B. chouteauensis Weller has been recognized only from the red limestone member.

All these species are typical of upper Kinderhookian faunas in the United States, though it does not seem possible to make any closer comparisons.

Spirifer cf. S. rowleyi Weller, Spirifer cf. S. gregeri Weller, Spirifer cf. S. grimesi Hall and ? Imbrexia forbesi (Norwood and Pratten) are common in the Utukok formation. In the type section,

Spirifer cf. S. rowleyi Weller occurs lowest in the formation and continues upward as high as spiriferid faunas have been collected. Spirifer cf. S. grimesi Hall occurs at locality 11060 and continues upward along with S. rowleyi. ? Imbrexia forbesi (Norwood and Pratten) occurs with both these species but most commonly in the upper beds. Spirifer cf. S. gregeri Weller has not been identified from the type area but occurs low in sections on the Nimiuktuk River.

The species to which these Alaskan forms are related are reported from Upper Kinderhookian and Lower Osagean formations in the United States: S. grimesi in the Burlington and its equivalents, S. rowleyi in the Fern Glen and S. gregeri in the Chouteau formation.

Two species of punctospiriferids have been recognized: Punctospirifer cf. P. northviewensis (Branson) from the α and β zones in the Kayak formation and Punctospirifer ? solidirostris (White) from the Utukok formation. These species are characteristic of upper Kinderhookian faunas in the Mississippi Valley.

Conclusions

Faunas from the Kayak formation are related to Upper Kinderhookian (Tournaisian) assemblages. Both Kinderhookian and Lower Osagen (Tournaisian - Lower Visean) forms are recognised in collections from the Utukok formation.

These formations can be faunally zoned, mainly on the basis of spiriferid brachiopods. Future field investigations will test the validity of this zonation and undoubtedly revisions will be made.

Tentative correlations based on lithologic and faunal evidence are shown on plate 3.

SYSTEMATIC PALEONTOLOGY

Phylum ECHINODERMATA

Subphylum PELMATOZOA

Class BLASTOIDEA

Order EUBLASTOIDEA

Family PENTREMITIDAE

Genus PENTREMITES Say, 1820

Pentremites alaskensis Dutro, n. sp.

Plate 9, figures 1-3

Description: Calyx monocyclic, pyriform, bud-like, higher than wide, width/height = 0.6; summit flattened; base truncated, appearing extended where one or two columnals have been preserved with the calyx; transverse outline subpentagonal. Dimensions of figured specimens: about 16.0 mm. high and 9.0 mm. wide; 19.1 mm. high and 13.5 mm. wide; about 20.5 mm. high and 11.5 mm. wide.

Basal plates small, from one-third to one-fifth the total height of calyx; radial plates long, about two-thirds height of calyx but not reaching to summit; deltoids very small, subtriangular, covered adorally by ambulacral plates; ornamentation consisting of very fine lirae, paralleling the radial sutures and joining in broad V's at base of ambulacral areas.

Ambulacra subpetaloid, about two-thirds height of calyx, sunken below level of radials; lancet plate with well-incised food groove; side plates not covering lancets, each with brachiole base, one rank for each half ambulacrum; hydrospire pores between side plates and radials, from 22 to 30 per half ambulacrum, apparently depending on size of individual specimen. Oral surface not well-shown on any of the Alaskan specimens.

Discussion: There are three distinct calyx-shapes included in this species, but since all the specimens come from a single collection, it seems best to regard these as normal variations in size and shape. The smallest has more the appearance of an opening bud, with radials (in lateral view) almost vertical. The longest form is more ovate, having the appearance of a closed bud, with radials relatively longer and more closely approaching the summit than in the smaller form. These and an intermediate form are illustrated. This variation seems normal among species of *Pentremites*. Etheridge and

Carpenter (1886, pl. 2, figs. 24-30) illustrate a similar degree of variation in P. pyriformis Say. Hambach (1903, pl. 6) illustrates variation in P. sulcatus (Roemer) showing, in addition to changing shape, the gradual increase in size of deltoids with increase in calyx size. This feature is present also among the Alaskan specimens, the deltoids being extremely small in smaller forms and quite distinct in larger ones.

P. alaskensis is somewhat similar to P. ovalis Goldfuss (Schmidt, 1930, p. 65) but the deltoids are more prominent in the elongate Alaskan forms and the ornamentation is not like that of the German species.

The elongate specimen (plate 9, fig. 3) is very like P. kirki described by Hambach (1903, p. 55) from the Lower Burlington. However, the only specimen is in Edwin Kirk's collection and is not now available for study.

Distribution: Northern Alaska: U.S.N.M. loc. 3242 from Kayak formation, a_4 zone.

Material: Holotype: U.S.N.M. 118296; Paratypes: U.S.N.M. 118295, U.S.N.M. 118268, all from U.S.N.M. loc. 3242.

Pentremites ascitus Dutro, n. sp.

Plate 9, figure 4

Description: Calyx monocyclic, subovate, higher than wide, width/height = 0.86; summit low convex; base truncated; transverse outline subpentagonal. Dimensions of figured specimen: 19.2 mm. high and 16.4 mm. wide.

Basal plates not preserved in single available specimen; radial plates long, about 17 mm.; deltoids small, subtriangular, about 2.5 mm. long, not quite reaching oral surface; ornamentation consisting of very fine lirae which parallel sides of radial plates.

Ambulacra subpetaloid, broad, about nine-tenths height of calyx; lancet plate with well-incised food groove; two sets of side plates, each with a brachiole base and shallow groove running towards lancet plate food groove; hydrospire pores between outer side plates and radials, about 50 for each half-ambulacrum. Oral surface not exposed.

Discussion: This species differs from P. alaskensis in shape, width/height ratio, length of ambulacra, and general character of ambulacra. P. ascitus has two sets of side plates, each with a brachiole base. Thus there were apparently four ranks of brachioles per ambulacrum

while in P. alaskensis there were only two. This character has been observed in other species of Pentremites in the Springer collection at the U. S. National Museum. In general shape, P. ascitus resembles P. burlingtonensis Meek and Worthen, but the latter has only one row of side plates and has fewer hydrospire pores per ambulacrum.

It is possible that the inner row of pits and the short groove running from them towards the food groove are not a part of the food gathering system but they seem analogous to the outer pits which are quite surely brachiole bases.

Etheridge and Carpenter (1886, pl. 1, figs. 1-3, 9) have figured the two different types of ambulacra in species of Pentremites, but considered them to have no great taxonomic significance. If there are species which consistently had four rows of brachioles per ambulacra while others had only two, it might be advisable to reconsider this factor in the light of a taxonomic revision of the Pentremitidae. As far as can be ascertained at present the following species have the simpler ambulacra: Pentremites alaskensis, P. sulcatus, P. burlingtonensis; those with more complex ambulacra: Pentremites ascitus, P. pyriformis.

The trivial name (L. ascitus = foreign, strange) refers to the unusual ambulacra.

Distribution: Northern Alaska: U.S.N.M. loc. 3232 from Kayak formation, red limestone member.

Material: Holotype: U.S.N.M. 118325 from U.S.N.M. loc. 3232.

Family ORBITREMITIDAE

Genus CRYPTOBLASTUS Etheridge and Carpenter, 1886

Cryptoblastus melo (Owen and Shumard) var. A

Plate 9, figure 5

1850 Pentremites melo Owen and Shumard, Acad. Nat. Sci. Philadelphia Jour., vol. 2, pt. 1, pp. 65-66, pl. 7, figs. 14a-c.

1937 Cryptoblastus melo (Owen and Shumard). Cline, Jour. Paleontology, vol. 11, no. 8, pp. 636-637, pls. 87-88.

Description: Calyx subspheroidal, about as high as wide; figured specimen 11.3 mm. high and 11.2 mm. wide; transverse section pentagonal; summit and base both flattened.

Basals missing from single available specimen; radials large, forming most of calyx, about 11.0 mm. long; inner edge of radials raised to form rim bordering ambulacral area; radials joining along rather deep groove which appears to widen toward top; deltoids small, subtriangular, about 1.d mm. long, less than one-tenth height of calyx in lateral view; ornamentation on radials consisting of about 10 rows of fine granules which cross the plate diagonally and meet along the radial sutures to form a V.

Ambulacral areas narrow, elevated above level of radials and bounding ridges; lancet plate about as wide as thick; food groove incised; side plates covering most of lancet plate except food groove; hydrospire plates between lancets and radials, each with one pore; about 50 pores for each half ambulacrum or 100 per ambulacrum; ambulacral area not well preserved but apparently similar to that figured for Cryptoblastus sp. A.

Discussion: This form differs from the other two Alaskan species in its height/width ratio and its ornamentation. It would be included in Cryptoblastus mnlo (Owen and Shumard) sensu lato, as defined by Cline (1937, p. 636) but does not correspond with any of the varieties described in the same paper. More material should be on hand before any formal variety is proposed.

Distribution: Northern Alaska: U.S.G.S. loc. 3095 from the Kayak formation.

Material: Figured specimen: U.S.N.M. 118298.

Cryptoblastus sp. A

Plate 9, figure 6

Description: Calyx subovate, keg-shaped, higher than wide; figured specimen about 11.5 mm. high and 10.0 mm. wide; transverse section pentagonal.

Basals missing from only specimen; radials large, forming most of calyx, about 10.0 mm. long in lateral view; inner edge of radials upturned to form ridge which borders ambulacral area; radials joining along suture which is not deeply grooved; deltoids subtriangular, about one-tenth height of calyx in lateral view; ornamentation consisting of vertical rows of fine granules, about 15 to 20 rows for each interambulacral area, rows less distinct adorally.

Ambulacral areas narrow, not raised above bounding ridges; food groove incised; side plates covering most of lancet plate near base but less of it adorally; about 25 side plates for each half ambulacrum; hydrospire plates between lancets and radials, junction with lancets clear but junction with radials indistinct; section of ambulacral area shown in figure 8; apparently four hydrospire folds.

Discussion: This species is related to Cryptoblastus pisum (Meek and Worthen) but differs from it in length/width ratio, in size, and in having much shorter deltoids. The ornamentation and relatively large side plates are similar to C. pisum. No formal species name will be applied at this time because of lack of sufficient material.

Distribution: Northern Alaska: U.S.N.M. loc. 3239, Kayak formation.

Material: Figured specimen: U.S.N.M. 118297.

Cryptoblastus cf. C. pisum (Meek and Worthen)

Plate 9, figure 7

1869 Granatocrinus pisum Meek and Worthen, Acad. Nat. Sci. Philadelphia Proc., p. 89.

1937 Cryptoblastus pisum (Meek and Worthen). Cline, Jour. Paleontology, vol. 11, no. 8, p. 645, pl. 88, figs. 1-6.

Description: Calyx small, subspherical, slightly higher than wide; figured specimen 8.5 mm. high and 8.0 mm. wide; transverse section subpentagonal; basal area concave, pentagonal in outline.

Basals not well preserved; radials long, composing most of calyx, about four-fifths of height in lateral view; inner edge upturned to form ridge bordering ambulacral area; radial sutures not conspicuous; deltoids subtriangular, visible in lateral view, about one-fifth height of calyx; ornamentation consisting of vertical rows of fine granules, as in Cryptoblastus sp. A but considerably finer.

Ambulacral area narrow and not raised above bounding ridges; ambulacral area as in Cryptoblastus sp. A; four hydrospire folds per ambulacrum well shown; eight oval spiracles present, bounded partly by deltoids and partly by side plates.

Discussion: This form is very close to C. pisum in nearly every detail except the relative size of the deltoids. This difference may be within limits of variation for the species, however. Cline indicates in one place that the radials are almost three-quarters the length of calyx (therefore, deltoids about one-quarter) and in another place states that deltoids reach almost one-fourth the length of the calyx, though specimens in the Springer collection at the U. S. National Museum show considerable variation in this character. As Cline states, however, the relatively long deltoids seem a specific character.

Distribution: Northern Alaska: U.S.N.M. loc. 3095, Kayak formation; Burlington limestone from Mississippi Valley and Lake Valley formation from New Mexico.

Material: Figured specimen: U.S.N.M. 118326

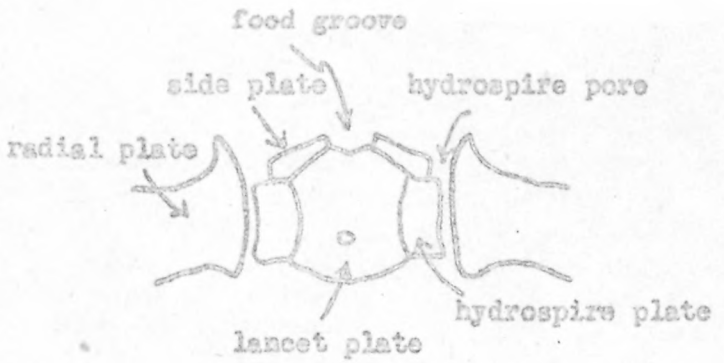

Figure 8. Diagrammatic section through ambulacrum of Cryptoblastus sp. A (enlarged)

Class CRINOIDEA

Subclass CAMERATA

Family ACTINOCRINITIDAE

Genus ACTINOCRINITES Miller, 1821

Actinocrinites accinctus Dutro, n. sp.

Plate 9, figure 8

Description: Dorsal cup monocyclic; three equal basal plates; radials hexagonal and in contact except where anal plate intervenes; first primabrachials hexagonal; axillary second primabrachials eight or nine-sided; axillary secundibrachials giving rise to one arm on the outside of the ray which continues without further branching; axillary third tertibrachials on inside of rays, giving rise to two arms; arms biserial; estimated number of arms 30; interbrachial plates hexagonal; interray area with about 15 plates, ten in triangular area bounded by rays and a line connecting tops of second primabrachials; cup about 45 mm. in diameter and 35 mm. high, though figured specimen slightly flattened.

Ornamentation of plates quite distinctive, rather thin, rounded ridges radiating out from center of plates and connecting midpoints of lines of juncture between plates; ridges tending to be double on radial plates but single on others.

Discussion: This species is most closely related to the genotype A. triacontadactylus Miller but differs from the British form in several respects. The second primabrachials of the genotype species are five or six-sided, reflecting the fact that fewer plates are included in the interray area than the number found in A. accinctus. Miller's figure (1821, pl. 7) shows about nine interbrachial plates with about six for the same triangular area which has 10 plates in the Alaskan species. This enlargement of the interray area and accompanying change in size and shape of the second primabrachials are considered characters of specific importance.

Trivial name (L. accinctus = well-armed) refers to the large number of plates in the dorsal cup, compared to other species in the genus.

Distribution: Northern Alaska: U.S.N.M. locs. 3240, 3242 from Kayak formation.

Material: Holotype: U.S.N.M. 118294 from U.S.N.M. loc. 3240.

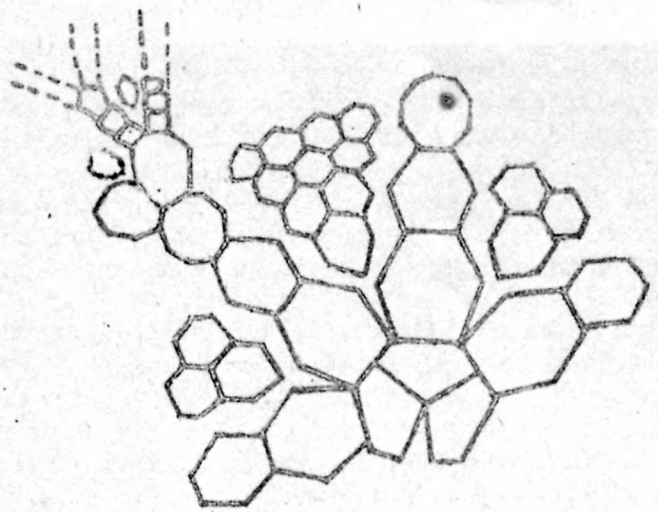

Figure 9. Plate diagram of *Actinocrinites accinctus* showing parts of four rays and three interrays.

Actinocrinites ? cf. A. ? stellaris (deKoninck and Lehon)

Plate 9, figure 9

1854 Actinocrinus stellaris deKoninck and Lehon, Rec. Crin. Carb. Belg., p. 136, pl. 3, figs. 3a, b, 4a-g; pl. 4, fig. 3.

1930 Actinocrinus stellaris deKoninck and Lehon. Schmidt, Preuss. geol. Landesanstalt Abh., n.f., Heft 122, p. 25.

Description: Dorsal cup monocyclic; three equal basal plates; radials hexagonal, on contact except where anal plate intervenes; primabrachials hexagonal; axillary second primabrachials pentagonal; axillary pentagonal secundibrachials each giving rise to two arms; estimated number of arms 20; interbrachial plates hexagonal, six plates in interray area; cup about 22 mm. in diameter and 14 mm. high, figured specimen flattened and measurements approximate.

Plate ornamentation consisting of rounded ridges which radiate from centers of plates to centers of line of contact between plates, generally six ridges on each plate.

Discussion: The reduced number of arms and smaller size, with accompanying reduction of size of interray area, differentiate this species from A. accinctus Dutro. It resembles A. ? stellaris except that arm bases in latter protrude away from surface of cup while those of the Alaskan species do not. This characteristic may or may not be of specific value.

Arthur L. Bowsher of the U. S. National Museum, who is undertaking a revision of the actinocrinids, believes that these 20-armed forms do not belong in Actinocrinites and is establishing a new genus to which this species will be referred.

Distribution: Northern Alaska: U.S.N.M. loc. 3242 from Kayak formation; Tournaisian of Belgium; Lower Carboniferous of England.

Material: Figured specimen: U.S.N.M. 118327, from U.S.N.M. loc. 3242.

Family PLATYCRINITIDAE

Genus PLATYCRINITES Miller, 1821

Platycrinites cf. P. annosus (S.A.Miller)

Plate 9, figure 10

1891 Platycrinus annosus S. A. Miller, Missouri Geol. Survey Bull. 4, p. 14, pl. 1, fig. 12.

1938 Platycrinus annosus S. A. Miller. Branson, Univ. Missouri Studies, vol. 13, no. 4, p. 90, pl. 30, figs. 6-8.

Description: Dorsal cup monocyclic: three unequal basals; five large radials in contact all around cup, plates longer than wide; arms arising from shallow U-shaped facet in upper part of radials; cup bowl-shaped with rather steep, convex sides; dimensions: approximately 9 mm. wide and 7 mm. high.

Ornamentation of radials consisting of U-shaped rows of fine granules paralleling sides of plates; columnar facets small, about 3 mm. in diameter.

Discussion: This form is very similar to P. annosus as described by Branson (1938, p. 90). The distinguishing characters are the small arms facets and relatively small column. It differs from P. chouteauensis (S. A. Miller) only in smaller size and differently shaped arm facets; the latter species has large transversely oval facets. Branson suggested that P. annosus may be a young stage of P. chouteauensis but no intermediate sizes are present in the Missouri material. As long as the species in Missouri are in doubt it seems best only to compare the Alaskan form with the Chouteau one.

Distribution: Northern Alaska: U.S.N.M. loc. 3242, Kayak formation; Chouteau limestone of Missouri.

Material: Figured specimen: U.S.N.M. 118328, U.S.N.M. loc. 3242.

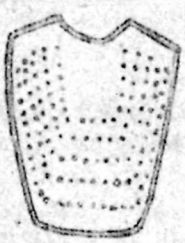

Figure 10. Radial plate of Platycrinites cf. P. annosus showing ornamentation (X 4).

Subphylum ELEUTHEROZOA

Class ECHINOIDEA

Order PERISCHOECHINOIDEA

Genus LEPIDOCIDARIS Meek and Worthen, 1872

Lepidocidaris squamosa (Meek and Worthen)

Plate 16, figure 15

1869 Eocidaris (?) squamosa Meek and Worthen, Philadelphia Acad. Nat. Sci. Prox., p. 79.

1873 Lepidocidaris squamosa (Meek and Worthen). Meek and Worthen, Illinois Geol. Survey, vol. 5, p. 478.

1912 Lepidocidaris squamosa (Meek and Worthen). Jackson, Boston Soc. Nat. History Mem., vol. 7, p. 282, pl. 16, figs. 1-3; pl. 17, figs. 1-14.

Description: Interambulacral plates hexagonal, about 10 mm. across, with large perforate primary tubercle surrounded by deep, sunken scrobicular area, no basal terrace; high, rounded area beyond the scrobicular area with many small secondary tubercles; spines not present and no other details observed.

Discussion: This species is represented only by half a dozen, disarticulated interambulacral plates. The nature of the plates is distinctive, however, and they appear similar in all respects to those figured by Jackson as Lepidocidaris squamosa.

Distribution: Northern Alaska: U.S.N.M. loc. 3242 from Kayak formation; Lower Burlington limestone at Burlington, Iowa.

Material: Figured specimen: U.S.N.M. 116278, U.S.N.M. loc. 3242.

Phylum BRYOZOA

Genus PTYLOPORA McCoy, 1844

Ptylopora aff. P. acuta (Ulrich)

Plate 16, figure 12

1890 Ptilopora acuta Ulrich, Illinois Geol. Survey, vol. 8, sect. 6, p. 622, pl. 65, fig. 4-4a.

Description: Zoarium leaf-like, with strong central branch 1.2 mm. in diameter at base, tapering to 0.8 mm. near top; lateral branches thinner, slightly flexuous, diverging from central branch at angle of about 45° near base, decreasing to about 25° near top; 12 lateral branches in 10 mm. at line of origin along central branch; 16 to 20 lateral branches in 10 mm. measured perpendicular to branches about 10 mm. away from central branch; occasionally bifurcating lateral branches; dissepiments joining branches into rigid fenestrate structure with 8 to 10 fenestrules per 10 mm.; only reverse side exposed; zoecial characters and arrangement not known; reverse of central branch and lateral branches longitudinally striated.

Discussion: This form resembles P. prouti Hall in the size and spacing of fenestrules and branches but is more like P. acuta (Ulrich) in the shape of central branch and the angle of divergence of lateral branches. For these reasons, in addition to the similar subrectangular shape of the fenestrules, the relationship to P. acuta seems closer.

Distribution: Northern Alaska: U.S.N.M. loc. 3095 from Kayak formation; Iowa, Burlington formation and Keokuk limestone.

Material: Figured specimen: U.S.N.M. 118289 (reverse of zoarium), U.S.N.M. loc. 3095.

Genus POLYPORA McCoy, 1844

Polypora aff. P. simulatrix Ulrich

Plate 9, figures 11, 12

1890 Polypora simulatrix Ulrich, Illinois Geol. Survey, vol. 8, sect. 6, p. 589, pl. 59, figs. 4-4b.

Description: Zoarium fenestrate with nearly straight branches about 1.0 to 1.5 mm. wide; branches connected by very thin dissepiments forming regular, subrectangular fenestrules, about 4 to 5 per 10 mm. and about 0.8 to 1.0 mm. wide; four or five rows of zoecia; tubercles scattered at random between zoecia where there are five rows, but restricted to mid-line of branches where there are four rows of zoecia; four to six zoecia per fenestrule, most often five; six branches per 10 mm., measured perpendicular to length of branches.

Discussion: While resembling P. simulatrix in size and distribution of apertures and number of fenestrules per cm., this form is more like P. maccoyana Ulrich in shape of zoarium and shape of fenestrules. It is possible that better material might enable one to erect a new species for the Alaskan form.

Distribution: Northern Alaska: U.S.G.S. loc. 12799 from Utukok formation; Iowa, Keokuk limestone; Indiana, Salem limestone.

Material: Figured specimen: U.S.N.M. 118329 (part of zoarium), U.S.G.S. loc. 12799.

Phylum BRACHIOPODA

Family DISCINIDAE

Subfamily ORBICULOIDEINAE

Genus ORBICULOIDEA d'Orbigny, 1847

Orbiculoidea subelliptica Dutro, n. sp.

Plate 10, figure 1

Description: Outline subelliptical, elongate in axis of pedicle groove; length 13.8 mm. and width 11.1 mm. for holotype.

Pedicle valve nearly flat, apex centrally located, pedicle groove extending posteriorly about 4.5 mm. from apex. Surface with concentric growth lamellae, about 2 per mm. in long axis and 3 per mm. in short axis, total of 14 in holotype; six to eight rounded, indistinct plications extending from apex to anterior margin. Shell material chitino-phosphatic. Brachial valve not known.

Discussion: The subelliptical shape and strong concentric ornamentation, along with size and the nearly centrally located apex, distinguish this from described species known to the author. It most closely approaches O. davreuxiana (deKoninck) which, however, is smaller and nearly circular in outline. The radial ornamentation anterior of the apex may be an expression of internal pallial sinuses as suggested by Hall (1894, pl. 5, fig. 15).

Distribution: Northern Alaska: U.S.N.M. loc. 3240, Kayak formation. No specimens other than the holotype are known.

Material: Holotype: U.S.N.M. 118256 (pedicle valve), from U.S.N.M. loc. 3240.

Superfamily DALMANELLACEA

Family RHIPIDOMELLIDAE

Genus RHIPIDOMELLA Oehlert, 1890

Rhipidomella michelini (Léveillé) Oehlert

Plate 10, figures 2, 3

1835 Terebratula Michelini Léveillé, Soc. geol. France Mém., ser. 1, vol. 2, part 1, p. 39, pl. 2, figs. 14-17.

1845 Orthis Michelini (Léveillé). Murchison-Verneuil-Keyserling, Geol. Russia Europe, vol. 2, p. 185, pl. 12, fig. 7; pl. 13, fig. 1.

1861 Orthis Michelini (Léveillé). Davidson, Brit. Carb. brach., p. 132, pl. 30, figs. 6-11, not 2.

1890 Rhipidomella Michelini (Léveillé). Oehlert, Jour. Conchyliologie, ser. 3, vol. 30, p. 372, text fig.

1930 Orthis (Rhipidomella) michelini (Léveillé). Paeckelmann, Preuss. geol. Landesanstalt Abh. N.F., no. 122, p. 176, pl. 9, figs. 16, 17; pl. 10, figs. 1, 2; pl. 13, fig. 11; pl. 14, fig. 1.

1934 Rhipidomella michelini (Leveille). Demanet, Mus. royale histoire nat. Belgique Mém. 61, pp. 37-41, pl. 2, figs. 1-9.

Description: Outline subcircular to heptagonal; lateral profile convexo-concave to biconvex; shell wider than long with greatest width about two-thirds distance from beak to anterior margin; area narrow, triangular and short; cardinal margin submegathyrid with rounded cardinal extremities; anterior commissure nearly rectimarginate; lateral commissure slightly sinuate. Dimensions of figured specimen: width 25 mm., length 23 mm., thickness 4 mm. (slightly crushed).

Pedicle valve gently convex at umbo becoming concave towards margins, with slight fold near anterior margin; area short, triangular, apsacline; delthyrium open. Internally with rudimentary dental plates; muscle field flabellate, with low median ridge extending about one-half distance to anterior margin; ridge dividing to enclose elliptical adductor scars and rising just beyond their anterior ends; diductor scars large, extending anteriorly more than one-half distance from beak.

Brachial valve more convex than pedicle valve; slight sulcus extending from beak to anterior margin; area narrow, orthoclinal; notothyrium closed by chilidium. Internally with deep dental sockets; crural plates prominent; cardinal process erect, multilobate; low median ridge extending anteriorly from notothyrial cavity.

Exterior of both valves multicostellate, about 15 costellae per 5 mm. at anterior margin; generally about 5 prominent concentric growth lamellae. Shell punctate.

Discussion: The Alaskan form is very similar to the species as described by Demanet (1934, p. 37, pl. 2, figs. 1-9). Size, the unusual shape, and ornamentation are identical and interiors compare favorably. Weller (1909, p. 295, pl. 12, figs. 8-10) indicated the close resemblance of certain lower Mississippian forms from the Mississippi Valley to this species. I believe that the specimens he illustrated in that paper, along with the Rhipidomella sp. (Weller, 1914, pl. 20, figs. 19-21) of his later work belong in Rhipidomella michelini.

Distribution: Northern Alaska: U.S.N.M. locs. 3242, 3244, Kayak formation; Mississippi Valley, Fern Glen fm.; Kinderhookian of Ohio (?); Western Europe, Tournaisian through Viséan, but especially common in zone Tn_3 (upper Tournaisian); Kazakhstan, Rusakov and Ishim beds (upper Tournaisian and lower Viséan).

Material: Figured specimen: U.S.N.M. 118266 (nearly complete specimen) from U.S.N.M. loc. 3242; several specimens from U.S.N.M. loc. 3244 show additional external and internal features.

Family SCHIZOPHORIIDAE

Genus SCHIZOPHORIA King, 1850

Schizophoria resupinata cf. var. dorsosimuata Demanet

Plate 10, figures 5-7

1934 Schizophoria resupinata var. dorsosimuata Demanet, Mus. royale histoire nat. Belgique Mém. 61, p. 53, pl. 3, figs. 14, 15.

Description: Outline transversely elliptical to subrectangular, biconvex, shell wider than long with greatest width about at mid-length; area short, narrow, triangular, less than half the maximum width; cardinal extremities rounded; anterior commissure nearly rectimarginate to slightly sinuate; beaks small; figured specimen 21 mm. wide, 17.1 mm. long and 7.3 mm. thick.

Pedicle valve low convex, somewhat flattened in anterior region with development of slight sulcation; area apsaclinal. Internally with muscle field bounded by prominent ridges extending anteriorly from widely divergent dental plates; diductor scars long and subparallel; adductor scars narrow and paralleling a strong median ridge.

Brachial valve evenly convex, more so than pedicle valve; area orthoclinal; poorly defined sulcus extending from beak to anterior margin. Interior not observed.

Exterior of both valves multicostellate, costellae increasing by bifurcation and intercalation, about 15 per 5 mm. at anterior margin; about 5 concentric growth lamellae on either valve. Shell punctate.

Discussion: This species has approximately the dimensions of S. chouteauensis Weller but differs from it in having a low sulcus on the brachial valve and a concavity of the pedicle valve near the anterior margin. In these respects it is similar to S. swallovi (Hall) and may be a small, young form of that species. Apparently it is most closely allied to Schizophoria resupinata var. dorsosinuata Demanet. Length/width and length/thickness ratios are very nearly the same and shell form is similar. Since only two specimens are known so far from northern Alaska it seems unwise to establish a new species or make more exact comparisons at this time.

Distribution: Northern Alaska. U.S.N.M. loc. 3352 from the Kayak formation and U.S.G.S. loc. 12701 from the Utukok formation.

Material: Figured specimen: U.S.N.M. 118267 (complete specimen), U.S.N.M. loc. 3352.

Schizophoria resupinata cf. var. rotundata Demanet

Plate 10, figures 4, 8

1923 Schizophoria resupinata var. rotundata Demanet, Inst. géol. univ. Louvain, vol. 11, p. 122, pl. 5, fig. 5.

1934 Schizophoria resupinata var. rotundata Demanet, Mus. royale histoire nat. Belgique Mém. 61, p. 51, pl. 3, figs. 9-13; text fig. 10.

Description: Outline transversely subelliptical; biconvex; cardinal extremities rounded; greatest width about at midlength; figured brachial valve is 27.4 mm. wide, 21.7 mm. long and 8.0 ± mm. thick; figured pedicle valve is 19.5 mm. wide, 15.0 mm. long and 3.0 ± mm. thick.

Pedicle valve depressed convex. Internally with small muscle field, prominent cuseptum separating diductor scars, muscle scars extending about two-fifths distance toward anterior margin.

Brachial valve evenly convex, more so than pedicle. Internally with straight, thin median septum separating adductor scars; brachiophore plates extended as strong ridges bounding muscle field.

Externally multicostellate, costellae 15-18 per 5 mm. at anterior margin; shell punctate.

Discussion: The form and dimensions of these specimens are somewhat like S. chouteauensis Weller (1914, pp. 163-164, pl. 23, figs. 6-19). Only a few valves have been found in collections from northern Alaska, but the material on hand best compares with S. resupinata var. rotundata Demanet.

In the light of Bond's discussion (1941, pp. 289-295) it seems likely that the Alaskan specimens, as well as S. chouteauensis Weller, all belong in S. resupinata (Martin), the range of shape and size variation in that species being considerable. Species of Schizophoria described from the Mississippian of North American should be restudied with respect to Bond's findings.

Distribution: Northern Alaska: U.S.G.S. loc. 12795 from Utukok formation; Belgium: Tournaisian through lower Visean being most abundant in Tn3R (upper Tournaisian).

Material: Figured specimens: U.S.N.M. 110269 (exfoliated pedicle valve), U.S.N.M. 110270 (brachial interior), both from U.S.G.S. loc. 12795.

Superfamily STROPHOMENACEA

Family STROPHOMENIDAE

Subfamily RAFINESQUININAE

Genus LEPTAENA Dalman, 1828

Leptaena analoga (Phillips) Sowerby

Plate 10, figures 9, 10, 12, 14, 15

1836 Producta analoga Phillips, Geol. Yorkshire, vol. 2, p. 215, pl. 7, fig. 10.

1840 Leptaena analoga (Phillips) Sowerby, Min. Conchology, vol. 7, p. 10, pl. 615, fig. 2.

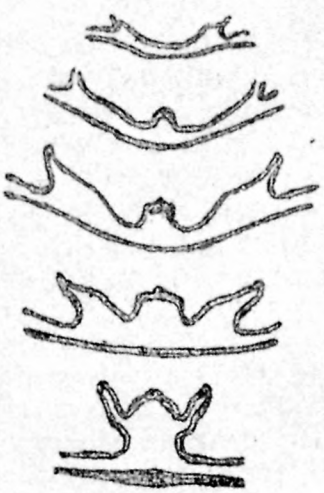

Figure 11. Sections through posterior of pedicle valve of Leptaena analoga showing pseudospondylium (after Demanet, X 5).

1841 Leptaena analoga (Phillips). Phillips, Figs. and desc. of Palaeozoic fossils of Cornwall, Devon and West Somerset, pp. 55-56, pl. 24, fig. 93.

1861 Strophomena rhomboidalis var. analoga (Phillips). Davidson, Brit. Carb. brach., p. 119, pl. 28, figs. 1-6, 9-13.

1914 Leptaena analoga (Phillips). Weller, Illinois Geol. Survey Mon. 1, p. 49, pl. 2, figs. 1-10.

1930 Leptaena rhomboidalis var. analoga (Phillips). Paeckelmann, Preuss. geol. Landesanstalt Abh. N.F., no. 122, p. 183, pl. 10, fig. 3; pl. 14, figs. 2, 3.

1934 Leptaena analoga (Phillips). Demanet, Mus. royale histoire nat. Belgique Mém. 61, pp. 61-73, pl. 5, figs. 1-14; text figs. 11-14.

Description: Outline subtrapezoidal, lateral profile concavo-convex to plano-convex, negathyrid cardinal margin, shell wider than long with greatest width along hinge line, cardinal extremities angular to moderately alate. Dimensions of adult specimens from northern Alaskan collections: eight pedicle valves, width 50.2 ± 16.4 mm. and length 25.7 ± 8.3 mm; six brachial valves, width 52.2 ± 16.5 mm. and length 23.4 ± 5.1 mm.; trail length approximately 15 mm.

Pedicle valve nearly flat to gently convex, greatest convexity in umbonal region becoming flattened toward anterior and lateral margins, abruptly geniculate with trail nearly perpendicular to plane of valve; trail sinuate in some specimens with ill-defined sulcus not extending onto visceral disc; area flat to slightly concave, narrow, orthocline; delthyrium broadly triangular; foramen epithyrid, piercing beak. Internally with well defined muscle area in form of a raised platform called spondylium simplex by Demanet (1934, pp. 63-64, text fig. 11), spondylium extending about one-third distance toward anterior edge of visceral disc, diductor scars occupying greater part of structure with adductor scars narrow and paralleling low median ridge, structure more like a pseudospondylium than a true spondylium as suggested by Demanet.

Brachial valve concave near beak becoming flattened towards margins and conforming with flexure of pedicle valve to form trail; area narrow, flat, hypercline; notothyrium triangular, with chilidium. Internally, visceral disc marked by prominent concentric ridge following line of flexure; cardinal process bilobed; crural ridges strong, making an angle of about 30° with posterior margin; posterior adductor scars large, subcircular, divided by low median ridge anteriorly, ridge continuing nearly to edge of visceral disc; anterior adductor scars small, separated by median ridge.

Exterior of both valves marked by 15-25 roughly concentric rugae, faint near umbo and coarsening toward margins, anastomosing and bifurcating commonly in posterolateral regions; radial ornamentation consisting of rounded costellae, about 3 per mm. near anterior margins, increasing by bifurcation and intercalation; very fine concentric filae also present. Shell pseudopunctate.

Discussion: This ubiquitous Lower Carboniferous species has been well described by Demanet (1934, pp. 61-73, pl. 5, figs. 1-14, text figs. 11-14) and Weller (1914, pp. 49-52, pl. 2, figs. 1-10) who, however, give no precise information regarding variation in size and ornamentation. The forms from Alaska exhibit nearly the same size variation as those figured by Demanet. Measurements of Demanet's figured adult specimens give a width of 48.5 ± 20.7 mm. and a length of 22.3 ± 6.3 mm. with trail length of 14-18 mm. Phillips' original figured specimen is approximately 43 mm. wide and 22 mm. long with a trail 14 mm. long while the specimen figured in 1841 is about 40 mm. wide (or 51 mm. as reconstructed by Phillips) and 19 mm. long. A nearly perfect specimen from the Lake Valley formation of New Mexico, figured by Girty (1927, pl. 22, figs. 6-8) is 39 mm. wide, 24.5 mm. long with trail length of 16 mm. Weller gives dimensions of a nearly complete example as: width, 40 mm., length, 25 mm. Smaller specimens, present in the Alaskan collections along with the larger forms, seem best interpreted as immature individuals. They are generally more subcircular in outline, have a poorly developed trail and fewer rugae on the visceral disc.

There seems little doubt that the forms present in the lower Mississippian formations of northern Alaska are true representatives of the species.

Distribution: Northern Alaska: U.S.N.M. localities 3242, 3243, 3245, 3248 from Kayak formation; U.S.G.S. localities 11858, 12706, 12709, 12793, 12795 from the Utukok formation; Mississippi Valley Kinderhookian plus Fern Glen fm., St. Joe fm., Boone chert, Lower Burlington fm.; Madison fm. of Cordilleran region; Lake Valley fm. of New Mexico; Tournaisian and Lower Viséan of western Europe and British Isles; Kassin and Russakov beds, Kazakhstan.

Material: Figured specimens: U.S.N.M. 118257 (pedicle exterior), U.S.G.S. loc. 12709; U.S.N.M. 118258 (brachial interior), U.S.G.S. loc. 12709; U.S.N.M. 118259 (brachial exterior), U.S.N.M. loc. 3242; U.S.N.M. 118260 (pedicle exterior), U.S.N.M. loc. 3243.

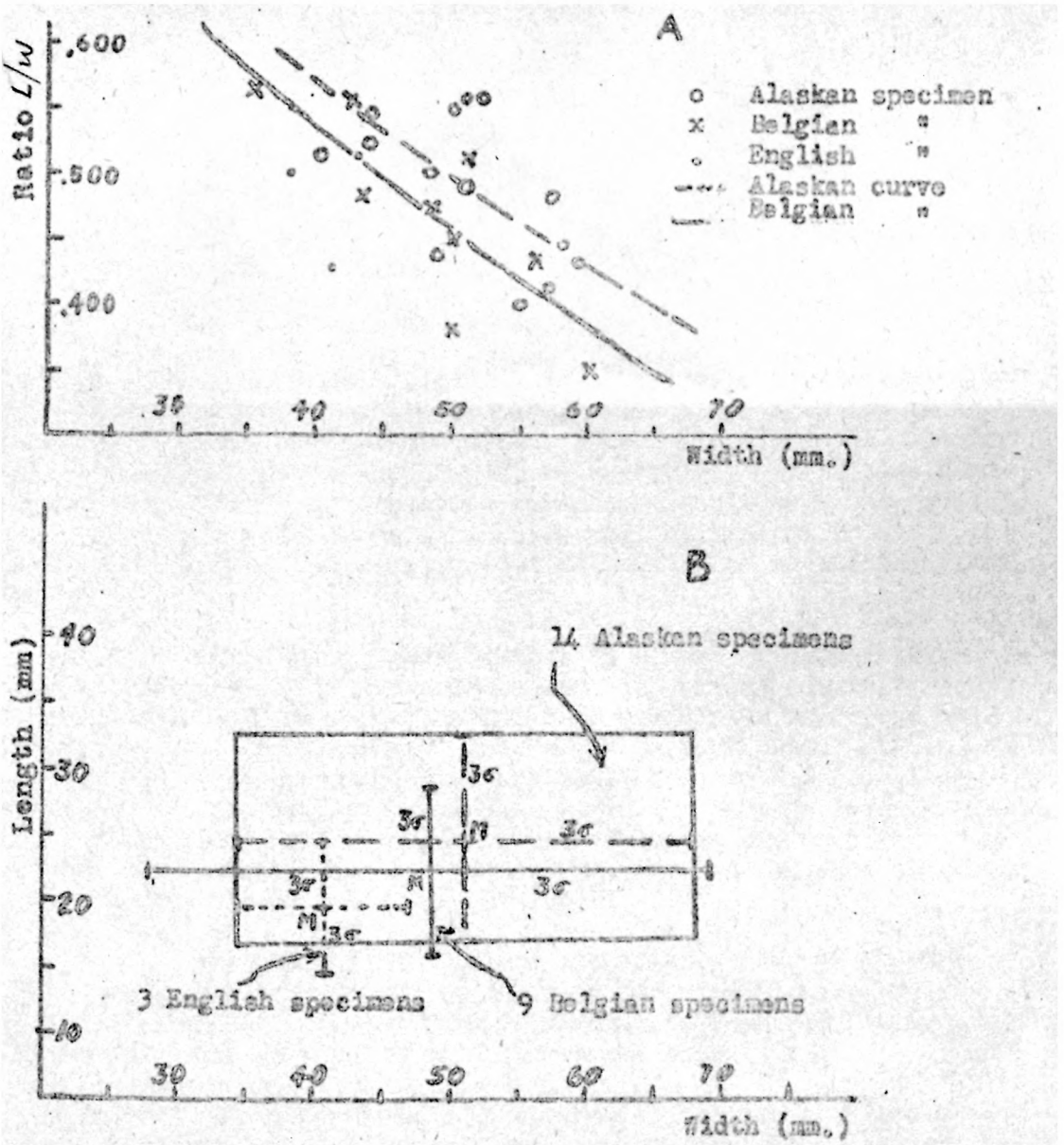

Figure 12. A. L/W plotted against width for Alaskan, Belgian and English specimens of Leptaena analoga, latter two groups based on figured specimens of Demanet (1934) and Phillips (1836, 1841). Curves fitted by eye.

B. Variation in length and width of same collections used for A. Shaded area shows range of variation of dimensions for Alaskan material.

Subfamily ORTHOTETINAE

Genus SCHUCHERTELLA Girty, 1904

Schuchertella ampla Dutro n. sp.

Plate 11, figures 1, 3, 5, 7, 8

Description: Outline subelliptical to subrectangular, lateral profile convexo-plane to convexo-concave, shell wider than long with greatest width about one-third distance from hinge line to anterior margin; cardinal margin megathyrid, with cardinal extremities forming angle of about 115°; anterior commissure rectimarginate; pedicle valve (holotype) with hinge width 51.8 mm., maximum width 61 mm., length 42.1 mm., and thickness about 18 mm.; other specimens slightly larger.

Pedicle valve nearly flat, convex in umbonal region flattening rapidly toward cardinal extremities and with slight concavity near anterior margin; area narrow, catacline; delthyrium small and completely covered by deltidium. Internally without dental plates or septa of any kind; muscle field very small and divided into four areas by five ridges, strong median ridge, two strong ridges bounding the diductor scars diverging from the median ridge at 45° angle, two less prominent ridges separating diductor and adductor scars and diverging from median ridge at 10° angle.

Brachial valve uniformly convex with greatest convexity about one-third distance from beak to anterior border; thickness nearly that of the shell. Internally with short, stout crural plates and deep notothyrial cavity; other features not observed.

Exterior of both valves with alternating coarse and fine costellae increasing radially by bifurcation and intercalation, coarse costellae tending to increase by bifurcation with finer ones being intercalated just anterior to points of bifurcation, about 10-12 costellae per 5 mm. at anterior border; fine concentric ornamentation with about 3-5 filae per mm., more pronounced in interspaces than on costellae.

Discussion: This species, because of its large size and ornamentation, seems quite distinct. It appears most closely related to "Schellwienella" alternata reported by Weller (1914, p. 67) from the Burlington limestone. The generic reference of Weller's species is doubtful since it was established on a single brachial valve. Large schuchertellids described from Europe are S. fascifera (Tornquist) and S. portlockiana (v. Semenov) but these can be distinguished from the Alaskan form by their ornamentation. Neither the fine fascicles of lirae of the former nor the prominent primary costellae of the latter are found in S. ampla. The figured brachial valve is from a

different collection than the holotype and may not be a true representative of the species. However, it occurs at approximately the same stratigraphic level and only one orthotetid of this size has so far been recognized from the Alaskan material.

Trivial name (L. amplus = large) refers to the unusually large size of this species.

Distribution: Northern Alaska: U.S.N.M. loc. 3139 from the Kayak formation; U.S.G.S. locs. 11861, 12707, 12709, 12713, 12793 from the Utukok formation.

Material: Holotype: U.S.N.M. 118261 (pedicle interior), U.S.G.S. loc. 12709; paratype: U.S.N.M. 118262 (exfoliated brachial valve), U.S.G.S. loc. 11861.

Schuchertella ampla var. complanata Dutro, n. var.

Plate 11, figures 2, 4, 6

Description: Same as for species except in shape of brachial valve. Brachial valve gibbous, umbonal area flattened and slightly sulcate, lateral slopes precipitous, anterior commissure uniplicate; flattening and sulcation reflected internally by shallow notothyrial cavity as opposed to deep one common for the species; ornamentation same as in species.

Discussion: This unusual variety appears to have a relatively narrow stratigraphic range, having been found so far only near the base of the Utukok formation, and may prove important in that respect. I consider this form a modification of S. ampla, the differences being of less than specific importance. Future studies may justify making it a separate species if additional material shows a consistent trend to sulcation in the brachial valve. A pedicle valve of about same size occurs with the holotype and is definitely of the genus Schuchertella.

Varietal name (L. complanatus = flattened) refers to flattened brachial valve.

Distribution: Northern Alaska: U.S.G.S. loc. 11858, Utukok formation.

Material: Holotype: U.S.N.M. 118263 (partially exfoliated brachial valve), U.S.G.S. loc. 11858.

Genus SCHELLWIENELLA Thomas, 1910

Schellwienella radialiformis (Demanet) Dutro

Plate 10, figures 11, 13

1861 Streptorhynchus crenistrea Davidson (part), Brit. Carb. Brach., p. 124, pl. 26, fig. 3 only.

1930 Schellwienella aff. aspis Smyth, Proc. Roy. Irish Acad., vol. 39, sect. B, no. 26, p. 555, pl. 16, fig. 6a, b.

1934 Schellwienella aspis mut. radialiformis Demanet, Mus. royale hist. nat. Belgique Mém. 61, p. 65, p. 7, figs. 6-12.

Description: Outline subelliptical, convexo-plane, anterior commissure rectimarginate, cardinal margin megathyrid, cardinal extremities alate, shell wider than long with greatest width along hinge line; figured pedicle valve 24 mm. wide and 16 mm. long, figured brachial interior 24 mm. wide, 16 mm. long and about 3 mm. thick.

Pedicle valve nearly flat with slight convexity at midwidth; area narrow, apsacline; cardinal extremities alate; delthyrium not observed. Internally with rather short dental plates diverging at angle of about 90°; muscle area not observed.

Brachial valve evenly convex with flattening in posterolateral regions near the alate cardinal extremities. Internally with prominent bi-lobed cardinal process, crural plates widely divergent, notothyrial cavity poorly defined; short, low median ridge dividing rather large, poorly defined muscle field, ridge rapidly dying out anteriorly.

Exterior with primary costellae increasing by bifurcation; secondary costellae intercalated, generally three between the primary ones near the margins; prominence of every fourth costella a distinctive feature.

Discussion: The small size, alate cardinal extremities and peculiar ornamentation distinguish this from other similar species of Schellwienella. First referred by Smyth with affinities to S. aspis and later given the value of a mutation by Demanet, it seems to me that there are enough distinctive characters to warrant specific rank, especially as this form occurs stratigraphically higher than the true S. aspis. The name radialiformis, used for the mutation by Demanet, therefore becomes the trivial name. This species can be differentiated from S. aspis on two characters: 1. it has a convexo-plane profile as contrasted with the convexo-concave S. aspis; 2. the ornamentation is quite different from the uniformly costellate S. aspis. The two species seem definitely related, however, S. radialiformis probably having been derived directly from the Lower Tournaisian S. aspis. The latter, in turn, seems very much like S. chouteauensis Weller and occupies about the same stratigraphic position.

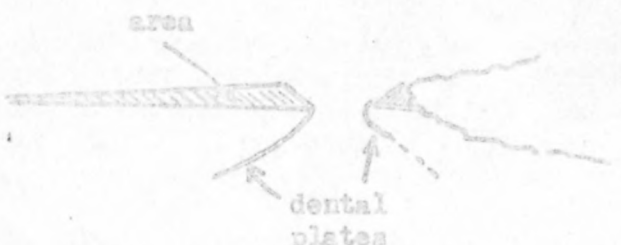

Figure 13. Sketch showing dental plates in *Schallreinella radialiformis* (magnification X 7).

Distribution: Northern Alaska: U.S.G.S. locs. 12709, 12712 from the Utukok formation; C_1 zone of Ireland; Tn_3 zone of Belgium.

Material: Figured specimens: U.S.N.M. 118264 (pedicle valve and pedicle mold), U.S.G.S. loc. 12709; U.S.N.M. 118265 (brachial interior), U.S.G.S. loc. 12712.

Superfamily PRODUCTACEA

Family CHONETIDAE

Genus CHONETES Fischer 1837

Chonetes sp. A

Plate 14, figures 1, 2

Description: Outline subrectangular, concavo-convex; hinge line straight; shell wider than long with greatest width at or near hinge line; cardinal extremities angular in most specimens. Dimensions of 11 specimens: 8.4 ± 3.3 mm. wide, 5.8 ± 1.7 mm. long, thickness varying from 2 to 4 mm.

Pedicle valve evenly and strongly convex, greatest arching near umbo, posterolateral flattening more pronounced than lateral or anterolateral; area low and triangular; delthyrium closed by convex deltidium. Interior with low median septum extending about half the length of valve; adductor scars small, narrow and parallel septum; diductor scars subovate and rather large, lying outside adductors.

Brachial valve concave, slightly smaller than pedicle; area narrower than that of pedicle valve, with chilidum. Interior with median septum; muscle scars but faintly impressed in available specimens.

Exterior multicostellae on entire valve; costellae increasing by bifurcation anteriorly and laterally from beak; narrow angular striae. Shell pseudopunctate.

Discussion: Small chonetids are found rather infrequently in collections from the Kayak and Utukok formations. This species has a form similar to Chonetes logani Norwood and Pratten though the latter has coarser ornamentation, in general, with about 3 costellae per mm. and has crenulations produced by concentric ornamentation which the Alaskan form does not appear to have. Chonetes geniculatus White is much smaller but is otherwise similar to the Alaskan species. Perhaps the closest comparison can be made to Chonetes sp. 1 aff. elegans of Paeckelmann (1930, p. 263, pl. 19, figs. 4, 5). This or similar forms are present in the Tournaisian of both Belgium and Germany. Until more material is available, it seems best to refrain from giving this group a new specific name.

Distribution: Northern Alaska: U.S.N.M. localities 3139, 3246 and 3095, Kayak formation; U.S.G.S. localities 12709 and 12712, Utukok formation.

Material: Figured specimens: U.S.N.M. 118271 (brachial exterior), U.S.G.S. loc. 12712; U.S.N.M. 118272 (brachial interior), U.S.G.S. loc. 12712.

Chonetes sp. B

Plate 14, figure 7

Description: Shell small, subsemicircular, concavo-convex; hinge line straight; wider than long with greatest width at or near hinge line; cardinal extremities angular, with lateral margins meeting hinge line nearly at right angles; rectimarginate. Dimensions of figured specimen: 6.7 mm. wide, 5.4 mm. long, 2.0 mm. thick.

Brachial valve strongly concave becoming flattened toward the cardinal extremities, slightly smaller than pedicle valve, greatest thickness just posterior of midlength.

Pedicle valves and interiors not observed.

Shell multicostellate with about 4 simple, rounded costellae per mm. at anterior margin, about 50 on entire valve. Shell pseudopunctate.

Discussion: This form is much smaller, more convex, and has fewer costellae on the entire valve than Chonetes sp. A. It is most similar to C. geniculatus White, from the Louisiana limestone. Specimens are very rare in Alaskan collections and definite comparisons cannot be made until more material is available. It may be conspecific with C. geniculatus, however.

Distribution: Northern Alaska: U.S.N.M. loc. 3246, Kayak formation.

Material: Figured specimen: U.S.N.M. 118277 (brachial valve), U.S.N.M. loc. 3246.

Chonetes utukokensis Dutro, n. sp.

Plate 14, figures 3-6

Description: Outline subelliptical, concavo-convex; hinge line straight; shell wider than long with greatest width about one-third distance from hinge to anterior margin; cardinal extremities rounded to angular, making obtuse angle of about 120°. Dimensions of 18 specimens: 24.1 ± 15.3 mm. wide, 15.3 ± 8.1 mm. long, 5.8 ± 2.6 mm. thick (thickness based on only 6 measurements).

Pedicle valve uniformly convex with greatest thickness about mid-length, sloping regularly to lateral and anterior margins; area triangular, apsaclinal; delthyrium with convex deltidium. Interior with median septum extending less than one-half length of valve; adductor scars small, narrow, paralleling septum; diductor scars flabellate, lying outside adductors, rather large.

Brachial valve concave, smaller than pedicle valve; area narrow, triangular, hyperclinal, with chilidium. Interior with median septum, extending as low ridge well beyond half-length; adductor scars subovate and located in elevated areas on either side of septum; brachial process massive, quadrilobate; crural supports extended as well-defined ridges nearly parallel to hinge line.

Exterior multicostellate with about 3 rounded costellae per mm. at anterior border; costellae increasing by bifurcation and tending to be more or less tenuous and irregular with narrow, deep striae between; both valves with more or less well-developed irregular plicae, becoming more pronounced in larger specimens; shell pseudopunctate.

Discussion: This species is found in great numbers in coquina beds in the Utukok formation but has not been recognized in the Kayak formation. The only species from the upper Mississippi Valley which approaches the northern Alaskan one is Chonetes missouriensis Weller but it is not as large nor does it have the irregular plicae.

Paeckelmann describes two groups of large chonetids from Germany, each frequently radially folded. The Alaskan material most closely resembles his Chonetes hemisphaericus (1930, p. 268, pl. 17, figs. 11-18, 20-22) but is a somewhat larger form and has more costellae per mm. with narrow striae between. The Chonetes zimmermanni group has similar ornamentation but shape, dimensions and greatest width at hinge line are distinguishing features.

These possibly all could be included in Chonetes papilionacea (Phillips) but that species contains at least two quite different types as illustrated by Davidson (1860, pl. 46, figs. 3-6) and the name apparently has been misused by authors. The original drawing of Phillips (1836, pl. 11, fig. 6) suggests that his species would belong to the Chonetes zimmermanni group of Paeckelmann. It seems wisest to propose a new species for this Alaskan chonetid, which is so abundant in the Utukok formation.

The trivial name is taken from the Utukok River, along which the formation crops out in many places.

Distribution: Northern Alaska: U.S.G.S. localities 12711, 11868, 11862, 12794 from the Utukok formation.

Material: Holotype: U.S.N.M. 118273 (brachial exterior), U.S.G.S. loc. 11868; paratypes: U.S.N.M. 118274, 118275, 118276 (brachial interior, brachial exterior, pedicle exterior respectively), U.S.G.S. loc. 12794.

Family PRODUCTIDAE

Subfamily PRODUCTELLINAE

Genus PRODUCTELLA Hall, 1867

Productella pyxidata (Hall) Hall and Clarke

Plate 12, figures 8-11

1858 Productus pyxidatus Hall, Geol. Iowa, vol. 1, pt. 2, p. 498, pl. 3, figs. 8a-3.

1892 Productella pyxidata (Hall). Hall and Clarke, Introduction Study Brachiopods, part 1, pl. 21, figs. 20, 23.

1914 Productella pyxidata (Hall). Weller, Illinois Geol. Survey Mon. 1, pp. 100-101, pl. 19, figs. 1-21.

1938 Productella pyxidata (Hall). Sutton, Jour. Paleontology, vol. 12, no. 5, p. 551, pl. 62, figs. 3, 4; text figs. 1h, i.

Description: Shell small, subrectangular, concavo-convex; hinge line straight, nearly equal to greatest shell width. Dimensions: width 7.2 mm., length 6.6 mm., thickness 2.7 mm., hinge width 6.9 mm.

Pedicle valve gently convex, scattered oblique spines, well-developed concentric ornamentation. Neither interiors nor brachial valve yet found in Alaskan material. Shell pseudopunctate.

Discussion: This small productellid is very similar to those figured by Weller and Sutton and probably can safely be assigned to Productella pyxidata (Hall). It is possible that more material might show up differences not discernable on the fine pedicle valve illustrated.

Distribution: Northern Alaska: U.S.N.M. loc. 3246 in Kayak formation; Kinderhookian of Missouri.

Material: Figured specimen: U.S.N.M. 118310 (pedicle exterior), U.S.N.M. loc. 3246.

Subfamily PRODUCTINAE

Genus SPINULICOSTA Nalivkin, 1937

Spinulicosta cf. S. concentrica (Hall) Nalivkin

Plate 12, figures 1-6

1857 Productus concentricus Hall, 10th Ann. Rept. New York State Cab. Nat. Hist., p. 180.

1914 Productella concentrica (Hall). Weller, Illinois Geol. Survey Mon. 1, p. 98, pl. 19, figs. 22-34.

1937 Productus (Spinulicosta) concentricus (Hall). Nalivkin, Cent. Geol. and Prosp. Inst. Trans., fasc. 99, p. 52, pl. 6, figs. 7-10.

Description: Shell small, subovate, concavo-convex; hinge line much less than greatest width; cardinal extremities angular. Dimensions of figured pedicle valve: 7.5 mm. wide, 8.6 mm. long, 7.1 mm. thick.

Pedicle valve strongly convex, productiform; scattered large spines over entire surface with no development of costae anteriorly. Interior not observed.

Brachial valves not present in collections. Shell pseudopunctate.

Discussion: This small productid can be closely compared with S. concentricus (Hall) as described and figured by Nalivkin and there seems no doubt about his specific assignment. Spinulicosta was established as a subgenus by Nalivkin with genotype species as Productus spinulicostus Hall. Diagnostic features are: "apical part covered with large irregularly set spines which become longer and confused toward the frontal margin, and form irregular plications. . . it is obviously replaced (in Upper Tournaisian and Viséan) by the genus Avonia Thomas (Productus youngianus Dav. group) the representatives of which differ in more regular plications approaching the apex." (Nalivkin 1937, p. 140).

Distribution: Northern Alaska: U.S.N.M. locs. 3139 and 3246 from zone β faunule of Kayak formation; Kinderhookian of Missouri and Iowa; Madison fm. of Cordilleran region; Kassin beds (lower Tournaisian) of Kazakhstan.

Material: Figured specimens: U.S.N.M. 118311 (pedicle exterior), U.S.N.M. loc. 3246.

Genus SETIGERITES Girty, 1939

Setigerites ? truncicostis Dutro, n. sp.

Plate 13, figures 7-14

Description: Shell small, productiform, subhemispherical, concavo-convex; hinge line straight, about two-thirds maximum width. Dimensions of holotype: width 16.6 mm., length 16.0 mm., thickness 10.5 mm., hinge width 11.7 mm.

Pedicle valve strongly convex, slightly flattened on umbo with tendency to shallow sulcation anteriorly in large specimens; scattered, large, erect spines with about five concentrated on each ear.

Brachial valve gently concave, flexing strongly to form trail, subcircular in plan; bifid cardinal process; musculature not observed.

Both valves with fine, nearly straight costae, becoming obsolete in umbonal region, about 2 per mm. near anterior margin; costae broadly rounded tending to become flattened with broad, flat striae between; concentric rugae on beak and umbo becoming obscure anteriorly where costae are well developed; very fine concentric growth lines producing fine reticulation where they cross costae, about 10 per mm. Shell pseudopunctate.

Discussion: This Alaskan species has so far been found only in the red limestone member of the Kayak formation and is stratigraphically an important form. The shape and ornamentation are very like Setigerites but the specimens on hand do not show the upturned anterior and lateral borders, designated as an important feature by Girty. Mackenzie Gordon of the U. S. Geological Survey has undertaken, with Miss Helen Muir-Wood, a reclassification of some North American productids and has tentatively included in Setigerites several species in which the upturned border is obscure or absent. It is possible that such forms belong in a new genus which would include several species of early Mississippian productids of this nature.

The trivial name (L. truncus = truncated, cut off + L. costa = rib) refers to the flattened nature of the costae.

Distribution: Northern Alaska: U.S.N.M. locs. 3140, 3142, 3239.

Material: Holotype: U.S.N.M. 116312 (pedicle exterior), U.S.N.M. loc. 3239; paratypes from other collections in red limestone member.

Setigerites sablei Dutro, n. sp.

Plate 12, figures 12-17

Description: Shell subquadrate, productiform, concavo-convex, hinge line straight and about four-fifths maximum width. Dimensions of figured pedicle valve: width 30.2 mm., length 28.5 mm., thickness 25.0 mm., hinge width 24.5 mm.; figured brachial valve: width 30 mm., length 19.4 mm., hinge width 28.6 mm.

Pedicle valve strongly convex, slightly flattened over umbo; lateral slopes precipitous; ears small; a few large erect spines scattered over valve with about five grouped in posterolateral region; rounded costae, about 7 per 5 mm., rather uniform in posterior and umbonal regions becoming irregular and sinuous on trail; concentric band of fine spine bases near anterior margin; broad concentric rugae produce crude reticulation; upturning of trail in anterior and anterolateral portion poorly shown.

Brachial valve gently concave, with rounded radiating costae and concentric rugae producing reticulate pattern; bilobate cardinal process; median septum narrow, extending about half length of valve; anterior adductor scars on elevated ridges which parallel median septum; ridges rising anteriorly; septum extending anteriorly beyond adductor platforms; posterior adductor scars dendritic, approximately bisect angle made by septum and hinge line. Shell pseudopunctate.

Discussion: This species approaches Setigerites setigus (Hall) but is smaller, has more regularly convex form, and has finer costae.

This species is named for Edward G. Sable, U. S. Geological Survey, who measured the type section of the Utukok formation and collected a great quantity of fossil material from that formation.

Distribution: Northern Alaska: U.S.G.S. locs. 11858, 11860, 12793 from Utukok formation.

Material: Holotype: U.S.N.M. 118314 (pedicle exterior), U.S.G.S. loc. 11860; paratypes: U.S.N.M. 118315 (brachial interior), U.S.G.S. loc. 12793; U.S.N.M. 118316 (brachial interior), U.S.G.S. loc. 11858.

Genus BUXTONIA Thomas, 1914

Buxtonia ? parva Dutro, n. sp.

Plate 13, figures 1-6

Description: Shell small, productiform, subhemispherical, concavo-convex; hinge line straight, about two-thirds maximum width. Dimensions of holotype: width 17.2 mm., length 18.4 mm., thickness 12.3 mm., hinge width 11.5 mm.

Pedicle valve strongly convex, flattened slightly in umbonal region; lateral slopes abrupt, nearly vertical; oblique spines distributed over entire valve, anteriorly directed, spine bases forming elongate nodes on costae, thickly concentrated on lateral slope just anterior of ears; fine costae discontinuous and sinuose because of spine bases, becoming obscure in posterior region, about 2 per mm. at anterior margin; concentric rugae in beak region becoming obscure anteriorly. Interior not observed. Shell pseudopunctate.

No brachial valves in collections.

Discussion: In the red limestone this small productid occurs along with Setigerites ? truncicostis, n. sp. differing from it in ornamentation and shape. The ornamentation is that of Buxtonia but some doubt has been raised about placing such a small form from the early Mississippian in this genus. A new genus of Muir-Wood and Gordon, (not yet published) may include this species. For the present it seems best to assign it tentatively to Buxtonia.

Distribution: Northern Alaska: U.S.N.M. loc. 3239, Kayak formation.

Material: Holotype: U.S.N.M. 118313 (pedicle exterior), U.S.N.M. loc. 3239.

Genus PUSTULA Thomas, 1914

Pustula cf. P. morbilliana (Winchell) Sutton

Plate 13, figures 17, 18

1865 Productus morbillianus Winchell, Acad. Nat. Sci. Philadelphia Proc., p. 113.

1914 Echinoconchus morbillianus (Winchell). Weller, Illinois Geol. Survey Mon. 1, p. 142, pl. 18, figs. 13-15.

1938 Pustula morbilliana (Winchell). Sutton, Jour. Paleontology, vol. 12, no. 6, p. 555.

Description: Shell small, subovate, concavo-convex, about as long as wide; hinge line short. Dimensions of figured specimen: width 12.0 $\pm$ mm., length 11.0 mm., thickness 3.5 mm.

Pedicle valve evenly convex, posterolateral slopes more abrupt than anterior slope, faint sulcus present near anterior margin; fine, oblique, closely packed spines arranged in concentric bands; one bank of spines in each band, bands averaging 1 mm. in width. Shell pseudopunctate.

Interiors or brachial valves not present in collections.

Discussion: This single specimen from northern Alaska is very similar to Pustula morbilliana (Winchell). It is slightly smaller and less convex than the holotype as figured by Weller and has a faint sulcus while the holotype does not. Until more material is available it seems unwise to do more than compare it to P. morbilliana.

Distribution: Northern Alaska: U.S.N.M. loc. 3237 from Kayak formation; from base of Burlington limestone in Mississippi Valley.

Material: Figured specimen: U.S.N.M. 116316 (pedicle exterior), U.S.N.M. loc. 3237.

Pustula sp. A

Description: Shell rather large, productiform, concavo-convex; hinge line straight and about three-fourths maximum width. Dimensions of figured specimen: width 28.5 mm., length 25.2 mm., thickness 10.5 mm., hinge width 22.4 mm.

Pedicle valve flattened convex, prominent umbo with beak curving over hinge line; ears well-developed; shallow sulcus present anterior of umbo; oblique spines over entire valve, in concentric bands, one rank of spines on each band with banding irregular on some parts of valve. Interior not observed. Shell pseudopunctate.

No brachial valves present in collections.

Discussion: This form is similar to an undescribed species from the Lake Valley formation and is like specimens of Pustula pustulosa (Phillips) in the U. S. National Museum, except for the latter's slightly larger size and more pronounced sulcus. The concentric distribution of spines is not as regular as in Pustula cf. morbilliana (Winchell) but is about as variable as in the genotype species. No formal species name will be applied until more material is on hand.

Distribution: Northern Alaska: U.S.G.S. loc. 12709 from Utukok formation; possibly Lake Valley formation, New Mexico.

Material: Described specimen: U.S.N.M. 116330 (exfoliated pedicle exterior), U.S.G.S. loc. 12709.

Genus LABRIPRODUCTUS Cooper and Muir-Wood, 1951

Labriproductus cf. L. wortheni (Hall)

Plate 12, figure 7

1858 Productus wortheni Hall, Geology Iowa, vol. 1, pt. 2, p. 635, pl. 19, figs. 1a-b.

1914 Productus wortheni Hall. Weller, Illinois Geol. Survey Mon. 1, p. 126, pl. 13, figs. 13-17.

1951 Labriproductus wortheni (Hall). Cooper and Muir-Wood, Washington Acad. Sci. Jour., vol. 41, no. 6, p. 195.

Description: No pedicle valves available.

Brachial valve transversely subquadrate, nearly flat being sharply flexed at anterior and lateral margins to form trail; hinge line straight; hinge width about three-quarters maximum width. Dimensions: width 27 mm., length 20 mm., hinge width 20 mm.; valve with five distinct areas produced by two rounded sulci which trend anterolaterally from beak, flattened ears thus separated from low median fold; concentration of spine bases on ears, about 35 on each ear; rounded costae radiating away from beak but not present on ears; faint concentric rugae producing reticulation where crossing costae, continuing across ears to cardinal margin. Shell pseudopunctate.

Discussion: This is a typical Labriproductus brachial valve and, though no pedicle valves have yet been recognized, there seems no doubt about the generic assignment. Dimensions are similar to those of L. wortheni (Hall) and the Alaskan form is provisionally compared with the genotype species. More material may provide data for differentiating the two.

Distribution: Northern Alaska: U.S.G.S. loc. 12793 from Utukok formation; Kaolak limestone in Mississippi Valley.

Material: Figured specimen: U.S.N.M. 118317 (cast of brachial valve), U.S.G.S. loc. 12793.

Genus LINOPRODUCTUS Chao, 1927

Linoproductus ? cf. L. ? belliplicatus (Branson) Dutro

Plate 13, figures 15, 16

1938 Productus belliplicatus Branson, Univ. Missouri Studies, vol. 13, no. 3, pl. 34, pl. 3, figs. 12-14.

Description: No pedicle valves available.

Brachial valve deeply concave becoming flattened on ears, transversely subrectangular, shell wider than long; hinge line straight and less than maximum width. Dimensions of figured specimen: width 18.1 mm., length about 11.0 mm., hinge width about 14.0 mm. Surface with rounded costellae which increase mainly by implantation with some bifurcation; about 3 to 4 costellae per mm.; ears and lateral slopes with broad concentric rugae dying out across medial region. Shell pseudopunctate.

Discussion: This form is much like Branson's species in shape, dimensions and ornamentation. The method of bifurcation and implantation is similar though there are more costellae per millimeter in the Alaskan form.

Distribution: Northern Alaska: U.S.N.M. loc. 3139, Kayak formation; Chouteau limestone, Missouri.

Material: Figured specimen: U.S.N.M. 118319 (exfoliated brachial interior), U.S.N.M. loc. 3139.

Superfamily RHYNCHONELLACEA

Family CAMAROTOECHIIDAE

Subfamily CAMAROTOECHIINAE

Genus CAMAROTOECHIA Hall and Clarke, 1893

Camarotoechia cf. C. chouteauensis Weller

1910 Camarotoechia chouteauensis Weller, Bull. Geol. Soc. Amer., vol. 21, p. 510, fig. 10.

1914 Camarotoechia chouteauensis Weller, Illinois Geol. Survey Mon. 1, p. 176, pl. 24, figs. 34-40.

Description: Shell rhynchonelliform, subtriangular, uniplicate, biconvex, wider than long. Dimensions of figured specimen: 14.0 ± mm. wide, 11.0 ± mm. long, 8.0 ± mm. thick.

Pedicle valve depressed convex; sulcus with about three angular costae separated by rounded furrows; lateral slopes with 7 to 9 angular costae, becoming fainter towards cardinal margins. Internally with strong diverging dental plates extending about one-third length of valve.

Brachial valve strongly convex; low flat fold with about four costae separated by rounded furrows; lateral slopes ornamented as on pedicle valve. Interior with median septum extending about one-fifth length of valve.

Both valves with fine concentric ornamentation, about six filae per mm., and 6 to 8 stronger, irregularly spaced growth lamellae. Shell fibrous and impunctate.

Discussion: Branson (1938, p. 45) indicates that C. tuta (Miller) and C. chouteauensis Weller are conspecific, with a complete gradation of characters between the two. The Alaskan material, composed of the figured specimen and similar ones from the Kayak formation and

nearly one hundred specimens from the Utukok formation, resembles more closely the form described as C. chouteauensis. Of 78 adult or nearly adult shells, 68 have four costae on fold and three in sulcus, 6 have five costae on fold and four in sulcus, 4 have three costae on fold and two in sulcus.

Weller states of C. chouteauensis, "...the plications are sharply angular and originate at the beak, three or four occupy the bottom of the sinus, these being a little less angular than those upon the lateral slopes..." Of C. tuta, Branson writes: "...three or four plications in the sulcus (one-sixth of the specimens have three plications), four or five on the fold (one-fourth of the specimens have four)..." It is clear that the Alaskan form, with nearly nine-tenths of the specimens having four costae on fold and three in sulcus, cannot be C. tuta as described by Branson. This character is a constant one, found in the smallest specimens as well as in the larger ones. Weller figures one specimen with four costae on the fold and one with five; but nothing is stated about the variation of this character in his C. chouteauensis.

The dental plates are stronger in Alaskan specimens than in C. chouteauensis. This feature, along with the apparent stabilization to four costae on the fold, may provide a basis for erecting a new species in future work.

It seems probable that Nalivkin (1937, p. 72, pl. 14, figs. 1-5) has erroneously included specimens similar to the Alaskan ones in his C. rowleyi (Weller). Small shells from Alaskan collections agree in form with Tolmatchoff's Rhynchonella quadriplex (1924, p. 127).

Distribution: Northern Alaska: U.S.N.M. loc. 3246 from Kayak formation, U.S.G.S. loc. 12796 from Utukok formation; Chouteau limestone of Missouri; Kassin beds (Lower Tournaisian) of Kazakhstan (?); Carboniferous of Kousnetzk basin (?).

Material: Described specimen: U.S.N.M. 118293 (specimen with incomplete brachial valve), U.S.N.M. loc. 3246; about 100 specimens from U.S.G.S. loc. 12796.

Genus PARAPHORHYNCHUS Weller 1905

Paraphorhynchus smithi Dutro, n. sp.

Plate 17, figures 11-15

Description: Shell small, rhynchonelliform, convexo-concave, subtriangular; cardinal margin terebratulid; anterior commissure uniplicate. Dimensions of holotype: 9.7 mm. long, 11.0 mm. wide, 8.3 mm. thick, and length/width is 0.88; largest specimen available; 10.6 ± mm. long, 12.8 ± mm. wide, 6.7 ± mm. thick and length/width of 0.83; smallest specimen: 6.0 - mm. long, 7.3 mm. wide, 2.8 mm. thick and length/width of 0.82; average length/width for ten specimens of all sizes: 0.84 ± 0.11; apical angle about 110°.

Pedicle valve slightly convex near beak becoming concave anteriorly with linguiform extension of sulcus; sulcus with two, rarely three, plicae; lateral slopes with two plicae; beak small, slightly incurved. Internally with short diverging dental plates.

Brachial valve flattened near beak, strongly convex anteriorly and laterally; sharp fold with three, rarely four, plicae; lateral slopes with two plicae. Internally with short medium septum and divided hinge plate, attached to septum so as to form small cruralium.

Fine lirae covering entire shell, about 3 to 5 lirae per mm. at anterior margin. Lirae more prominent on flanks of plicae than on crests, though difference may be due to preservation. Fine concentric filae crossing the lirae, producing reticulate pattern where shell material is well preserved. Plicae, usually six to eight in number, obscure near beaks becoming very strong and angular anteriorly. Shell material fibrous and impunctate.

Discussion: This species is smaller than others referred to the genus and may not belong in Paraphorhynchus. Weller's diagnosis lists the following distinguishing generic characters:

1. shell rhynchonelliform; 2. medium size or larger; 3. transversely subovate to subrhomboidal in outline; 4. well-developed fold and sinus; 5. broad, rounded plications on both valves, reaching nearly or quite to the beak; 6. fine radiating striae cover both plications and intervening furrows; internal characters of rostral portion of both valves entirely similar to Camarotoechia.

Though differing somewhat in general outline, P. smithi differs from the above diagnosis mainly in size and in the character of the plicae. P. smithi is small and the plicae are angular anteriorly, becoming obscure near the beaks.

It is interesting that Castor (1930, pp. 21-24) described three species of this genus from the Corry sandstone, basal Mississippian of northwestern Pennsylvania (see also Castor, 1934, pp. 122-124). The genus is known to occur in Kinderhookian formations in Missouri and New Mexico and possibly in the uppermost Devonian of New Mexico. Nalivkin (1937, pp. 78-82) describes several species of Paraphorhynchus from the Fammenian and lower Tournaisian of Kazakhstan.

Distribution: Northern Alaska: U.S.G.S. loc. 12701, Utukok formation.

Material: Holotype: U.S.N.M. 118331 (complete specimen), U.S.G.S. loc. 12701; paratypes from the same collection.

Superfamily TEREBRATULACEA

Family DIELASMATIDAE

Genus DIELASMA King, 1859

Dielasma cf. D. chouteauensis Weller

Plate 14, figure 8

1914 Dielasma chouteauensis Weller, Illinois Geol. Survey Mon. 1, p. 257, pl. 32, figs. 1-17.

1938 Dielasma chouteauensis Weller. Branson, Univ. Missouri Studies, vol. 13, no. 3, p. 55, pl. 5, figs. 28-30.

Description: Shell large, terebratuliform, longitudinally suboval, biconvex. Dimensions of partially reconstructed figured pedicle valve: 32.0 ± mm. long, 19.0 ± mm. wide, 7.2 ± mm. thick.

Pedicle valve evenly convex, nonsulcate, smooth except for 6 to 8 concentric growth lamellae on anterior third of valve. Internally with strong subparallel dental plates and long median ridge. Shell abundantly endopunctate. Brachial valve not observed.

Discussion: In size and general shape, this form is very similar to D. chouteauensis. It cannot definitely be determined as conspecific, however, because complete specimens are not present in Alaskan collections. In addition, the faint radial ornamentation reported by Weller and Branson has not been seen on Alaskan specimens.

Distribution: Northern Alaska: U.S.N.M. locs. 3139, 3246 from Kayak formation; Chouteau limestone of Missouri; Kassin beds (Lower Tournaisian) of Kazakhstan; Lower Carboniferous of Verkhnie-Zyriansk district, eastern Siberia (?); Alberta, Lower Mississippian of Lake Minnewanka region.

Material: Figured specimen: U.S.N.M. 118284 (incomplete pedicle valve), U.S.N.M. loc. 3139.

Superfamily SPIRIFERACEA

Family SPIRIFERIDAE

Subfamily SPIRIFERINAE

Genus SPIRIFER Sowerby, 1814

Spirifer cf. S. gregeri Weller

Plate 15, figures 8, 9

1914 Spirifer gregeri Weller, Illinois Geol. Survey Mon. 1, p. 359, pl. 55, figs. 1-8.

Description: Shell medium to large, spiriferoid, biconvex, subovate, longer than wide; hinge line straight and apparently much shorter than maximum width. Dimensions of figured specimen: 35.0 ± mm. wide, 43.5 ± mm. long, and 8.3 ± mm. thick.

Pedicle valve subovate, evenly convex, beak rather small and curved over short, concave area; sulcus not well defined. Internally with short, subparallel, dental plates; diductor scars narrow and paralleling median ridge which carries adductor scars; diductor scars bounded by dental plates laterally and extending about one-fifth distance to anterior margin. Surface covered with rounded, bifurcating costae, about 8 to 10 per 10 mm. at anterior margin, 10 to 12 occupying sulcus, 25 + on each lateral slope. Shell impunctate.

Brachial valves not present in collections.

Discussion: Only a few fragments of this form are found in collections from the Utukok formation where they occur at about same level as Spirifer cf. S. rowleyi Weller. The shape of pedicle valve seems distinctive and makes the comparison with S. gregeri Weller a reasonable one.

Distribution: Northern Alaska: U.S.G.S. locs. 12706, 12707 from Utukok formation; lower Burlington limestone and Upper Kinderhookian of Mississippi Valley.

Material: Figured specimen: U.S.N.M. 118299 (pedicle exterior), U.S.G.S. loc. 12707; internal characters of beak area also shown.

Spirifer cf. S. grimesi Hall

Plate 15, figures 4-7

1858 Spirifer grimesi Hall, Geol. Iowa, vol. 1, pt. 2, p. 604, pl. 14, figs. 1-5.

1894 Spirifer grimesi Hall. Hall and Clarke, New York Geol. Survey, Paleontology, vol. 8, pt. 2, pl. 31, figs. 8, 16-19.

1914 Spirifer grimesi Hall. Weller, Illinois Geol. Survey Mon. 1, p. 361, pl. 51, figs. 1, 2; pl. 52, figs. 1-4; pl. 53, figs. 1,2.

Description: Shell large, spiriferoid, biconvex, subcircular to subquadrate in outline; hinge line straight and less than maximum width; cardinal extremities rounded. Dimensions of figured specimens: pedicle valve, 73.0 ± mm. wide, 51.0 ± mm. long, 23.0 ± mm. thick; brachial valve, 57.0 ± mm. wide, 44.0 ± mm. long, 12.0 + mm. thick (compressed), 53.5 mm. hinge width; maximum width about one-third distance from beak to anterior margin.

Pedicle valve strongly convex with greatest convexity anterior of umbo, broad poorly defined sulcus about one-third total width anterior of the umbonal region, forming lingual extension at anterior margin; hinge line straight; curved apsaclinal area. Interior not observed.

Brachial valve convex with lateral slopes flattening toward cardinal extremities and lateral margins, broad poorly defined fold not sharply differentiated from lateral slopes. Interior not observed.

Both valves with rounded bifurcating costae over entire surface, about one per mm. at anterior margin, 20 occupying sulcus and approximately 70 on each valve; five or six strong concentric growth lamellae producing crude reticulation on anterior half of valve; where shell material well preserved, each costa with about 8 fine radial lirae. Shell impunctate.

Discussion: These large spiriferids are tentatively referred to S. grimesi Hall though the specimens from northern Alaska do not reach the maximum size indicated by Weller (1914, p. 361). Spirifers of this type occur in Siberia and Kazakhstan and it seems reasonable that they should be present in the Brooks Range.

Distribution: Northern Alaska: U.S.G.S. locs. 11861, 11859, 11860 from Utukok formation; Burlington limestone of Mississippi Valley; St. Joe limestone of Ozark region; Russakov and Ishim beds, Kazakhstan.

Material: Figured specimens: U.S.N.M. 118301 (pedicle exterior), U.S.G.S. loc. 11861; U.S.N.M. 118300 (brachial mold), U.S.G.S. loc. 11859.

Spirifer missouriensis Swallow

Plate 16, figure 11

1860 Spirifer missouriensis Swallow, St. Louis Acad. Sci. Trans., vol. 1, p. 643.

1914 Spirifer missouriensis Swallow. Weller, Illinois Geol. Survey Mon. 1, p. 319, pl. 39, figs. 11-23.

Description: Shell rather small, spiriferoid, biconvex, wider than long with greatest width along hinge line; hinge line straight with alate cardinal extremities. Dimensions of figured pedicle valve: 32.0 ± mm. wide, 15.0 + mm. long, 8.5 mm. thick, 3.1 mm. height of area.

Pedicle valve strongly convex, flattening toward cardinal extremities; apsacline area rather broad, concave and triangular; beak small and not much incurved; sulcus well defined with median costa, and one on either side originating by bifurcation of bounding costae; lateral slopes with 15 to 20 angular costae, the second and third ones away from sulcus often splitting into three near beak, others generally double all the way to margins, bifurcation most common in first 5 or 6 costae on either side of sulcus. Interior not observed.

Brachial valve less convex than pedicle; fold well defined by deeper furrows on either side, two costae bifurcating to give about 8 near anterior margin; lateral slopes with costae as on pedicle valve. Interior not observed. Shell impunctate.

Discussion: The Brooks Range material is very similar to that from the Missouri Kinderhookian. Tendency toward fasciculation is the distinguishing feature and is well-developed in all the specimens. This might be considered a precursor of the Neospirifer stock, related to other Mississippian species like Spirifer mortonanus Miller. In the overlying Lisburne formation a form with very pronounced fasciculation occurs with a Visean assemblage and is identical to specimens figured by Nalivkin (1937, pl. 31, figs. 1-4) and referred to Spirifer mortonanus. This occurrence of Lower Carboniferous fasciculate forms will be studied later in relation to the origin of the neospiriferid stock.

Distribution: Northern Alaska: U.S.N.M. locs. 3137, 3138, 3232 from Kayak formation; Ishim beds of Kazakhstan; Chouteau limestone of Missouri; Alberta, Lower Mississippian of Lake Minnewanka section.

Material: Figured specimen: U.S.N.M. 118286 (pedicle exterior), U.S.N.M. loc. 3137.

Spirifer cf. S. osagensis Swallow

Plate 16, figures 6-8

1860 Spirifer osagensis Swallow, St. Louis Acad. Sci. Trans., vol. 1, p. 641.

1914 Spirifer osagensis Swallow. Weller, Illinois Geol. Survey Mon. 1, p. 314, pl. 37, figs. 18-21.

Description: Shell small, spiriferoid, subtriangular, biconvex, wider than long, greatest width along hinge line; hinge line straight with alate cardinal extremities. Dimensions of figured specimens: pedicle valve, 22.0 ± mm. wide, 13.3 mm. long, 5.2 mm. thick; brachial valve, 23.6 mm. wide, 13.0 mm. long, 5.4 mm. thick.

Pedicle valve evenly convex with posterolateral flattening; narrow beak curved over a narrow subrectangular apsaclinal area, concave under beak and flattening toward extremities; well defined sulcus with two bounding costae normally bifurcating inward twice to produce six costae at anterior margin; about 15 narrow rounded simple costae on each lateral slope, about 6 per 5 mm. at anterior margin. Interior not observed.

Brachial valve evenly convex with flattening and slight upturning near cardinal extremities; beak not prominent; fold with two central costae, each bifurcating once; fold set off from lateral slopes by deep furrows; costae on lateral slopes exactly as on pedicle valve; anterior half of valve with imbricate growth lamellae. Interior not observed. Shell impunctate.

Discussion: This small spiriferid most closely resembles Weller's description of S. osagensis Swallow though other closely allied forms are S. marionensis Shumard and S. centronatus Winchell. It differs from the former in not having a cataclinal, rectangular cardinal area and in having simple lateral costae. S. centronatus has a sulcus with a median costa and two adjacent ones (not counting the bounding costae) or five in all, while this species has six and no median costa. In this respect it also differs from S. osagensis as described by Weller, but resembles that species in general shape, size and in the character of the brachial valve. It may be that this is a new species but the material on hand does not warrant establishing one.

Distribution: Northern Alaska: U.S.N.M. locs. 3095, 3246, 3242, 3142, 3141; Kinderhookian of Missouri.

Material: Figured specimens: U.S.N.M. 118287 (pedicle exterior), U.S.N.M. loc. 3246; U.S.N.M. 118288 (brachial exterior), U.S.N.M. loc. 3095.

Spirifer platynotus Weller

Plate 16, figure 10

1914 Spirifer platynotus Weller, Illinois Geol. Survey Mon. 1, p. 317, pl. 39, figs. 1-10.

Description: Shell rather small, spiriferoid, subtriangular to subelliptical, biconvex, wider than long with greatest width at hinge line; hinge line straight; cardinal extremities angular to slate. Dimensions of figured pedicle valve: 33.0 ± mm. wide, 20.5 mm. long, 7.5 mm. thick.

Pedicle valve evenly convex, uniformly convex lateral slopes with some flattening toward cardinal extremities; beak small and incurved; area triangular, concave, apsaclinal; sulcus not well defined, with median costa and bounding costae bifurcating once, occasionally twice, inwardly; lateral slopes with 20 + broad, rounded costae seperated by narrower rounded furrows, costae narrower and fainter towards cardinal extremities; about 6 to 8 concentric growth lamellae on most shells. Interior not observed.

Brachial valve less convex than pedicle; fold not well defined, with two costae each bifurcating once; lateral slopes with about 20 broad rounded costae as on pedicle valve; costae on either side of fold tending to bifurcate but the rest simple. Interior not observed. Shell impunctate.

Discussion: This species resembles S. osagensis Swallow but has more lateral costae becoming faint towards cardinal extremities. S. platynotus is also somewhat larger and more subelliptical in shape. Specimens referred to this species range through the upper Kayak formation but are especially common in the argillaceous limestone member.

Distribution: Northern Alaska: U.S.N.M. locs. 3250, 3242, 3142, 3246, 3232 from Kayak formation; Kinderhookian of Missouri and Iowa; Upper Devonian of Kazahkstan ? (Nalivkin's figured forms may not be true S. platynotus).

Material: Figured specimen: U.S.N.M. 118292 (pedicle exterior), U.S.N.M. loc. 3242.

Spirifer cf. S. rowleyi Weller

Plate 15, figures 1-3

1914 Spirifer rowleyi Weller, Illinois Geol. Survey Mon. 1, p. 360, pl. 53, figs. 3-6; pl. 54, figs. 1-4.

Description: Shell medium to large, spiriferoid, biconvex, transversely subelliptical, wider than long; hinge line straight and shorter than maximum width; cardinal extremities angular. Dimensions of figured pedicle valve: width 50.0 ± mm., length 34.8 mm., thickness 13.0 mm.

Pedicle valve strongly convex, greatest thickness near umbo, lateral slopes abruptly convex with flattening posterolaterally, sulcus well defined and rather angular, beak narrower than in S. grimesi Hall and curving over a concave apsaclinal area, area nearly as wide as greatest shell width. Internally with strong dental plates, musculature not observed.

Brachial valves not present in collections.

Ornamentation consisting of rounded, bifurcating costae, about one per mm. at anterior border, approximately 15 to 20 in sulcus and 25 to 30 on each lateral slope; fine radial lirae, about 10 per costa, seen where shell material is well-preserved. Shell impunctate.

Discussion: This form occurs along with Spirifer cf. S. grimesi Hall in collections from the Utukok formation and can be differentiated by its more transverse shape, longer hinge line, smaller beak and well defined sulcus. The ornamentation is similar in both species. In most respects it is quite similar to Spirifer rowleyi as defined by Weller, though a little smaller. The lirae are about the same number as in S. cf. S. grimesi and not more numerous as Weller indicates for S. rowleyi. More material, expecially some brachial valves, might result in a precise comparison.

Distribution: Northern Alaska: U.S.G.S. locs. 11858, 12793, 11860, 11861 and 12713 from Utukok formation; Fern Glen formation and lower Burlington limestone from Mississippi Valley.

Material: Figured specimen: U.S.N.M. 118302 (pedicle exterior), U.S.G.S. loc. 11860.

Spirifer striatiformis Meek

Plate 16, figure 14

1875 Spirifer (Trigonotreta) striatiformis Meek, Paleontology Ohio, vol. 2, p. 269, pl. 14, figs. 8a-e.

1914 Spirifer striatiformis Meek. Weller, Illinois Geol. Survey Mon. 1, p. 364, pl. 48, figs. 17-21.

Description: Shell of medium size, spiriferoid, transversely subelliptical, biconvex, wider than long; hinge line straight with hinge width nearly equal to maximum width; cardinal extremities angular, lateral margins making nearly right angle with hinge line. Dimensions of figured pedicle valve: 54.0 ± mm. wide, 30.0 ± mm. long, 14.0 ± mm. thick.

Pedicle valve strongly convex with greatest thickness at umbo; lateral slopes abrupt with pronounced flattening in posterolateral region; beak small, incurved over rather high, triangular, apsacline area; sulcus well defined, deep angular sides with about 5 narrow, rounded costae near anterior margin, originating by bifurcation of bounding costae; median costa originates near beak and continues unmodified to anterior margin; lateral slopes with 20 to 25 narrow, rounded costae decreasing in strength toward cardinal extremities; costae tending to bifurcate close to beak and separated by narrow furrows. Very fine radial lirae on costae and in furrows but generally difficult to observe because of shell exfoliation. Interior not observed. Brachial valves absent from collections. Shell impunctate.

Discussion: Size, proportions, character of sulcus and ornamentation are similar to the description of Weller. There seems little doubt as to the identification of the Alaskan forms with S. striatiformis Meek.

Distribution: Northern Alaska, U.S.N.M. locs. 3137 from β fauna zone of Kayak formation; Chouteau limestone of Missouri; Waverly group of Ohio; Alberta, lower Mississippian, Lake Minnewanka section.

Material: Figured specimen: U.S.N.M. 116291 (pedicle exterior), U.S.N.M. loc. 3137.

Genus IMBREXIA Nalivkin, 1937

? Imbrexia forbesi (Norwood and Pratten) Nalivkin

Plate 16, figures 1-3

1855 Spirifer forbesi Norwood and Pratten, Acad. Nat. Sci. Philadelphia Jour., (2), vol. 2, p. 73, pl. 9, figs. 3a-c.

1858 Spirifer forbesi Norwood and Pratten. Hall, Geol. Iowa, vol. 1, pt. 2, p. 600, pl. 13, fig. 1.

1914 Spirifer forbesi Norwood and Pratten. Weller, Illinois Geol. Survey Mon. 1, p. 331, pl. 42, figs. 1-3; pl. 43, fig. 16; pl. 83, figs. 1, 2.

1937 Spirifer (Imbrexia) forbesi Norwood and Pratten. Nalivkin, Centr. Geol. and Prosp. Inst. Trans., fasc. 99, p. 106, pl. 30, fig. 5.

Description: Shell transversely spiriferoid, biconvex, wider than long with greatest width along hinge line; mucronate cardinal extremities. Dimensions of figured specimen: width 56.0 mm., length 19.7 mm., thickness 13.4 mm., height of area 2.4 mm.; other specimens as large as 86 mm. wide and 22.5 mm. long.

Pedicle valve convex with well defined angular sulcus and evenly convex lateral slopes; area high, flat, subrectangular, apsaclinal, with large open delthyrium; sulcus with median costa and two bounding costae near beak, these costae bifurcating inward twice so that normal number of costae in sulcus at anterior margin is seven; lateral slopes each with about 20 simple rounded costae; costae in sulcus slightly larger than those on slopes. Internally with thick widely diverging dental plates; musculature not observed.

Brachial valve evenly convex; area narrow, orthoclinal; beak small; fold rather flat with two costae normally bifurcating once to give four costae on fold at anterior margin; costae on fold slightly larger than costae on lateral slopes, fold otherwise not sharply differentiated. Internal characters not observed.

Most specimens from the Brooks Range more or less exfoliated, a few showing the concentric imbricate lamellae which distinguish the genus.

Discussion: Nalivkin (1937, p. 105) established Imbrexia as a subgenus with Spirifer imbrex Hall as genotype and assigned to it Spirifer forbesi Norwood and Pratten. It is here considered of generic rank, as other spiriferoid subgenera of the same paper have been so considered by Cooper (in Shimer and Shrock, 1944). The general shape, mucronate hinge line, shape of area, imbricate ornamentation and widely divergent dental plates seem to constitute good generic characters.

The Alaska form compares closely with the original description of Norwood and Pratten and the subsequent discussion of Weller. Better preserved material should show the imbricate lamellae to better advantage. Because imbricate lamellae are not well shown, the generic assignment is indicated as questionable.

Distribution: Northern Alaska: U.S.G.S. locs. 12709, 12710, 11861, 11859, 12793, Utukok formation; Burlington limestone of Mississippi Valley; Ishim beds of Kazakhstan; Madison limestone (?) in Cordilleran region.

Material: Figured specimen: U.S.N.M. 118303 (nearly complete exfoliated specimen), U.S.G.S. loc. 12793.

Genus BRACHYTHYRIS McCoy, 1844

Brachythyris aff. B. choutcauensis Weller

Plate 16, figures 4, 5, 9

1914 Brachythyris choutcauensis Weller, Illinois Geol. Survey Mon. 1, p. 373, pl. 57, figs. 4-11.

Description: Shell small, suborbicular, biconvex, about as wide as long; submegathyrid cardinal margin; hinge line about one-half greatest width; cardinal extremities rounded. Dimensions of figured pedicle valves; 18.0 ± mm. wide, 19.8 mm. long, 5.4 mm. thick, 10.0 ± hinge width; 17.4 mm. wide, 16.2 mm. long, 4.0 ± mm. thick.

Pedicle valve depressed convex; small narrow beak incurved over small triangular area; sulcus sharply defined, narrow, deep; one or two flat, rounded indistinct costae on flanks of sulcus; lateral slopes with about 10 broad, flat, rounded costae separated by narrow furrows; costae about one mm. wide at anterior margin. Interior not observed. Shell impunctate.

Brachial valves not present in collections.

Discussion: There is not enough material from Alaskan collections for a more precise description but it seems probable that, although related to B. choutcauensis, this form is a new one. In the latter there are about 3 to 4 costae per 5 mm., considerably coarser ornamentation than that present in the Alaska form. In addition, B. choutcauensis tends to be wider than long with hinge width about two-thirds maximum width; the Alaskan form is more equidimensional and has hinge width about one-half maximum width. If more material showing internal features and brachial valves becomes available this might well prove to be a new species.

Distribution: Northern Alaska; U.S.N.M. locs. 3232, 3142 from Kayak Formation; Kinderhookian of Missouri.

Material: Figured specimens: U.S.N.M. 118279 (complete pedicle valve), U.S.N.M. loc. 3142; U.S.N.M. 118280 (partial pedicle valve), U.S.N.M. loc. 3232.

Subfamily RETICULARIINAE

Genus TORYNIFER Hall and Clarke, 1895

Torynifer cf. T. cooperensis (Swallow) Dutro

Plate 16, figure 13

1860 Spirifer cooperensis Swallow, St. Louis Acad. Sci. Trans., vol. 1, p. 643.

1899 Reticularia cooperensis (Swallow). Girty, U. S. Geol. Survey Mon. 32, p. 555, pl. 70, figs. 9a-c.

1914 Reticularia cooperensis (Swallow). Weller, Illinois Geol. Survey Mon. 1, p. 428, pl. 75, figs. 21-33.

1938 Reticularia cooperensis (Swallow). Branson, Missouri Univ. Studies, vol. 13, no. 3, p. 69, pl. 9, figs. 9, 10; p. 175, pl. 19, figs. 28, 29; vol. 13, no. 4, p. 26.

Description: Shell small, biconvex, transversely subelliptical, wider than long; cardinal extremities rounded; hinge width much less than maximum width, anterior commissure nearly rectimarginate. Dimensions of figured pedicle valve: 10.4 ± mm. wide, 7.7 mm. long, 3.2 mm. thick.

Pedicle valve strongly convex, greatest convexity at umbo, beak small and incurved, ill defined narrow sulcus becoming obscure anteriorly. Internally with strong diverging dental plates and median septum. Concentric lamellae on outside of valve not well preserved due to exfoliation of shell material; nature of spines not known for same reason. Shell impunctate.

No brachial valves in collections.

Discussion: In general appearance this form closely resembles T. cooperensis (Swallow) as described by Weller and Branson. It is smaller than specimens from both the Chouteau limestone and Northview shale; and Branson remarks that specimens from the latter formation tend to be smaller than those from the former. If more material were available this size difference might prove to be sufficient justification for establishing a new species.

The assignment of T. cooperensis to the genus Torynifer seems a sound one, Weller having noted how closely it is allied to T. pseudolineatus (Hall), the genotype species. The only point in question is the nature of the spines, which in Torynifer are double-barreled. Girty, Weller and Branson place the species in Reticularia but since that genus, as defined by George (1932, p. 524), probably has single-barreled spines and a strongly uniplicate shell form, the earlier generic assignment was probably incorrect.

Distribution: Northern Alaska: U.S.G.S. loc. 12709 from Utukok formation; Kinderhookian of Missouri and Iowa; St. Joe formation of Arkansas; Madison formation of Cordilleran region.

Material: Figured specimen: U.S.N.M. 118290 (pedicle exterior), U.S.G.S. loc. 12709.

Subfamily MARTINIINAE

Genus AMBOCOELIA Hall, 1860

Ambocoelia parva Weller

Plate 17, figures 1-5

1899 Ambocoelia parva Weller, Acad. Sci. St. Louis Trans., vol. 9, p. 20, pl. 4, figs. 1-4.

1914 Ambocoelia parva Weller. Weller, Illinois Geol. Survey Mon. 1, p. 424, pl. 77, figs. 32-35.

1938 Ambocoelia parva Weller. Branson, Missouri Univ. Studies, vol. 13, no. 3, p. 69, pl. 9, figs. 25-27; vol. 13, no. 4, p. 25, pl. 22, figs. 27-30.

Description: Shell small, planoconvex to unequally biconvex, subcircular to transversely subelliptical, about as wide as long in most specimens; hinge line straight, less than maximum width; cardinal extremities rounded; anterior commissure rectimarginate. Dimensions of large figured specimen: 6.6 mm. long, 6.6 mm. wide, 5.0 hinge width, 4.3 mm. thick; medium sized specimen: 5.0 mm. long, 5.5 mm. wide, 4.0 hinge width, 3.4 mm. thick; small specimen: 4.3 mm. long, 4.3 mm. wide, 3.5 hinge width, 2.7 mm. thick.

Pedicle valve gibbous, greatest convexity posterior of midlength; sulcus narrow, becoming obscure near anterior margin; area triangular, curved, apsaclinal; delthyrium open, rather large. Internally without dental plates.

Brachial valve depressed convex, subelliptical; beak small; poorly defined sulcus extending from beak to anterior margin in most specimens; area narrow, anaclinal; notothyrium broadly triangular.

Surface smooth, in some specimens concentric growth lamellae present near anterior margin. Shell fibrous and impunctate.

Discussion: I agree with Branson (1938, p. 25) that A. parva Weller may be identical with A. levicula Rowley. Specimens from Alaskan material range in shape from nearly subcircular to transversely elliptical, and the sulcus on pedicle valve varies considerably in strength. If the two species from Missouri should prove identical,

A. parva has priority because of earlier publication date. All the specimens upon which this description is based come from the same collection of Alaskan material. Because of the state of preservation, no details of musculature of the brachial valve could be observed. On most specimens the shell material has spalled off but in a few places enough remains to make it probable that the surface was originally smooth and not spinose.

Distribution: Northern Alaska: U.S.G.S. loc. 12796, Utukok formation; Northview siltstone and Chouteau limestone of Missouri.

Material: Figured specimen: U.S.N.M. 118332 (complete specimen), U.S.G.S. loc. 12796.

Superfamily PUNCTOSPIRACEA

Family SPIRIFERINIDAE

Subfamily SPIRIFERININAE

Genus PUNCTOSPIRIFER North, 1920

Punctospirifer ? solidirostris (White)

Plate 14, figures 10-13

1860 Spirifer solidirostris White, Boston Soc. Nat. History Jour., vol. 7, p. 232.

1862 Spiriferina solidirostris (White). White, Boston Soc. Nat. History Proc., vol. 9, p. 24.

1899 Spiriferina solidirostris (White). Girty, U. S. Geol. Survey Mon. 32, pt. 2, p. 545, pl. 71, fig. 10a.

1914 Spiriferina solidirostris (White). Weller, Illinois Geol. Survey Mon. 1, p. 292, pl. 36, figs. 25-34.

1938 Spiriferina solidirostris (White). Branson, Missouri Univ. Studies, vol. 13, no. 3, pt. 1, p. 57, pl. 6, figs. 27, 28.

Description: Shell spiriferoid, biconvex, wider than long with greatest width at or near hinge line; cardinal extremities rounded to angular; anterior commissure sulciplicate. Dimensions of figured specimens: pedicle valve, 18.4 mm. wide, 13.4 mm. long, 5.5 mm. thick; brachial valve, 20.2 mm. wide, 12.0 mm. long, 4.0 mm. thick.

Pedicle valve strongly convex with prominent umbo and beak curved over a triangular, concave, apsaclinal area; triangular, open delthyrium; deep sulcus marked by angular sides and strong angular median costa, lateral slopes with about eight simple angular costae. Internally with short, stout dental plates and median septum which extends nearly half way to anterior margin, muscle scars not observed.

Brachial valve evenly convex with nearly flat, narrow orthoclinal area; prominent fold divided into two costae by pronounced angular furrow; about eight simple angular costae on each lateral slope.

Costae crossed by concentric lamellose imbrications, less well developed posteriorly. Shell abundantly punctate.

Discussion: This species is quite distinct and the Alaskan form closely resembles that from the Madison formation and from the Kinderhookian of Missouri. Size variation in Alaskan specimens is similar to that in other U. S. Geological Survey collections. I am confident that all belong to a single species but the generic assignment is doubtful. The punctate shell, shape and internal characters would indicate Punctospirifer without question but it is sulciplicate rather than uniplicate as indicated by North (1920, p. 212). This species consistently has been referred to Spiriferina in the literature but it does not belong in that genus for reasons given by North when establishing Punctospirifer. North stated (1920, p. 209):

"The essential characters of Spiriferina, as portrayed by the Liassic species, may be summarized as follows: Hinge-line not greater than the diameter of the shell; cardinal extremities rounded; area moderately low and curved; distinct incurved beak; few angular costae; angular fold and sinus not sharply differentiated from the costae; well-developed ventral median septum; coarsely-punctate shell structure.

"The possession of the two last-named characters is not alone sufficient to justify the reference of a shell to Spiriferina."

There is abundant material from several places in North America and the sulciplicate character is a consistent one. It may be advisable, in the future, to establish a new genus for this form but to erect a monotypic genus at this time seems inadvisable.

Distribution: Northern Alaska: U.S.G.S. locs. 11858, 11859, 11860, 11862, 12712, 12709 (?) from Utukok formation; Madison formation in Cordilleran region; Kinderhookian of Missouri and Iowa.

Material: Figured specimens: U.S.N.M. 118304 (pedicle exterior), U.S.G.S. loc. 11858; U.S.N.M. 118305 (brachial exterior), U.S.G.S. loc. 11858.

Punctospirifer cf. P. northviewensis (Branson)

Plate 14, figure 9

1938 Spiriferina northviewensis Branson, Missouri Univ. Studies, vol. 13, no. 4, p. 27, pl. 22, figs. 16-19.

Description: Shell small, spiriferoid, biconvex, uniplicate, transversely subelliptical; hinge line straight, less than maximum width. Pedicle valve depressed convex; small, narrow beak but slightly incurved; broad, angular, noncostate sulcus 5.0 mm. wide at anterior margin; lateral slopes with seven angular costae. Internally with dental plates and median septum. Shell abundantly endopunctate.

Brachial valves absent from collections.

Discussion: This species from the Kayak formation is easily distinguished from Punctospirifer ? solidirostris (White) by its noncostate fold and sulcus and smaller size. The Alaskan form is quite like that figured by Branson except in its lesser convexity. This may be due to preservation, however, since the figured valve appears somewhat flattened.

Distribution: Northern Alaska: U.S.N.M. locs. 3246, 3141 from Kayak formation; Northview formation of Missouri.

Material: Figured specimen: U.S.N.M. 118285 (exfoliated pedicle valve), U.S.N.M. loc. 3246.

Family SYRINGOTHYRIDAE

Genus SYRINGOTHYRIS Winchell, 1863

Syringothyris halli Winchell

Plate 14, figures 14-16

1863 Syringothyris halli Winchell, Acad. Nat. Sci. Philadelphia Proc., p. 8.

1914 Syringothyris halli Winchell. Weller, Illinois Geol. Survey Mon. 1, p. 390, pl. 72, figs. 13-23.

Description: Shell small, spiriferoid, biconvex, wider than long with maximum width along hinge line; uniplicate; megathyrid cardinal margin; cardinal extremities alate. Dimensions of figured specimens: pedicle interior 14.5 mm. wide, 9.0 ± mm. long; partial brachial exterior 26.0 ± mm. wide, 14.3 ± mm. long; partial pedicle exterior 22.0 + mm. wide, 14.4 ± mm. long.

Pedicle valve evenly convex, subpyramidal; sulcus well-defined, angular, smooth; lateral slopes with broad, flat costae, about one mm. wide at anterior margin; area high, triangular, cataclinal. Internally with strong diverging dental plates; apical plate extending about one-half distance from apex to hinge line, below the level of the area; syrinx attached to underside of apical plate.

Brachial valve depressed convex; fold noncostate, broad, rounded; lateral slopes with 12 + broad costae as on pedicle valve. Internal characters not observed. Surface of both valves pustulose, shell endopunctate.

Discussion: This small syringothyrid is almost certainly conspecific with S. halli Winchell though the Alaskan form is longer in relation to width than is S. halli. This difference may be more apparent than real because no specimens with cardinal extremities completely preserved have been found and widths have been estimated.

Distribution: Northern Alaska, U.S.N.M. locs. 3139, 3239 from Kayak formation; Kinderhookian of Mississippi Valley.

Material: Figured specimens: U.S.N.M. 118281 (pedicle interior), U.S.N.M. loc. 3239; U.S.N.M. 118282 (partial pedicle exterior), U.S.N.M. loc. 3139; U.S.N.M. 118283 (partial brachial exterior), U.S.N.M. loc. 3139.

Superfamily ROSTROSPIRACEA

Family ATHYRIDAE

Genus CLEIOTHYRADINA Buckman 1906

Cleiothyradina glenparkensis Weller

Plate 17, figures 6-10

1914 Cleiothyradina glenparkensis Weller, Illinois Geol. Survey Mon. 1, p. 473, pl. 78, figs. 21-24.

Description: Shell subequally biconvex, outline transversely elliptical, slightly wider than long; anterior commissure rectimarginate; cardinal margin terebratulid. Figured specimen about 15.0 mm. wide, 13.7 mm. long and 7.5 mm. thick.

Pedicle valve evenly convex; beak small, rostrate; foramen circular, epithyrid. Brachial valve about as strongly convex as pedicle; beak small and covering delthyrium of pedicle valve.

Surface of both valves lamellose, lamellae with long spines, forming fringe at anterior and lateral margins. Shell impunctate.

Discussion: A single specimen of this species has been collected from the Kayak formation. Since nothing is known of its interior, there is a possibility that the identification is erroneous. In general shape and external ornamentation, however, the Alaskan form resembles G. glenparkensis Weller very closely.

Distribution: Northern Alaska: U.S.N.M. loc. 3237, Kayak formation; Fern Glen formation of Missouri.

Material: Figured specimen: U.S.N.M. 118333 (complete specimen), U.S.N.M. loc. 3237.

Genus COMPOSITA Brown, 1849

Composita humilis (Girty)

Plate 17, figures 17-20

1899 Semimula humilis Girty, U. S. Geol. Survey Mon. 32, part 2, p. 565, pl. 71, figs. 6a-c.

1927 Composita humilis (Girty). Girty, U. S. Geol. Survey Prof. Paper 152, pl. 22, figs. 38, 39.

Description: Shell terebratuliform, subcircular, biconvex, greatest width about at midlength; cardinal margin terebratulid; anterior commissure rectimarginate or slightly sinuate. Dimensions of four specimens from Alaska collections: 13.5 ± 3.1 mm. long, 13.5 ± 2.6 mm. wide, 8.7 ± 3.3 mm. thick.

Pedicle valve evenly convex, rostrate; foramen circular; beak rather large and incurved; slight sulcation near anterior margin. Interior with dental plates about one-quarter length of valve; diductor scars elongate, subparallel, completely surrounding subelliptical adductor scars; low median ridge extending from delthyrial cavity to anterior border of muscle field.

Brachial valve nearly circular in outline, more convex than pedicle valve; beak small; slight fold near anterior margin. Interior with subovate muscle field divided by low median ridge extending about one-fifth length of valve; details of musculature unknown.

Shell smooth, concentric growth lamellae becoming crowded near anterior border. Shell impunctate.

Discussion: Girty's type specimens from the Gallatin Range are about as long as wide and fall well within the range of variation shown by the Alaskan forms. Measurements of the two type specimens; 14.6 mm. long, 14.4 mm. wide, 9.0 mm. thick; 12.2 mm. long, 12.0 mm. wide, 7.4 mm. thick. Figured specimens from the Henry quadrangle, Idaho:

15.7 mm. long, 14.5 mm. wide, 10.3 mm. thick; 12.6 mm. long, 13.1 mm. wide, 8.5 mm. thick. An unfigured specimen from the same lot: 12.3 mm. long, 11.9 mm. wide, 8.7 mm. thick (somewhat distorted). The largest of these last specimens has a more pronounced sulcus in the pedicle valve and is much like C. humilis var. A, described below.

Distribution: Northern Alaska: U.S.G.S. locs. 11861, 11867, 11858 (?), 12709 (?), Utukok formation; Cordilleran region, Madison formation (Lodge Pole equivalents); Alberta, Lower Mississippian, Lake Minnewanka region.

Material: Figured specimen: U.S.N.M. 118334 (nearly complete exfoliated specimen), U.S.G.S. loc. 11867.

Composita humilis var. A.

Plate 17, figure 16

Description: Shell terebratuliform, subpentagonal, biconvex; greatest width slightly posterior of midlength; anterior commissure uniplicate; figured pedicle valve is 13.7 mm. long, 13.1 mm. wide and 4.5 mm. thick. Pedicle valve subpentagonal; sulcus well-defined anteriorly from umbonal region; valve evenly convex with flattening across umbonal region; beak rather large and incurved. Interior as in C. humilis. Brachial valves absent from collections.

Surface smooth; shell impunctate.

Discussion: This variety is about the same size as C. humilis (Girty) but differs in shape and degree of sulcation. Girty figured a specimen from Idaho (1927, plate 22, fig. 39) which approaches this one, and included it in C. humilis. In general shape and sulcation this variety is similar to the larger C. madisonensis (Girty) which, however, occurs quite high in the Madison formation. Since this sulcate form occurs in about the same stratigraphic position as C. humilis, I think it best to call it a variety of that species. More material from other sections in the region might warrant erecting a new species.

Distribution: Northern Alaska: U.S.G.S. loc. 12793, Utukok formation.

Material: Figured specimen: U.S.N.M. 118335 (pedicle mold), U.S.G.S. loc. 12793.

Phylum MOLLUSCA

Class PELECYPODA

Genus EDMONDIA de Koninck, 1841

Edmondia burlingtonensis White and Whitfield

Plate 18, figure 1

1862 Edmondia burlingtonensis White and Whitfield, Boston Soc. Nat. Hist. Proc. vol. 8, p. 301.

1885 Edmondia burlingtonensis White and Whitfield. Hall, Paleontology New York, vol. 5, part 1, p. 390, pl. 64, fig. 22; pl. 95, figs. 13, 14.

1938 Edmondia burlingtonensis White and Whitfield. Branson, Missouri Univ. Studies, vol. 13, no. 4, p. 35, pl. 23, figs. 8, 9.

Description: Shell subovate to subelliptical, length greater than height; hinge line straight, extending anteriorly beyond beaks; beaks one-fourth distance from anterior end of shell; valves evenly convex, flexing sharply to anterior extremity of hinge line. Ornamentation consisting of fine, concentric, angular growth lines, irregularly bifurcating and anastomosing. Dimensions of figured specimen: 31.0 mm. long, 20.0 mm. high, about 9 mm. thick; hinge line extending about 4 mm. anteriorly beyond beaks; height/length = 0.65.

Discussion: The specimen illustrated resembles most closely E. burlingtonensis, though some doubt exists as to the validity of this species. Branson in one place states that E. burlingtonensis is synonymous with E. marionensis Swallow (1938, part 1, p. 87), yet further on in the same work he describes E. burlingtonensis separately and lists the two species in the faunal summary, (1938, part 2, pp. 35 and 185). They are certainly similar forms, though the specimens figured as E. burlingtonensis are more elongate than those illustrated as E. marionensis. The height/length ratio of the neotype of E. marionensis, figured by Branson, is 0.77; that of E. burlingtonensis figured by Branson, 0.59; E. burlingtonensis described and figured by Hall: 0.67 and 0.68. It seems that two species are represented and that E. burlingtonensis has a consistently different form. Indeed, if we consider the work of Branson chronologically, his later opinion seems to have been that these are two distinct species.

Distribution: Northern Alaska: U.S.G.S. loc. 12793, Utukok formation; Northview siltstone of Missouri; Kinderhookian at Burlington, Iowa.

Material: Figured specimen: U.S.N.M. 118336 (cast of external mold), U.S.G.S. loc. 12793.

Genus CONOCARDIUM Bronn, 1835

Conocardium sp.

Plate 18, figure 2

Description: Shell subtriangular, anterior short, flattened; strong umbonal ridge extending nearly vertically from beak downward; posterior gently convex, in wing-like extension; strong radial ribs crossed by two concentric growth lamellae; six ribs on umbonal ridge. Height about 10.0 mm., length about 12.0 mm. for figured specimen.

Discussion: Specimens of this genus are rare in lower Mississippian rocks and this is the only one present in Alaskan material. No specific identification is attempted on the basis of this single fragmentary specimen.

Distribution: Northern Alaska: U.S.N.M. loc. 3237, Kayak formation.

Material: Figured specimen: U.S.N.M. 118337 (partial left valve), U.S.N.M. loc. 3237.

Class GASTROPODA

Genus NATICOPSIS McCoy, 1844

Naticopsis sp.

Plate 18, figure 3

Description: Shell naticiform; body whorl large; sutures channeled; aperture large, subelliptical, with nearly straight outer lip; umbilicus lacking; ornamentation consisting of fine growth lines only. Height of shell (partially reconstructed) about 37 mm., height of body whorl about 29 mm., aperture about 34 mm. long and 20 mm. wide; apical angle about 100°.

Discussion: This large specimen is unique in Alaskan collections and is unlike other species of this genus described from Lower Mississippian rocks. Since the specimen is incomplete, no new specific name will be proposed.

Distribution: Northern Alaska: U.S.G.S. loc. 12709, Utukok formation.

Material: Figured specimen: U.S.N.M. 118338, U.S.G.S. loc. 12709.

Genus STRAPAROLUS Montfort, 1810

Straparolus blairi Miller

Plate 18, figure 5

1891 Straparolus blairi Miller, Adv. Sheets 17th Rept. Geol. Survey Indiana, pp. 86, 87, pl. 15, fig. 3.

1938 Straparolus blairi Miller. Branson, Missouri Univ. Studies, vol. 13, no. 3, p. 105, pl. 14, figs. 20, 28, 29.

Description: Shell large, discoidal consisting of two whorls in addition to body whorl; whorls in contact, rounded; umbilicus wide; aperture simple, subcircular. Approximate diameter of illustrated specimen 40 mm., body whorl about 10 mm. in diameter.

Discussion: Two partial specimens from Alaska are somewhat smaller than the cotype figured by Miller and Branson, but are similar in shape and size to the other specimen figured by Branson (1938, pl. 14, figs. 28, 29). S. blairi is Straparolus in the strict sense because its rounded whorls are in contact (see Shimer and Shrock, 1944, p. 463).

Distribution: Northern Alaska: U.S.N.M. loc. 3137, Kayak formation; U.S.G.S. loc. 11861, Utukok formation; Chouteau limestone of Missouri.

Material: Figured specimen: U.S.N.M. 118339 from U.S.G.S. loc. 11861.

Genus EUOMPHALUS Sowerby, 1814

Euomphalus sp.

Description: Shell large, discoidal, at least three whorls in addition to body whorl; whorls in contact; shoulder well-marked, angular. Diameter of described specimen about 35 mm., width of body whorl about 10 mm.

Discussion: A single mold is present among Alaskan collections so far examined. Because apertural and ornamentation details are not preserved, it would be unwise to attempt specific identification.

Distribution: Northern Alaska: U.S.G.S. loc. 11858, Utukok formation.

Material: Described specimen from above locality, U.S.N.M. 118340.

Genus PLATYCERAS Conrad, 1840

Platyceras nasutum Miller

Plate 18, figure 8

1891 Platyceras nasutum Miller, Adv. Sheets 17th Rept. Indiana Geol. Survey, pp. 82-83, pl. 14, figs. 17-18.

1938 Platyceras nasutum Miller. Branson, Missouri Univ. Studies, vol. 13, no. 3, p. 109, pl. 14, figs. 15-18.

Description: Shell small, subconical, highly arched with ridge extending from apex to base on convex side; apex incurved, slender; aperture subovate. Figured specimen 9.5 mm. high, aperture with diameters of 9.0 mm. anteroposteriorly and 8.0 mm. laterally. Two other specimens about 14.0 mm. and 11.0 mm. high, respectively; aperture of largest 18.0 mm. by 16.0 mm., longer direction anterior-posteriorly. Fine growth lines paralleling aperture are only ornamentation.

Discussion: This platycerid is fairly common in the Kayak formation and seems conspecific with P. nasutum Miller. It uncoils rapidly after first whorl or so and approaches some species of Orthonychia wherein the whorls are free and uncoiled in all growth stages.

Distribution: Northern Alaska: U.S.N.M. loc. 3095, Kayak formation; Chouteau limestone and Northview formation of Missouri.

Material: Figured specimen: U.S.N.M. 118341 from U.S.N.M. loc. 3095.

Platyceras sp.

Description: Shell subconical, horn-shaped; margin fluted, very irregular; diameter about 30 mm. at base; nature of external ornamentation or early whorls unknown.

Discussion: This platycerid shell is preserved base up in a rock layer composed mainly of bryozoan and echinoderm debris. Inside the apex of the conical shell are concentrated several crinoidal plates. It seems likely that this specimen was attached to the oral surface of a crinoid during growth, the fluted margin conforming with the irregularities of the crinoid. Since the early whorls are not exposed, it is impossible to determine whether this is Platyceras sensu stricto or Orthonychia.

Distribution: Northern Alaska: U.S.N.M. loc. 3242, Kayak formation.

Material: Described specimen: U.S.N.M. 118342.

Class CEPHALOPODA

Genus MOOREOCERAS Miller, Dunbar and Condra, 1933

Moореoceras ? sp.

Plate 18, figures 4, 6

Description: Conch orthoceraconic, transversely subelliptical, smooth; septa simple, convex apically; sutures slightly sinuous; siphuncle small and near central edge. Dimensions near body chamber: first specimen, diameters 18.3 mm. and 16.4 mm., 4 chambers in 10-12 mm.; second specimen, 18.2 mm. and 16.9 mm., 4 chambers in 16 mm. Siphuncle 1.2 mm. in diameter and about 2 mm. from edge of septum in second specimen.

Discussion: Two specimens from the Utukok formation are referred to Moореoceras but insufficient detail prevents the establishing of a new species at this time.

Distribution: Northern Alaska: U.S.G.S. loc. 11862, Utukok formation.

Material: Figured specimens: U.S.N.M. 118343, U.S.G.S. loc. 11862.

Phylum TRILOBITA

Family PROETIDAE

Genus PHILLIPSIA Portlock, 1843

Phillipsia sp.

Plate 18, figure 7

Description: Glabella subcylindrical, tapering toward front margin, reaching nearly to front border, evenly convex in lateral profile, more strongly convex in anterior profile; border upturned; glabellar furrows not deeply incised; glabellar lobes subtriangular and set apart from rest of glabella; occipital furrow sinuous; occipital ring broad; posterior limbs narrow; eyes not present on specimens but by position of facial suture they seem to have been rather small and lay just antero-laterally of glabellar lobe. Dimensions of described specimen: length of cranidium, 15.0 mm.; width of cranidium at front border, 13.6 ± mm.; length of glabella, 11.0 mm.; width of glabella, 8.5 mm.; length of occipital ring at midline, 3.2 mm.; width of posterior limb, 4.0 ± mm.

Ornamentation consisting of large pustules on glabella, widely spaced, located on high areas between glabellar furrows, exfoliation of specimen making it impossible to ascertain the overall distribution of pustules.

Discussion: Because only a few fragments of this trilobite have been found in Alaskan collections, it is not considered advisable to name a new species, though it is probably new.

Distribution: Northern Alaska: U.S.N.M. locs. 3139, 3236, 3237, Kayak formation; U.S.G.S. loc. 12709, Utukok formation.

Material: Figured specimen: U.S.N.M. 118344 (cranidium), from U.S.N.M. loc. 3139.

APPENDIX

Locations of the measured sections are indicated on figure 3. Sections A, B, and E from the Noatak type region are shown on plate 1, sections G and H on plate 2.

In describing the units, the Wentworth scale has been used for textural terminology of clastic rocks including carbonates, with calcirudite, calcarenite, and calcisiltite as rock types paralleling conglomerate, sandstone, and siltstone. Color names conform with those used in the Rock Color Chart distributed by the National Research Council (1948).

Section A. Type section of the Noatak formation (restricted), located on mountain side 4.5 miles N. 15° W. of junction of Nimiuktuk and Noatak Rivers (see plate 1).

Unit	Description	Thickness (feet)
NOATAK FORMATION (RESTRICTED)		
1.	Covered interval, grassy saddle	160.0 +
2.	Sandstone, fine-grained, medium gray, well-indurated, micaceous, in thin uniform beds about 0.4 feet thick. Lithologic sample 50 ADu 125 from bed 8 feet above base	10.0
3.	Sandstone, fine-grained, reddish brown (10R 4/4), highly calcareous, with calcarenite lenses, fractures along irregular subparallel surfaces, weathers moderate brown (5 YR 4/4). Sample 50 ADu 124 from 3 feet above base	4.0
4.	Sandstone, fine-grained, medium gray (non-calcareous), in massive beds 3 to 6 feet thick, with few irregular fractures parallel to bedding; strong vertical joints striking N 50° E	9.0
5.	Covered interval, probably shale as below . .	25.0
6.	Shale, silt to clay size, dark gray, with some thin plates of ferruginous mudstone less than 0.01 feet thick; partly covered	8.5
7.	Sandstone, fine-grained, medium gray, non-calcareous, with closely spaced planar weathering breaks producing thin platy bedded appearance, slightly cross bedded; no argillaceous material observable; attitude of beds N. 20° W., 30° SW.; lower 1 foot covered	11.0
8.	Sandstone, fine-grained, light gray, non-ferruginous, noncalcareous to slightly calcareous, dense, without planar weathering breaks	5.0
9.	Sandstone, very fine grained, medium gray, very slightly calcareous, with planar weathering breaks approximately 0.1 foot apart, without cross bedding; ferruginous mudstone lenses at base	3.0

10.	Sandstone, fine-grained, medium gray, moderately calcareous, without planar weathering breaks, fracturing along irregular undulating surfaces, locally cross bedded	14.0
11.	Sandstone, fine-grained, medium gray, very slightly calcareous, cross-bedded with truncation indicating that beds are upright; dip of cross beds approximately 10° in N. 35° E. direction; scattered ferruginous mudstone nodules	6.0
12.	Covered interval	6.0
13.	Sandstone, very fine grained, medium gray, noncalcareous; attitude N. 40° W., 15° SW	2.4
14.	Covered interval	5.0
15.	Sandstone, fine-grained, medium gray, ferruginous, noncalcareous; weathering breaks irregular and subparallel; primary bedding massive, with beds up to 3 feet thick; about 80 percent of lower 15 feet covered	26.0
16.	Sandstone, very fine grained, medium gray, slightly calcareous; about 40 percent of beds platy, slightly cross bedded and 0.1 foot thick; about 60 percent of beds thicker, about 0.4 foot thick; more dense and less calcareous than typical* lithology.	10.5
17.	Sandstone, fine-grained, medium gray, very slightly to noncalcareous, in beds about 0.6 foot thick, more dense than typical*	6.5
18.	Sandstone as above, platy, slightly cross bedded, in beds about 0.4 foot thick.	1.3
19.	Sandstone, fine- to medium-grained, medium gray, moderately calcareous, with planar weathering breaks 0.2 foot apart; sample 50 ADu 123 collected 0.5 foot from top of unit. .	5.5

* Sandstone referred to as typical throughout descriptions is that of units 27 and 86.

20. Sandstone, fine-grained, less ferruginous and less calcareous than typical lithology, with weathering breaks not parallel but irregular and spaced about 0.8 foot apart, slightly cross bedded with dip to south at about 25°; with lenses of similar sandstone about 1.0 foot x 0.3 foot in cross section, long diameter paralleling bedding; dolomitic shell about 0.2 foot thick, weathered deeply and accentuating boundary of lens; outer contact of dolomitic shell discontinuous but inner one gradational, mica flakes paralleling surface of lens 3.0

21. Sandstone, very fine grained to fine-grained, medium gray, in platy beds approximately 0.5 foot thick; lower 10 feet partly covered. . . 15.0

22. Sandstone, fine-grained, medium gray, in planar flaggy beds 1.5

23. Sandstone, fine-grained, medium gray, in massive beds 2.0

24. Sandstone, very fine grained to fine-grained, medium gray, with weathering breaks about 0.2 foot apart, slightly cross bedded in lower 13 feet; beds showing streaks of magnetite (?) but no cohesive breaks 21.5

25. Sandstone, fine-grained, medium gray, in platy beds about 0.1 foot thick, exposed in receding slope. 10.0

26. Sandstone, very fine grained to fine-grained, with large-scale cross bedding, in beds 0.05 foot thick; truncation shows beds upright. . 4.5

27. Sandstone, very fine grained to fine-grained, medium-gray weathering to moderate pale reddish-orange-brown (10 R 5 5/3), with about 15 percent magnetite grains giving mottled appearance to fresh surfaces, without cross bedding, weathering to flaggy blocky talus; weathering occurring along streaks of argillaceous and micaceous material spaced about 0.4 foot apart; attitude N. 20° W., 25° SW. 13.5

28. Sandstone, typical*, with little or no cross bedding; weathering breaks 0.1 foot apart 13.0

* Sandstone referred to as typical throughout descriptions is that of units 27 and 86.

29.	Sandstone, fine-grained, medium gray, more ferruginous than typical, with ferruginous material concentrated in planes giving streaked appearance to outcrop face, with large scale cross bedding; sandstone lens about 4.0 feet x 0.8 foot (lithologically similar to those described in unit 20); abundant ferruginous mudstone nodules about 0.2 foot diameter; lower 5 feet with large scale cross bedding; attitude N. 40° W., 30° SW.	19.0
30.	Sandstone, typical, without cross bedding; weathering breaks 0.1 to 0.4 foot apart.	7.0
31.	Sandstone, typical, in single massive bed, containing a few irregular ferruginous mudstone nodules; fracture system at angle of 60° to bedding	2.0
32.	Sandstone, typical but extremely ferruginous; ferruginous mudstone nodules 0.5 foot x 0.2 foot with long diameter paralleling bedding	5.5
33.	Covered interval	10.0
34.	Sandstone, typical, in flaggy platy beds varying from 0.1 to 0.5 foot thick; without cross bedding	10.0
35.	Sandstone, fine-grained, medium gray; very strong cross bedding on small scale with no cohesive breaks, truncation showing beds upright; unit more massive in upper 4 feet	9.0
36.	Covered interval	25.0
37.	Shale and sandstone; shale, clay size, medium dark gray, micaceous; sandstone, typical, comprising about 20 percent of lower foot of unit	2.5
38.	Sandstone, typical, but slightly cross bedded, with weathering breaks about 0.2 foot apart	10.0

39.	Sandstone, fine-grained, medium gray, thin bedded, in irregular platy beds, friable, with trace of shaly material; a few ferruginous mudstone nodules in upper foot; lenses of sandstone, 3 feet x 1-foot, fine-grained, micaceous and highly ferruginous, dark moderate yellow-orange-brown color (10 YR 5.5/5), similar to lenses in units 20 and 29; sample 50 ADu 122 from lower foot of unit. . .	4.0
40.	Sandstone, typical, upper 0.4 foot highly ferruginous, with weathering breaks 0.1 to 0.4 foot apart	2.9
41.	Sandstone, typical, with large-scale cross bedding	1.6
42.	Sandstone, typical, in single massive bed.	1.3
43.	Sandstone, typical, strongly cross bedded, ferruginous streaks accentuating cross bedding and approximately 0.1 foot apart; true bedding about 0.8 foot thick.	4.5
44.	Covered interval	9.0
45.	Sandstone, typical, ferruginous and friable. . . .	2.0
46.	Sandstone, typical, very dense, moderately cross bedded, with weathering breaks about 0.2 foot apart; quartz veining roughly perpendicular to bedding, with veins up to 0.1 foot thick.	9.5
47.	Covered interval	5.0
48.	Sandstone, typical, with strong irregular cross bedding, having pitted weathered surfaces. .	3.5
49.	Shale, clay size, medium gray, micaceous	1.0
50.	Sandstone, typical, without cross bedding, with weathering breaks about 0.1 foot apart, very dense	4.0
51.	Sandstone, more ferruginous than typical, strongly cross bedded; truncation indicating beds upright	12.5
52.	Shale, clay size, medium gray, fissile, micaceous; upper half of unit covered; sample ADu 121 MF from entire unit.	3.5

53.	Sandstone, typical but about 40 percent of the ferruginous type, with platy fracturing; ferruginous mudstone granules and pebbles alined parallel to cross bedding; very thin shale interbeds comprising about 10 percent of thickness	9.0
54.	Sandstone, fine-grained, medium gray, without cross bedding, attitude N. 30° W., 30°SW . .	7.0
55.	Sandstone, as above, ferruginous, cross-bedded, in beds 0.03 to 0.1 foot thick	6.5
56.	Covered interval.	3.0
57.	Sandstone, as above, cross-bedded	5.0
58.	Sandstone, fine-grained, medium gray, having every 10 to 15 feet zones of approximately 0.4 foot of highly ferruginous sandstone grading into argillaceous sandstone and usually deeply weathered; unit of general massive appearance.	43.0
59.	Sandstone, typical, with planar bedding	10.0
60.	Sandstone and shale; sandstone as above; shale about 30 percent of thickness.	2.0
61.	Covered interval, lithology probably as in unit 62	15.0
62.	Sandstone, shaly, with low ferruginous content, having about 30 percent argillaceous material; weathering breaks about 0.1 to 0.2 foot apart; forming receding slope	11.5
63.	Sandstone, very fine grained, medium gray, containing a few small ferruginous mudstone pebbles, in massive 2-foot beds	7.5
63a.	Covered interval	50.0
64.	Sandstone, typical, strongly cross bedded, with weathering breaks about 0.1 foot apart; ferruginous and argillaceous interbeds and lenses up to 1.5 feet x 0.2 foot x 1.0-foot dimensions (longer diameters paralleling bedding planes); plant fragments in lower 3 feet. .	10.0

65.	Sandstone and shale interbedded; sandstone about 65 percent, very fine grained, medium light gray, platy, with undulating bedding planes, nonferruginous, with cross bedding accentuated by argillaceous streaks; shale about 30 percent, medium gray, clay size, fissile, micaceous; ferruginous mudstone layers about 0.1 foot thick occur every 1 to 1.5 feet.	9.5
66.	Sandstone, typical, with slightly undulatory planar bedding; occasional ferruginous mudstone pebble flattened parallel to bedding.	7.5
67.	Sandstone, typical, strongly cross bedded with truncation both top and bottom	7.5
68.	Sandstone, typical; weathering breaks every 0.1 foot; top 0.3 foot with dark-gray, carbonaceous, comminuted plant fragments	6.0
69.	Sandstone, typical, prominantly rippled marked, in beds 0.5 foot thick, with many argillaceous streaks; lineation of crests of ripples N. 35° E., plunging 15° N.; wave length of ripples 0.3 foot, amplitude 0.01 foot . .	2.0
70.	Sandstone, typical, slightly cross bedded, in beds 0.1 to 0.2 foot thick; attitude N. 30° W., 30° S.	7.0
71.	Sandstone and shale; sandstone typical, thin-bedded; shale as argillaceous laminae near top but grading downward into shale unit below; contact between units 71 and 72 a gradational one; sample 50 ADu 120.	3.0
72.	Shale, medium gray, clay size, with abundant ferruginous mudstone pebbles alined parallel to bedding; small lenticular pockets of fine-grained sandstone up to 0.1 foot diameter; clay and sandstone bodies producing wavy bedding surfaces	0.7
73.	Sandstone, typical, with cross beds truncated showing beds upright; cross bedding dips northeast; a few ferruginous mudstone pebbles; sharp contact at upper surface with unit 72	4.3
74.	Sandstone, slightly more ferruginous than typical, in uniform beds approximately 0.2 foot thick.	5.0

75. Sandstone, with relatively little ferruginous material, in massive cliff, with weathering breaks 0.5 foot apart 10.0

76. Sandstone, typical in three beds 1 to 2 feet thick; argillaceous content varying along strike producing a less massive cliff in places . . 5.0

77. Sandstone, fine-grained, dark red brown and highly ferruginous at base, grading upward into medium gray slightly ferruginous strata, with granules and small pebbles of ferruginous mudstone in top 0.3 foot. 3.0

78. Sandstone, very fine grained, less ferruginous and less argillaceous than typical, medium light gray to light gray, in single massive bed, very resistant to concussion by hammer blow, resistance inversely proportional to argillaceous and ferruginous content; sample 50 ADu 119 from top 0.5 foot 3.0

79. Sandstone, typical, with pockets up to 1 foot diameter of very fine grained, very ferruginous sandstone, weathering moderate pale reddish-brown (10 R 5/5); sample 50 ADu 118 from lenses; cross bedded, with beds intersecting at angles up to 30° without good criteria 5.0

80. Covered interval. 2.5

81. Sandstone, fine-grained, medium gray, slightly cross bedded; close spaced argillaceous laminae giving fissile character, laminae spaced from 0.01 to 0.2 foot apart. 7.0

82. Shale, clay size, medium dark gray, highly argillaceous, in flexible plates, having lustrous sheen; lenticular pebbles of ferruginous mudstone very common; samples 50 ADu 116, 50 ADu 117 MF, attitude N. 70°W., 25° S.; this may be a fault zone. 1.2

83. Sandstone, typical, in massive cliff, slightly cross bedded; attitude N. 45° W., 40° S. 11.0

84. Sandstone, typical, containing ferruginous mudstone nodules up to 0.3 x 0.4 foot and stringers 2 to 3 feet long and 0.2 foot thick; sample 50 ADu 115. . . . . 0.5

85.	Sandstone, typical, in beds up to 1.5 feet thick; top foot cross-bedded, truncation showing beds to be upright	5.0
86.	Sandstone, very fine grained, light medium bluish-gray, (5 B 6/1) to medium gray (N 5), with limonitic specks disseminated throughout, tending to parallel bedding, slightly cross bedded, in beds 0.1 to 0.3 foot thick, well-indurated, flaggy appearance; argillaceous streaks paralleling bedding and accentuated by weathering; sample 50 ADu 114 from lower 2 feet; attitude N. 60° W., 25° SW.	12.0
Thickness.		862.7 +

SECTION INCOMPLETE

Note: Sandstone referred to as typical throughout descriptions is that of units 27 and 86.

Section B. Section of Utukok formation, showing upper and lower contact relationships, approximately 5.5 miles N. 15° W. of junction of Niniuktuk and Noatak Rivers (see plate 1).

Unit	Description	Thickness (feet)
UTUKOK FORMATION		
1.	Covered interval, possible fault, missing interval below Wachsmuth member contact estimated at 40 to 50 feet based on regional relationships (see correlation chart, plate 3). .	25.0 +
2.	Limestone, fine-grained calcarenite, dark gray, weathering yellowish-orange, with about 30 to 40 percent coarse crinoidal debris; sample 50 ALz 92	30.0
3.	Sandstone, fine-grained, medium gray, quartzose, weathering dark yellowish-orange, with limonite grains thin-bedded, platy; much of interval talus-covered	63.0
4.	Shale, clay size, medium dark gray, fissile . . .	10.0
5.	Limestone, fine-grained calcarenite, medium gray, weathering very dusky red (10 R 2/2). . . .	1.0
6.	Limestone, fine-grained calcarenite, medium dark gray, weathering light brown (5 YR 5/6) to dark yellowish-orange (10 YR 6/6), in thin platy beds, sample 50 ALz 91	3.0

7.	Covered interval, rubble of sandstone as in unit 8?	200.0 +
8.	Sandstone, fine- to medium-grained, medium gray, very slightly calcareous if at all, siliceous, in beds about 0.1 foot thick	50.0
9.	Sandstone, fine-grained, brownish-gray to medium dark gray, with carbonaceous inclusions; sample 50 ALs 90.	3.0
10.	Sandstone and limestone; sandstone as in unit 9 in beds 0.1 to 0.9 foot thick; limestone, medium-grained calcarenite, medium gray, in beds about 1 foot thick	15.0
11.	Sandstone, fine-grained to medium-grained, siliceous, slightly calcareous becoming more calcareous near top, weathering grayish-red (10 R 4/2) to dark reddish-brown (10 R 3/4), with crinoidal debris and fossil zones scattered throughout, in thin beds about 0.05 foot thick; sample USGS 12705 from 30 feet above base; attitude N. 20° E., 30° S.	55.0
12.	Shale and sandstone; shale, medium dark gray, clay size, fissile, with ferruginous concretions about 0.2 foot in diameter; sandstone, thin-bedded, very ferruginous, as in unit 11; shale comprising about 80 percent of heavings and rubble in this interval which is almost entirely talus covered .	170.0 +
Total thickness		625.0 +

NOATAK FORMATION

13.	Sandstone, fine-grained, medium gray, ferruginous, in single massive bed	6.0
14.	Covered interval	5.0
15.	Sandstone, fine-grained, grayish-red (10 R 4/2), dense, ferruginous, containing about 10 percent granules and pebbles of medium gray clay shale; and sandstone, medium-grained, brownish-gray, nonferruginous, with interbedded medium gray clay size and silt size shale	10.0 +

16.	Sandstone, fine- to medium-grained, medium light gray to medium dark gray, with grains of magnetite which weather to limonitic specks, in beds 0.05 to 0.2 foot thick, with some cross bedding; samples 50 ALx 87 and 88; this is general description for cliffs and hillside outcrops with thickness estimated from photographs and map	500.0 +
Thickness		521.0 +

SECTION INCOMPLETE

Section C. Hunt Fork formation, Fire Creek section approximately 14 miles west of Chandler Lake (about 68° 17' N. Lat., 153° 20' W. Long.), measured by W. W. Patton, Jr. in 1951.

Unit	Description	Thickness (feet)
KANAYUT FORMATION, LOWER MEMBER		
1.	Conglomerate, gray to greenish-gray, massive-bedded; with rounded to subrounded small pebbles of gray, black and white chert	80 +
Thickness		80 +
HUNT FORK FORMATION		
2.	Sandstone, fine-grained, gray to greenish-gray, medium-bedded; interbeds of dark gray silt shale; sandstone about 80 percent of thickness	820 ±
3.	Shale, clay to silt size, dark gray to black	120 ±
4.	Sandstone, fine- to medium-grained, light gray, medium- to massive-bedded, with some dark-gray silt shale.	165 ±
5.	Shale and siltstone; shale, clay to silt size, dark gray to black; siltstone, dark gray weathering yellowish-red, about 20 percent of thickness	600 ±
6.	Oxidized zone, lithology as in unit 5, with yellowish-red color	280 ±

7.	Shale and siltstone; shale black, clay to silt size, fissile, with well-developed cleavage; siltstone dark greenish-gray weathering yellowish-red, in thin beds, comprising about 10 percent of thickness	540 ±
8.	Shale and siltstone; shale greenish gray, silt size, with cleavage well-developed locally; siltstone dark gray weathering yellowish-red, thin-bedded; concretions of siltstone lithology (up to 0.35 foot in diameter) scattered throughout shale	700 ±
9.	Shale and sandstone; shale dark gray, clay to silt size, with hackly fracturing, with locally well-developed cleavage; sandstone greenish gray, fine-grained, weathering yellowish-red, comprising about 25 percent of thickness, zone of limonitic stained shale at base of unit	740 +
10.	Covered interval	200 ±
11.	Phyllite and slate, dark gray to black, clay to silt size, thin-bedded; much of interval is covered.	1,200 +
Total thickness		5,265 +

Section D. Composite section of the Utukok formation, exposed in anticline about 2 miles north of camp 2 (17 miles north of junction of Nimiuktuk and Noatak Rivers).

Unit	Description	Thickness (feet
LISBURNE FORMATION		
1.	Limestone, very fine grained calcarenite, dark brownish-gray, with about 10 percent light-gray coarse crinoidal debris, weathering light gray or bluish-gray; collection USGS 12716 from this unit; attitude N. 35° E., 20° N.	10.0 +
2.	Covered interval, rubble of limestone as in unit 1	29.0
Thickness		39.0 +

UTUKOK FORMATION

1. Limestone, fine-grained calcarenite, medium gray, having laminated appearance, weathering to thin plates, containing much limonite; sample 50 ADu 15 from upper 10 feet; USGS 12709 from 20 to 24 feet below Lisburne contact; about 75 percent of unit talus-covered 40.0

2. Limestone, interbedded 75 percent finer-grained and 25 percent coarser-grained calcarenite; finer beds composed of medium- to coarse- grained bioclastic calcarenite, medium light gray, containing about 25 percent very coarse crinoid debris in lenticular masses which appear to fill depressions in beds of finer lithology. 12.0

3. Limestone, as above, with coarse phase about 40 percent of thickness; partly talus covered 24.0

4. Limestone, as above, with coarse phase about 50 percent; sample 50 ADu 24 from 5 feet above base of unit 16.0

5. Limestone, fine-grained calcarenite, medium gray, with very little interbedded coarser material, in beds 1 to 3 feet thick; sample 50 ADu 26 from 6 feet above base of unit 19.5

6. Limestone, interbedded fine-grained calcarenite and coarse bioclastic calcarenite as in unit 7, in beds 0.6 to 0.9 foot thick 6.0

7. Limestone, interbedded fine-grained calcarenite and coarse bioclastic calcarenite; fine-grained calcarenite, medium gray, weathering light brown (5 YR 5/6), comprising about 30 percent of thickness; coarse bioclastic calcarenite, medium gray, weathering light gray (N 6), containing about 25 percent coarse crinoidal debris; undulating beds weathering to produce banded outcrop facies 15.0

8. Limestone, as in unit 7, with about 50 percent coarse bioclastic calcarenite; sample 50 ADu 25 from bed 7 feet above base of unit 9.5

9. Covered interval; rubble of the fine-grained calcarenite 130.0

3.	Sandstone, fine-grained, medium gray, weathering moderate reddish-orange (10 R 6/6), platy, limonitic, noncalcareous, moderately argillaceous, containing lenses and interbeds of micaceous siltstone with disseminated sulphides; sample 50 ALa 109 . .	25.0
4.	Sandstone, fine-grained, medium gray, limonitic, very slightly calcareous, in beds about 0.3 foot thick	20.0
5.	Sandstone, fine-grained, medium gray, limonitic, moderately calcareous, with argillaceous laminae and a flaggy fracture	30.0
6.	Limestone, very fine grained calcarenite, medium bluish-gray (5 B5/1), in blocky beds about 0.2 to 0.3 foot thick; sample 50 ALa 108	10.0
7.	Sandstone, fine-grained, medium gray, weathering light brown (5 YR 5/6) or reddish-orange (10 R 6/6), moderately argillaceous, limonitic; about 50 percent covered	20.0
8.	Sandstone, as in unit 7, forming massive cliff, very limonitic	20.0
9.	Sandstone, as in unit 7; about 80 percent covered. . . .	40.0
10.	Sandstone, as in unit 7, in thin platy beds, with some beds containing spheroidal granule-size ferruginous mudstone bodies; sample 50 ALa 107	10.0
11.	Covered interval	100.0 +
Thickness	. . . . .	355.0 +

NOATAK FORMATION

12.	Sandstone, fine-grained, medium light gray to light gray, without ferruginous content, with argillaceous laminae about 0.5 foot apart; slightly cross bedded, truncation showing beds to be upright . .	16.0
13.	Covered interval	70.0 +
14.	Sandstone, fine-grained, medium gray, moderately ferruginous, noncalcareous, slightly cross bedded, in beds 0.1 foot thick	40.0 +
Thickness	. . . . .	126.0 +

SECTION INCOMPLETE

10.	Limestone, fine-grained calcarenite, light gray, ferruginous, having saccharoidal texture, in beds 0.5 to 1.0 foot thick; sample 50 ADu 64 from 6 feet below top	19.0
11.	Covered interval; limestone rubble as in unit 10 . .	4.0
12.	Limestone, medium-grained calcarenite, medium dark gray, with about 10 percent coarser bioclastic debris, in platy beds 0.2 to 0.4 foot thick, weathering moderate yellow brown to light brown (10 YR 5/4 to 5 YR 5/6); sample 50 ADu 63 from 10 feet below top of unit	28.0
13.	Covered interval; limestone rubble as in unit 12 . .	5.0
14.	Sandstone, fine-grained, light gray to medium gray, quartzose, in beds 4 to 8 feet thick, having calcareous matrix in upper part, weathering moderate yellow brown (10 YR 5/4); sample 50 ADu 62 from 8 feet above base	38.0
15.	Breccia, fine quartzose sandstone matrix, with small angular blocks of sandstone, local development	1.0
16.	Shale, medium gray, silt size, argillaceous and calcareous, micaceous in places, with well-developed "pencil structure"; samples USGS 12713 and 50 ADu 61MF	20.0
17.	Covered interval, shale heavings	10.0 +
Thickness		397.0 +

SECTION INCOMPLETE

Section E. Utukok formation about 5.5 miles N. 30° W. of junction of Nimiuktuk and Noatak Rivers (see plate 1).

Unit	Description	Thickness (feet)
UTUKOK FORMATION		
1.	Shale, dark gray to black, clay size, fissile . . .	70.0 +
2.	Sandstone and limestone interbedded; sandstone, fine-grained, medium gray, limonitic, argillaceous, platy; limestone, coarse bioclastic calcarenite, medium gray, weathering light brown (5 YR 5/6), with about 30 percent crinoidal debris; samples 50 Ala 110 and USGS 12708 from this unit	10.0

Section F. Utukok formation, type section, near headwaters of Utukok River (about 68° 33' N. Lat., 161° 10' W. long.). Measured by Edward G. Sable in 1950.

Unit	Description	Thickness (feet)
	LISBURNE LIMESTONE	
1.	Limestone and chert; limestone, fine- to medium-grained calcarenite, medium dark gray to dark gray, weathering medium light gray to grayish-orange, having abundant crinoidal and other bioclastic debris; chert, dark gray to black, in irregular-shaped nodules; attitude N. 55° E., 47° S.; samples 50 ASa 238 and USGS 11869	20.0 +
	Thickness	20.0 +
	UTUKOK FORMATION	
2.	Limestone, very fine grained calcarenite, dark gray, weathering medium gray to yellow-brown; talus covered for most part	76.0
3.	Limestone and sandstone; limestone, very fine to fine-grained calcarenite, medium gray, weathering light gray to moderate yellowish-brown, in thin platy to laminated beds with sandy texture; sandstone, fine-grained, medium light gray to dark gray, orthoquartzitic, in blocky to massive beds to 0.7 foot thick; approximately 50 percent of each lithology; sample USGS 11868	390.0 ±
4.	Sandstone and limestone, as in unit 3; limestone comprising about 30 percent of thickness; sandstone quite calcareous and cross bedded on small scale; mainly talus-covered; sample 50 ASa 234	540.0 ±
5.	Sandstone and limestone, as in unit 3; limestone comprising about 40 percent of thickness; attitude N. 60° E., 35° S.	150.0 ±
6.	Limestone, as above, with a few beds of limestone, fine-grained, medium gray; a few thin orthoquartzitic sandstone beds; samples USGS 11862 and USGS 11867 from near base of unit	60.0
7.	Limestone and sandstone, as in unit 3; limestone about 60 percent of thickness, in blocky beds up to 2 feet in thickness	30.0

8.	Covered; platy limestone talus	10.0
9.	Limestone, as in unit 3, weathering dark yellowish-brown to red brown, with some orthoquartzitic sandstone in upper part; sample USGS 11861 from lower 10 feet. Sample USGS 11859 from units 6 through 9 . .	40.0
10.	Limestone, medium dark gray, but otherwise similar to unit 3; mainly talus covered, sample 50 ASa 234	25.0
11.	Limestone, as in unit 3, in platy 0.3 foot beds, laminated to slightly cross bedded, slightly bioclastic.	85.0
12.	Sandstone and limestone, as in unit 3, with limestone increasing toward top; attitude N. 65° E., 30° S	50.0
13.	Covered by talus	63.0
14.	Sandstone and limestone, as in unit 3, with orthoquartzitic beds up to 3 feet thick; limestone beds about 0.4 foot thick; sample USGS 11860 from units 11, 12, 14	20.0
15.	Sandstone and limestone, as in unit 3, with sandstone about 60 percent; mainly talus-covered sample USGS 12793.	187.0
16.	Sandstone and limestone, as in unit 3; attitude N. 87° E., 32° S	40.0
17.	Covered interval, talus as in unit 16. . . .	20.0
18.	Shale, clay size, dark gray, calcareous, ferruginous, as partings 0.02 foot thick; interbedded limestone and siltstone, calcareous, with worm trails and fucoidal markings	30.0
19.	Covered interval	20.0
20.	Sandstone and limestone, as in unit 3; limestone about 20 percent; sandstone slightly to moderately calcareous, in beds up to 10 feet thick	100.0

21.	Sandstone and limestone, as in unit 3, limestone 30 percent of thickness and shaly in some places; samples 50 ASa 225 and USGS 11358	25.0 +

FAULT CONTACT

Thickness . . . . . 1,961.0 +

Section Q. Kanayut formation, type section, ridge southeast of Kanayut Lake (approximately 68° 19' N. Lat., 150° 53' W. Long.). Measured by Arthur L. Bowsher and J. Thomas Dutro, Jr. in 1949

Unit	Description	Thickness (feet)
KAYAK FORMATION		
1.	Sandstone, fine-grained, quartzose, reddish-brown, in thin regular beds	11.0
2.	Talus covered, sandstone, as in unit 1 . . .	45.0
Thickness		56.0 +
KANAYUT FORMATION, STUVER MEMBER		
3.	Sandstone, fine-grained, medium dark gray, quartzose, orthoquartzitic, in beds 0.5 foot thick with thin shaly interbeds	3.0
4.	Sandstone, very fine grained, medium bluish-black, shaly, from feather edge to 0.5 foot thick	0.5
5.	Conglomerate, light gray, with large pebbles and small cobbles of black, gray and white chert in orthoquartzitic coarse, quartzose sandstone matrix . .	1.25
6.	Sandstone, very fine grained, light gray to bluish-gray, in beds 0.5 to 0.05 foot thick, with scattered chert granules in basal 0.5 foot	5.0
7.	Conglomerate, light gray, with small chert pebbles in coarse sand matrix, in platy beds from 0.25 to 0.5 foot thick . . .	4.0

8.	Conglomerate, light to dark gray, with pebbles and small cobbles of white, gray, black chert in matrix of coarse quartz sand; shaly stringers near base, containing plant fragments	4.0
9.	Shale, clay size, light medium gray, with thin lenses of conglomerate	1.5
10.	Sandstone, fine-grained, dark gray, orthoquartzitic	0.5
11.	Sandstone, fine- to medium-grained, dark gray, shaly	0.5
12.	Sandstone, fine- to medium-grained, dark gray, quartzose, ferruginous, with scattered small pebbles of white and black chert	5.0
13.	Conglomerate, dark gray, with about 20 percent small cobbles and pebbles of gray and black chert and white quartzite, in orthoquartzitic coarse quartz sand matrix; cobbles show internal primary bedding and seem silicified	9.0
14.	Covered interval	57.0
15.	Sandstone, medium-grained, medium gray, orthoquartzitic	3.0
16.	Sandstone, fine-grained, dark gray, bituminous; few stringers of coarse sand and conglomerate; plants from entire unit	7.0
17.	Sandstone, fine-grained, medium gray, orthoquartzitic, kaolinitic (?), in blocky beds	4.0
18.	Conglomerate, white to light gray, with medium to large pebbles of white, gray and black chert, in irregular beds; lenses of light gray coarse sandstone up to 0.5 foot thick	3.0
19.	Sandstone, fine-grained, dark gray, orthoquartzitic; thin lenses of pebble conglomerate near top	2.0

20.	Sandstone, medium-grained, light brownish-gray, orthoquartzitic, cross-bedded . . .	2.0
21.	Conglomerate, white to light gray, with pebbles and cobbles of white, red, gray chert and silicified sedimentites, massive-bedded; pebbles 90 percent at base decreasing to 20 percent at top	10.0
22.	Sandstone, medium-grained, dark gray, orthoquartzitic	0.7
23.	Conglomerate, as in unit 21; in addition, containing pebbles of sandstone of lower units	7.0
24.	Covered	0.5
25.	Sandstone, medium-grained, dark gray to greenish, irregularly bedded, orthoquartzitic.	2.3
26.	Sandstone, fine- to medium-grained, dark gray, shaly.	1.1
27.	Sandstone, medium- to coarse-grained, medium gray, orthoquartzitic; 0.3 foot lens of pebble conglomerate at top	1.9
28.	Conglomerate, with large black and white chert pebbles; grading laterally into gray silt shale.	0.5
29.	Sandstone, fine- to coarse-grained, medium gray, orthoquartzitic; basal part containing white, gray, black chert-pebble conglomerate, with pebbles from one-fourth to one-half inch diameter . .	1.8
30.	Sandstone, fine-grained, medium gray, ferruginous, orthoquartzitic.	2.1
31.	Conglomerate, light gray, with large rounded pebbles of white, gray and black chert	0.5
32.	Sandstone, as in unit 30	1.2
33.	Conglomerate, with granules of gray and black chert and white quartz in very fine grained, medium-gray sandstone matrix	0.3

34.	Sandstone, fine-grained, medium gray, in blocky beds, kaolinitic (?), with rounded frosted quartz grains	17.0
35.	Sandstone, coarse-grained, light grayish purple, with lenses of white, gray and black chert-pebble conglomerate	2.0
36.	Shale, clay size, medium gray to light brownish-gray, kaolinitic (?)	0.3
37.	Sandstone, fine- to medium-grained, light grayish purple, in single massive bed	3.0
38.	Sandstone, as in unit 35, with lenses of white, gray and purple chert pebble-cobble conglomerate; bauxitic in lower 0.7 to 0.8 foot	3.0
39.	Shale, clay size, brownish gray to greenish gray	85.0
40.	Claystone and clay shale, dark gray, with metallic sheen, kaolinitic (?), with some brownish-gray shale in upper part	177.0
41.	Covered, talus same as unit 42	53.0
42.	Conglomerate, dark gray, with pebbles and cobbles of white and black chert in coarse, orthoquartzitic sandstone matrix; scattered ferruginous mudstone nodules . . .	13.5
43.	Sandstone, very fine grained, light yellow green weathering to dark yellowish-orange, carbonaceous, micaceous, argillaceous, shaly; interval covered for most part	11.0
44.	Sandstone, fine- to medium-grained, light gray to dark gray, orthoquartzitic . .	10.0
45.	Sandstone, coarse-grained, dark gray, conglomeratic in places, poorly sorted, in blocky 3 to 5 foot beds; weathering to white or light yellowish-brown powder . .	38.0
46.	Covered interval, lithology thought same as unit 47	25.0

47.	Shale and sandstone; shale clay size, light bluish-gray to brownish-gray, platy; thin interbeds of fine-grained, dark-gray, micaceous, platy sandstone	10.0
48.	Sandstone, medium-grained, light gray, weathering reddish-brown, in beds 0.5 foot thick at base thinning to 0.1 foot at top	10.0
49.	Sandstone, as in unit 48 but more massive-bedded	5.0
50.	Sandstone, as in unit 48 but strongly cross bedded	3.0
51.	Conglomerate, with white, green and black chert pebbles to large cobbles in sandstone matrix as in unit 48	0.5-1.5
52.	Sandstone, as in unit 50, with very irregular bedding	3.0
53.	Conglomerate, white to light gray, with white, gray, green and black chert pebbles scattered in a matrix of coarse, frosted quartz sandstone	5.0
54.	Covered, rubble as in unit 55	15.0
55.	Shale and sandstone; shale clay size, reddish to greenish-gray, micaceous, fissile; thin interbeds of fine- to medium-grained, reddish-gray, quartzose sandstone	25.0
56.	Shale, clay size, black, micaceous, bituminous, hard, platy	37.0
57.	Covered, rubble of unit 58	5.0
58.	Sandstone, fine- to medium-grained, medium gray, orthoquartzitic, weathering reddish-brown	4.0
59.	Sandstone, medium-grained, medium gray, orthoquartzitic, with a few fine pebbles scattered throughout	2.0

60.	Sandstone, medium-grained, medium gray weathering greenish-gray, with ferruginous grains weathering reddish-brown, orthoquartzitic, in uniform beds 0.6 to 1.0 foot thick	4.1
61.	Conglomerate, medium gray, with gray and black chert pebbles in medium quartz sandstone matrix	0.3
62.	Sandstone and shale; shale very fine sand size, greenish-gray, hard; interbeds of dark-gray, fine-grained, orthoquartzitic, thin-bedded sandstone	1.1
63.	Sandstone, fine- to medium-grained, dark gray weathering reddish-brown, quartzose, orthoquartzitic, with scattered black chert grains, cross-bedded	7.0
64.	Sandstone, very fine grained, greenish-gray, shaly	0.2
65.	Sandstone, medium-grained, medium gray, dense, orthoquartzitic	0.5
66.	Sandstone, very fine grained to fine-grained medium gray, orthoquartzitic	0.5
67.	Conglomerate, light gray to medium gray, with 40 percent white, gray and black pebbles in matrix of fine-grained, reddish-brown weathering, quartzose and orthoquartzitic sandstone . . .	3.1
68.	Covered interval	140.0 +
Total thickness	. . . . .	860.2 +

KANAYUT FORMATION, MIDDLE CONGLOMERATE MEMBER

69.	Conglomerate, light gray weathering light brown, with pebbles to small cobbles of white, light-gray, dark-gray and black chert ranging from 20 to 90 percent; matrix of coarse-grained light-gray to medium-gray sandstone, in massive beds 2 to 10 feet thick	185.0 +
Thickness	. . . . .	185.0 +

SECTION INCOMPLETE

Supplementary section. Kanayut formation, upper Alapah Creek, approximately 68° 14' N. Lat., 150° 48' W. Long. (see unlettered section, plate 2).

Unit	Description	Thickness (feet)
	CONTACT WITH STUVER MEMBER	
	KANAYUT FORMATION, MIDDLE CONGLOMERATE MEMBER	
1.	Talus covered, conglomerate blocks as in unit 69 of section G	200.0 ±
2.	Conglomerate, light gray to medium gray, with cobbles of gray and black chert in matrix of coarse grained, light gray, massive-bedded sandstone . . .	10.0
3.	Conglomerate, light gray, with cobbles of gray chert in coarse-grained, medium-gray sandstone; less resistant than units above or below	3.0
4.	Conglomerate, as in unit 2, except beds about 1 foot thick	10.0
5.	Conglomerate, light to medium gray; 15 to 20 percent fine, medium and coarse pebbles of white, light-gray, grayish-black and olive gray chert scattered in a very coarse grained sandstone matrix; layers of small pebbles every 4 to 8 feet giving banded appearance; pebbles nearly 50 percent in two foot layer, eight feet above base of unit; massive beds 4 to 8 feet thick	34.0
6.	Conglomerate, as in unit 5, in massive beds; coarse constituents about 10 percent small cobbles	40.0
7.	Conglomerate, as in unit 5, with fine to medium pebbles grading upward to 50 percent small cobbles near top; cobbles and pebbles of conglomerate from beds below unit 16 are present in units 7 through 16	11.0
8.	Conglomerate, light gray to medium gray, with 30 percent pebbles and small cobbles of milky white, medium-gray, dark-gray mottled light and dark gray, yellowish-gray and black chert; rather nonresistent unit	10.0

9.	Covered, conglomerate talus	10.0
10.	Conglomerate, as in unit 8, with 10 to 40 percent pebbles concentrated in resistant bands; less resistant sandy zones interspersed between conglomerate bands	10.5
11.	Conglomerate, medium gray, with 50 percent large cobbles and small pebbles of milky white, medium dark gray and black chert in coarse sandstone matrix . . .	7.0
12.	Sandstone, medium-grained, medium light gray to light olive gray	0.4
13.	Conglomerate, as in unit 11	0.5
14.	Sandstone, as in unit 12	0.3
15.	Conglomerate, medium gray, with 25 percent medium to large pebbles and small cobbles of white, medium dark gray and black chert in coarse sandstone matrix; single massive bed forming rounded scarp face	11.0
16.	Conglomerate, medium gray, with 15 percent medium pebbles of gray and black chert and some pebbles of sandstone, lithology as in units 17 to 19	4.0
17.	Sandstone, medium to coarse grains, medium light gray to light olive gray, in thin, platy beds	0.3
18.	Sandstone, medium- to coarse-grained, light brownish-gray to light olive gray, containing 10 percent ferruginous grains, in single massive bed	1.5
19.	Sandstone, as in unit 18 but in thin beds . .	0.6
20.	Conglomerate, medium gray to yellowish-gray, with 70 percent fine to medium pebbles of white, light olive gray, medium gray and grayish-black chert and white quartzite, and some pebbles of silicified argillite and siltstone; matrix of coarse-grained sandstone; slightly cross bedded	13.0
21.	Conglomerate, as in unit 20, with some small and medium cobbles scattered throughout	6.0

22.	Conglomerate, as in unit 20 except with about 50 percent medium and coarse pebbles; thin lenticular bed of coarse-grained olive gray to medium-gray sandstone about 2 feet above base of unit	14.0
23.	Covered interval	9.0
24.	Conglomerate, lithologically similar to unit 20 with a very few cobbles scattered throughout	4.0
25.	Conglomerate, as in unit 24; small cobbles about 15 percent	3.0
26.	Conglomerate, medium gray to yellowish-gray, with 70 percent medium to coarse pebbles of white, light olive gray, medium gray and grayish-black chert, quartzite, and silicified argillite in matrix of coarse sandstone; massive beds 2 to 8 feet thick	33.0
27.	Covered interval	13.0
28.	Conglomerate, with 10 percent fine to medium pebbles of light-gray, medium-gray, white, yellowish-green chert in matrix of coarse-grained, light-gray to light yellowish-gray sandstone; pebbles increase to about 40 percent near top	8.0
29.	Conglomerate, with 30 percent medium to coarse pebbles and 10 percent small cobbles of white, gray, black, light yellowish-green, pale brown and dark reddish-brown chert, gray and greenish gray quartzite in matrix of coarse to very coarse, light-gray to light yellowish-gray sandstone; (this is typical conglomerate lithology as it will be referred to in lower beds, variation in size of the coarse components and in the texture of the matrix being indicated at proper places)	4.0
30.	Conglomerate, typical (see unit 29), with 40 percent medium to coarse pebbles . .	22.0

31.	Conglomerate, typical, with 60 percent fine to medium pebbles, thin-bedded . . .	22.0
32.	Sandstone, coarse-grained, light brownish-gray, with about 10 percent light-brown ferruginous grains	1.0
33.	Conglomerate, typical, with 30 percent medium to coarse pebbles in matrix of very coarse sand to granule size	35.0
34.	Conglomerate, typical, with 40 percent large cobbles	3.0
35.	Conglomerate, typical, with 50 percent medium to coarse pebbles	9.0
36.	Conglomerate, typical, with 90 percent medium to coarse pebbles	3.0
37.	Conglomerate, typical, with 50 percent small and large cobbles of chert and appreciable percentages of vein quartz and greenish-gray quartzite cobbles . .	9.0
38.	Conglomerate, typical, with 80 percent fine to medium pebbles and a few small cobbles, in beds 1 to feet thick in lower 12 feet; upper part massive . .	31.6
39.	Conglomerate, with 75 percent fine to medium pebbles in an orthoquartzitic matrix	7.0
40.	Conglomerate, typical, with 70 percent medium pebbles and scattered subangular cobbles alined parallel to bedding . .	16.0
41.	Conglomerate, typical, with 60 percent small cobbles near base grading upward through coarse to fine pebbles; slightly cross bedded in lower 10 feet	19.0
42.	Conglomerate, with 60 percent pebbles grading through small cobbles to large ones near top; some dark-green and jet black chert present; cobbles oblate spheroids with long axes parallaling bedding .	6.0

43.	Conglomerate, typical, with 50 to 60 percent fine to coarse pebbles in matrix of very fine pebbles and granules, cross-bedded	8.5
44.	Covered interval	30.0
45.	Conglomerate, typical, with 30 to 40 percent medium to coarse pebbles, in four massive beds	25.0
46.	Conglomerate, typical, with 30 percent fine to medium pebbles; 2-foot zone of 60 percent medium to coarse pebbles at top	17.0
47.	Conglomerate, typical, with 30 percent coarse pebbles, in three massive beds . .	11.0
48.	Conglomerate, typical, with 15 percent medium to coarse pebbles, in matrix containing 50 percent ferruginous grains, weathering light brown to yellowish-gray, in thin beds 0.3 to 0.4 foot thick	3.8
49.	Conglomerate, typical, with 30 to 50 percent fine to coarse pebbles in medium to coarse sandstone matrix containing 20 percent ferruginous grains in tabular massive beds 6 to 16 feet thick . .	68.0
50.	Covered	16.0
51.	Conglomerate, typical, with 50 to 75 percent medium to coarse pebbles, in three massive beds	16.0
52.	Covered	7.0
53.	Conglomerate, typical, in single massive unit	18.0
54.	Conglomerate, typical, with 25 percent fine pebbles in friable, thin-bedded sandstone matrix	10.5
55.	Conglomerate, typical, with 60 percent medium to coarse pebbles, becoming more sandy in upper 9 feet, in massive beds 3 to 14 feet thick	72.5
56.	Covered interval	20.0

57.	Conglomerate, with 60 percent medium to very coarse pebbles becoming 25 percent fine to medium pebbles in upper part; light gray, medium gray, dark gray, olive gray, dark reddish-brown (10 R 3/4), grayish-purple (5 P 4/2), and moderate red (5 R 5/4) chert, silicified sandstone and limestone as coarse components; matrix of coarse-grained, light olive gray (5 Y 5/2) sandstone; massive, regular beds 8 to 10 feet thick	55.0
Total thickness		1,018.0

KANAYUT FORMATION, LOWER CONGLOMERATE MEMBER

58.	Conglomerate, similar in lithology to that described in unit 57; matrix containing appreciable percentage of ferruginous grains which result in reddish-brown weathering color as compared to general gray-weathering of middle member; beds more uniform and thinner than those of middle member, tending to be 1 to 4 feet thick; member generally producing steep cliffs; total thickness estimated, with at least 500 feet cropping out just below bed 57	1,600.0
Total thickness		1,600.0
Total thickness of Kanayut formation		3,478.0

Section H. Type section of the Kayak formation, near Kanayut Lake (68° 18' N. Lat., 150° 57' W. Long.), measured by Arthur L. Bowsher and J. Thomas Dutro, Jr. in 1949. (Location of fossil collections shown on plate 3)

Unit	Description	Thickness (feet)
DISCONFORMABLE CONTACT WITH LISBURNE FORMATION		
KAYAK FORMATION, RED LIMESTONE MEMBER		
1.	Limestone, coarse-grained calcarenite, dark gray weathering reddish-brown, with fragments of brachiopods scattered throughout; fish teeth and phosphatic pebbles along many bedding planes; beds varying from 0.8 to 2 feet thick	13.1
Total thickness		13.1

2.	Shale, clay size, grayish-black, fissile, calcareous, argillaceous; upper part covered with talus from red limestone unit; two bands of limestone nodules in lower foot of unit, limestone being fine-grained, grayish-black, dense, ferruginous calcarenite	50.0
3.	Shale, clay size, grayish black, fissile, with band of limestone nodules, as in unit 2, about 19 feet below top of unit	25.7
4.	Shale, as above but containing many limestone nodules, limestone being a very fine grained, dark gray, dense sideritic (?) calcarenite weathering to dark reddish brown (10 R 3/4) or very dark red (5 R 2/6) . .	2.0
5.	Shale, as above, quite calcareous	23.2
6.	Limestone, medium-grained, medium dark gray, slightly argillaceous calcarenite, weathering dusky red (5 R 3/4), moderate brown (5 Y 4/4) and moderate red brown (10 R 4/6); fossiliferous	4.3
7.	Limestone and shale; fine-grained, dark gray, nonfossiliferous, thin-bedded calcarenite with interbedded grayish-black clay shale	1.5
8.	Shale, clay size, grayish black, fissile . . .	5.9
9.	Limestone, fine- to medium-grained, dark gray calcarenite, with many crinoidal fragments	0.8
10.	Shale, as in unit 8	24.2
11.	Limestone, fine-grained, grayish black, argillaceous calcarenite; unfossiliferous . . .	0.9
12.	Shale, as in unit 8 but weathering bluish gray	2.3
Total thickness		141.8

13.	Limestone, fine-grained, medium dark gray, extremely argillaceous, shaly calcarenite with scattered crinoidal debris; more shaly in upper 3 feet	13.6
14.	Limestone, medium to coarse, medium dark gray, calcarenite, with coarse sand and granule size crinoidal fragments, quite fossiliferous	4.6
15.	Limestone and shale; fine-grained grayish-black, nodular, argillaceous calcarenite beds varying from 0.1 to 3.1 feet thick and separated by zones of dark-gray to bluish-gray, splintery, calcareous clay shale from 0.1 to 3.7 feet thick; limestone a calcisiltite in places; amount of shale varying from 15 to 70 percent for any 5-foot interval	38.3
16.	Limestone, fine- to medium-grained, dark gray, fossiliferous calcarenite, weathering light brown (5 YR 5/6); a 0.1 foot bed of medium-gray to grayish-black chert at base of unit	1.5
17.	Limestone and shale; limestone as in unit 16 in beds 0.2 to 0.4-foot thick separated by medium dark gray, calcareous, clay shale, in zones 0.1 to 0.5 foot thick . .	2.7
18.	Limestone, as in unit 16, in beds 0.2 to 0.4 foot thick	1.6
19.	Limestone and shale; limestone, fine-grained, dark gray, argillaceous calcarenite in beds 0.1 to 0.3 foot thick with thin zones of medium dark gray, calcareous clay shale interspersed	1.5
20.	Limestone, medium-grained, dark-gray, argillaceous, nonfossiliferous calcarenite, weathering pale yellowish-orange (10 YR 8/6) to light brown (5 YR 5/6); base of upper limestone cliff at base of unit 20	1.5
21.	Limestone and shale, as in unit 19, forming receding slope	2.0

22.	Limestone, coarse calcarenite to granule-size calcirudite, medium dark gray to brownish black, weathering yellowish-gray (5 Y 7/2), argillaceous, with many crinoid plates, columnals and ossicles, in beds 0.4 to 1.9 feet thick and separated by thin partings of medium gray to dark gray, calcareous, soft clay shale from 0.1 to 0.3 feet thick; forming lower cliff in member	15.0
23.	Covered	2.0 +
Total thickness		84.3 +

KAYAK FORMATION, LOWER BLACK SHALE MEMBER

24.	Shale, clay to silt size, grayish black, micaceous, carbonaceous, fissile, weathering moderate yellow-brown (10 YR 5/4); zones of calcareous, ferruginous mudstone concretions about 35 and 60 feet below top of member	128.0 +
Thickness		128.0 +

SECTION INCOMPLETE

Supplementary section. Kayak formation, 1.5 miles east of Kanayut Lake (approximately 68° 19' N. Lat., 150° 53' W. Long.) Continuous above section G.

Unit	Description	Thickness (feet)

KAYAK FORMATION, LOWER BLACK SHALE MEMBER

1.	Shale, clay size, dark gray, micaceous, slightly calcareous, fissile; same as beds below unit 23 in section above; much of thickness being covered by talus from higher limestone units	590.0 +
Total thickness		590.0 +

KAYAK FORMATION, BASAL SANDSTONE MEMBER

2.	Sandstone, fine-grained, reddish brown, argillaceous, fucoidal, thick-bedded	1.2
3.	Sandstone, fine-grained, reddish brown, argillaceous, fucoidal, in hard, platy, irregular shaly beds	12.0

4.	Sandstone, fine-grained, white to light gray, orthoquartzitic, quartzose with grains well rounded but not frosted, in beds 0.2 to 0.3 foot thick	10.0
5.	Shale, clay size, light greenish-gray, soft, fissile	12.0
6.	Sandstone, fine-grained, dark gray, micaceous, carbonaceous, argillaceous, shaly	2.0
7.	Sandstone, fine-grained, dark gray, carbonaceous, micaceous, argillaceous, in uniform beds 0.05 to 0.1 foot thick; vertical worm (?) borings common	1.0
8.	Shale and sandstone; dark gray, micaceous clay shale and silt shale with thin interbeds of fine-grained brown sandstone, becoming fewer in upper 1.7 feet	3.7
9.	Shale, clay and silt size, dark gray, finely micaceous, very soft	3.0
10.	Sandstone, very fine grained, light brownish gray, in lenticular unit varying in thickness from feather edge to 0.2 feet	1.0
11.	Shale, silt-sized, dark gray, kaolinitic, brittle, fissile	2.0
12.	Covered, probably shale as in unit 11	13.0
13.	Sandstone, fine-grained, reddish brown, quartzose with well rounded, nonfrosted grains, in thin regular beds	4.0
14.	Talus cover, sandstone as in unit 13	10.0
15.	Sandstone, as in unit 13, forming low cliff. .	11.0
16.	Talus cover, sandstone as in unit 15	45.0 ±
Total thickness		130.9 ±
Total thickness of Kayak formation		969.1 ±

CONTACT WITH STUVER MEMBER (see section G)

Section I. Pre-Lisburne strata exposed about 2 miles northwest of Cape Thompson (approximately 68° 08' N. Lat., 166° W. Long.)

Unit	Description	Thickness (feet)
FAULT CONTACT (?) WITH LISBURNE FORMATION		
1.	Shale, clay size, gray black, calcareous and carbonaceous	25.0
2.	Shale, as in unit 1 but not calcareous, with some lenses of medium gray siltstone weathering to moderate brown or red brown (5 YR 4/4 or 10 R 4/6)	225.0
3.	Shale, limestone, sandstone; shale as in unit 1; limestone, medium to coarse bioclastic calcarenite, weathering dark yellowish-orange (10 YR 6/6), with coarse crinoidal debris about 25 percent; sandstone, very fine grained, moderate brown (5 YR 4/4), ferruginous; samples 51 ADu 52T-F, 51 ADu 53 T-MF 51 ADu 54T and 51 ADu 55T from this unit	63.5
4.	Shale, silt to clay size, dark gray, with nodules of red brown weathering ferruginous sandstone and ferruginous mudstone comprising about 15 percent of thickness; sample 51 ADu 9T from interval 300 to 400 feet above base of unit	480.0
5.	Sandstone and shale; sandstone, fine-grained, brownish gray (5 YR 5/1), siliceous, quartzitic, noncalcareous; shale, silt size, dark gray, micaceous, noncalcareous; alternating laminae of darker silt and lighter fine sand; unit containing lenses of sandstone, olive gray (5 Y 4/1), dark reddish-brown (10 R 3/4) weathering, dense, micaceous, with plant fragments and containing pyrite; samples 51 ADu 7T-F and 51 ADu 8T-F from 6 feet and 20 feet above base respectively	43.0
6.	Shale and sandstone; shale as in unit 5 with some dark-gray clay-size material as well; sandstone in lenses as in unit 5, lacking uniform bedding; sample 51 ADu 6T-MF from this unit	51.5
7.	Sandstone and shale, as in unit 5; samples 51 ADu 4T-F and 51 ADu 5T-F from 1 foot and 10 feet above base, respectively, sample 51 ADu 3T from middle of unit	28.0

8.	Shale, as in unit 6; sandstone apparently absent; largely covered by beach sands and gravels	300.0
9.	Sandstone, fine-grained, brownish-gray (5 YR 4/1), weathering light brown (5 YR 5/6), siliceous, quartzitic, in single massive bed	6.0
10.	Shale, silt size, dark-gray, noncalcareous, weathering to chips and discontinuous lenses; largely covered with beach sands and gravels; sample 51 ADu 2T-MF from unit	60.0
Total thickness		1,782.0

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PLATE 9

(All figures natural size, unless otherwise indicated)

Page

1-3. Pentremites alaskensis Dutro, n. sp. 39
1. Holotype from U.S.N.M. loc. 3242, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118296.
2, 3. Two specimens, paratypes, showing variation in calyx shape; also from U.S.N.M. loc. 3242. U.S.N.M. 118295; U.S.N.M. 118268.

4. Pentremites ascitus Dutro, n. sp. 40
Holotype from U.S.N.M. loc. 3232, red limestone member of Kayak formation, Itkillik Valley, Alaska. U.S.N.M. 118325.

5. Cryptoblastus melo (Owen and Shumard) var. A. 41
Characteristic specimen from U.S.N.M. loc. 3095, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118298. X 2.

6. Cryptoblastus sp. A. 42
Characteristic specimen from U.S.N.M. loc. 3239, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118297. X 2.

7. Cryptoblastus cf. C. pisum (Meek and Worthen) 43
Characteristic specimen from U.S.N.M. loc. 3095, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118326. Oral view, X 3.

8. Actinocrinites accinctus Dutro, n. sp. 45
Holotype from U.S.N.M. loc. 3240, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118294.

9. Actinocrinites ? cf. A. ? stellaris (DeKoninck and Lehon). 47
Characteristic specimen from U.S.N.M. loc. 3242, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118327.

10. Platycrinites cf. P. annosus (S. A. Miller) 48
Characteristic specimen from U. S.N.M. loc. 3242, Kayak formation. Kanayut Valley, Alaska. U.S.N.M. 118328. X 2.

11, 12. Polypora aff. P. simulatrix Ulrich 51
11. Part of zoarium from U.S.G.S. loc. 12799 from Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118329.
12. Enlargement of part of zoarium showing individual zoecia and other details, same locality as fig. 11. U.S.N.M. 118329. X 2.

Note: All figures are 1.35 larger than shown on plate.

1

2

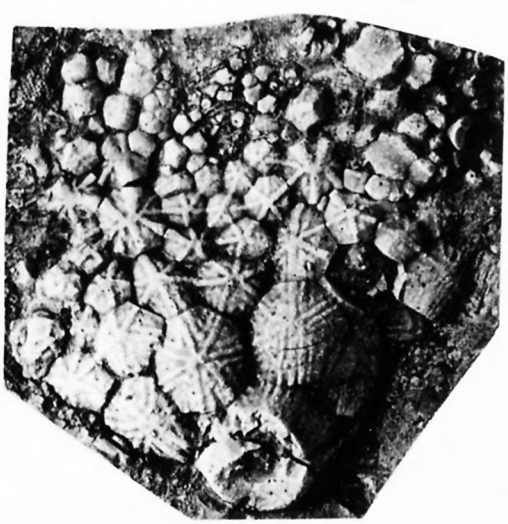
3

4

5 X 2

6 X 2

7 X3



8

9

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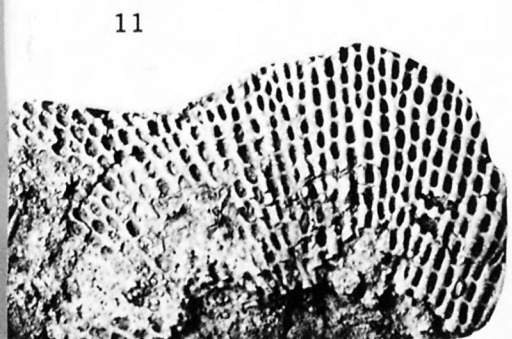

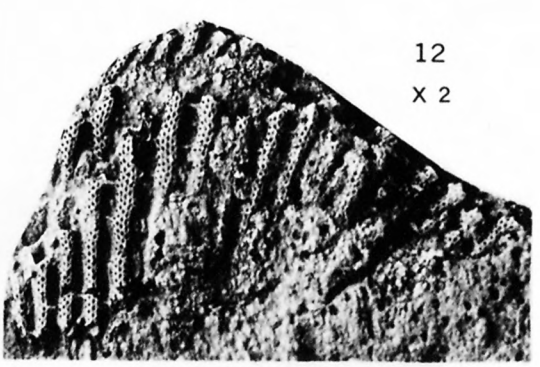

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PLATE 10

Page

1. Orbiculoidea subelliptica Dutro, n. sp. 52
Holotype, pedicle valve, from U. S.N.M. loc. 3240, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118256.

2, 3. Rhipidomella michelini (Léveillé) Oehlert 53
2. Pedicle valve; 3. Brachial valve. Specimen from U.S.N.M. loc. 3242, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118266.

4, 8. Schizophoria resupinata cf. var. rotundata Demanet . . 55
4. Exfoliated pedicle valve; 8. Interior, brachial valve. Both specimens from U.S.G.S. loc. 12795, Utukok formation, Nuka Valley, Alaska. U.S.N.M. 118269; U.S.N.M. 118270.

5-7. Schizophoria resupinata cf. var. dorsosinuata Demanet . 54
5. Posterior view; 6. Pedicle valve; 7. Brachial valve. Specimen from U.S.N.M. loc. 3352, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118267.

9, 10, 12, 14, 15. Leptaena analoga (Phillips) Sowerby . . . 56
9. Pedicle valve from U.S.G.S. loc. 12709, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118257.
10. Lateral view of same specimen.
12. Brachial valve from U.S.N.M. loc. 3242, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118259.
14. Pedicle valve, exposing cast of pseudospondylium, from U.S.N.M. loc. 3243, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118260.
15. Brachial interior, shadows retouched, from U.S.G.S. loc. 12709, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118258.

11, 13. Schellwienella radialiformis (Demanet) Dutro . . . 63
11. Mold of pedicle valve, from U.S.G.S. loc. 12709, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118264.
13. Brachial interior, from U.S.G.S. loc. 12712, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118265.

Note: All figures are 1.35 larger than shown on plate.

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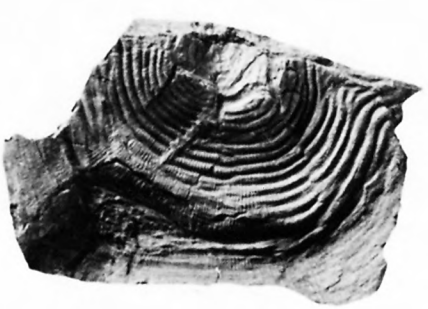

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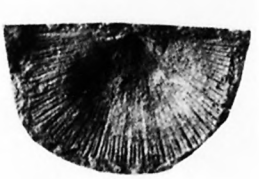

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PLATE 11

Page

1, 3, 5, 7, 8. Schuchertella ampla Dutro, n. sp. 61

1. Brachial valve, posterior view, from U.S.G.S. loc. 11861, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118262.
3. Brachial view, same specimen as in fig. 1.
5. Lateral view, same specimen as in figs. 1, 3.
7, 8. Holotype, pedicle interior, from U.S.G.S. loc. 12709, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118261. 7, natural size; 8, x 2.

2, 4, 6. Schuchertella ampla var. complanata Dutro, n. var. . 62

2. Brachial valve, posterior view, holotype, from U.S.G.S. loc. 11858, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118263.
4. Brachial view, same specimen.
6. Lateral view, same specimen.

Note: All figures are 1.35 larger than shown on plate.

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PLATE 12

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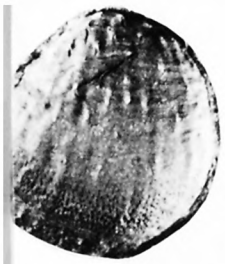
1-6. Spinulicosta cf. S. concentrica (Hall) Nalivkin 69
1, 4. Pedicle valve, from U.S.N.M. loc. 3246, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118311. 4, natural size; 1, x 3.
2, 5. Pedicle valve, posterior view, same specimen. 5, natural size; 2, x 3.
3, 6. Pedicle valve, lateral view, same specimen. 6, natural size; 3, x 3.

7. Labriproductus cf. L. worthani (Hall) 73
Cast of brachial exterior from U.S.G.S. loc. 12793, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118317.

8-11. Productella pyxidata (Hall) Hall and Clarke 68
8, 9. Pedicle valve, from U.S.N.M. loc. 3246, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118310. 8, natural size; 9, magnification: x 3.
10. Pedicle valve, posterior view, same specimen, x 3.
11. Pedicle valve, lateral view, same specimen, x 3.

12-17. Setigerites sablei Dutro, n. sp. 71
12-14. Holotype, pedicle valve, pedicle, posterior and lateral views, from U.S.G.S. loc. 11860, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118314.
15. Interior pedicle valve, paratype, showing muscle field, from U.S.G.S. loc. 11858, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118316. Magnification: x 2.
16, 17. Interior another pedicle valve, paratype, showing cardinal process, U.S.G.S. loc. 12793, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118315. 16; natural size; 17, magnification: x 2.

Note: All figures are 1.35 times larger than on original plate



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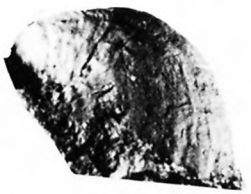

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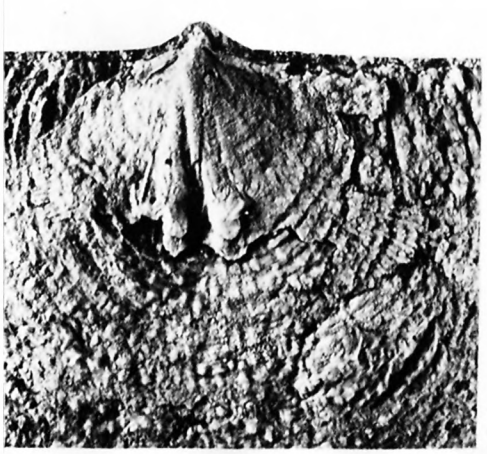

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PLATE 13

Page

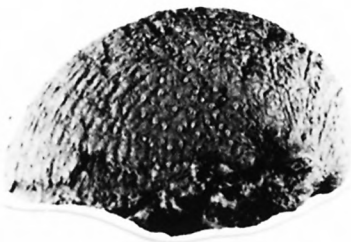
1-6. Buxtonia ? parva Dutro, n. sp. 71
1, 4. Holotype, pedicle valve, lateral view, from U.S.N.M. loc. 3239, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118313. 4, natural size; 1, magnification: x 2.
2, 5. Anterior view, same specimen. 5, natural size; 2, magnification: x 2.
3, 6. Posterior view, same specimen. 6, natural size; 3, magnification: x 2.

7-14. Setigerites ? truncicostis Dutro, n. sp. 70
7, 11. Holotype, pedicle valve, lateral view, from U.S.N.M. loc. 3239, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118312. 11, natural size; 7, magnification: x 2.
8, 14. Anterior view, same specimen. 14, natural size; 8, magnification: x 2.
9, 12. Posterior view, same specimen. 12, natural size; 9, magnification: x 2.
10, 13. Pedicle view, same specimen. 13, natural size; 10, magnification: x 2.

15, 16. Linoproductus ? cf. L. ? belliplicatus (Branson) Dutro. 74
Exfoliated brachial interior from U.S.N.M. loc. 3139, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118319. 16, natural size; 15, magnification: x 2.

17, 18. Pustula cf. P. morbilliana (Winchell) Sutton 72
Pedicle valve from U.S.N.M. loc. 3237, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118318. 17, natural size; 18, magnification: x 3.

Note: All figures are 1.35 larger than



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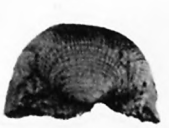

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PLATE 14

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1, 2. Chonetes sp. A. 65
1. Brachial exterior from U.S.G.S. loc. 12712, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118271. Magnification: x 2.
2. Brachial interior from same locality. U.S.N.M. 118272. Magnification: x 2.

3-6. Chonetes utukokensis Dutro, n. sp. 66
3. Paratype, pedicle exterior, showing spines along hinge line, from U.S.G.S. loc. 12794, Utukok formation, Nuka Valley, Alaska. U.S.N.M. 118276.
4. Paratype, brachial exterior, from same locality as fig. 3. U.S.N.M. 118275.
5. Paratype, brachial interior, from same locality as figs. 3, 4. U.S.N.M. 118274.
6. Holotype, brachial exterior, from U.S.G.S. loc. 11868, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118273.

7. Chonetes sp. B. 66
Brachial exterior from U.S.N.M. loc. 3246, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118277. Magnification: x 2.

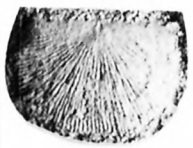
8. Dielasma cf. D. chouteauensis Weller 78
Incomplete pedicle valve, partially exfoliated, from U.S.N.M. loc. 3139, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118284. Magnification: x 2.

9. Punctospirifer cf. P. northviewensis (Branson) 92
Exfoliated pedicle valve from U.S.N.M. loc. 3246, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118285.

10-13. Punctospirifer ? solidirostris (White) 90
10, 11. Pedicle valve, pedicle and posterior views, from U.S.G.S. loc. 11858, Utukok formation, Upper Utukok Valley, Alaska. U.S.N.M. 118304.
12. Brachial exterior from same locality. U.S.N.M. 118305.
13. Same specimen as figs. 10, 11, showing punctae. Magnification: x 4.

14-16. Syringothyris halli Winchell 92
14. Brachial valve, partially reconstructed, from U.S.N.M. loc. 3139, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118283.
15. Pedicle interior, showing syrinx, from U.S.N.M. loc. 3239, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118281.
16. Partial pedicle exterior, showing pustulose surface ornamentation, from same locality as fig. 14. U.S.N.M. 118282. Magnification: x 4.

Note: All figures are 1.35 times larger than on original plate



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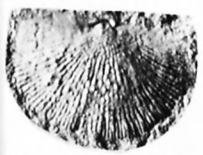

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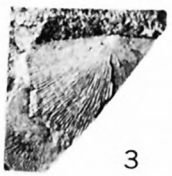

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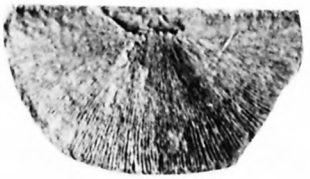

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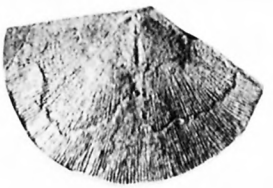

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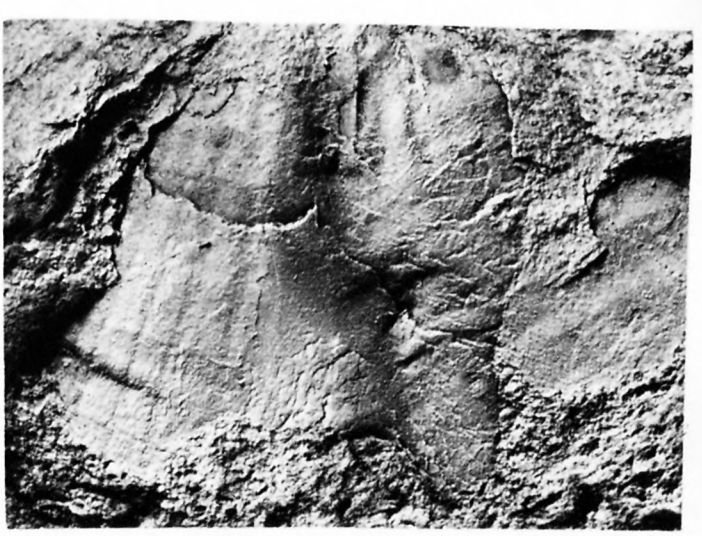

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PLATE 15

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1-3. Spirifer cf. S. rowleyi Weller 84
Pedicle valve, pedicle, lateral and posterior views, from U.S.G.S. loc. 11860, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118302.

4-7. Spirifer cf. S. grimesi Hall 80
4, 5, 7. Pedicle valve, lateral, posterior and pedicle views, from U.S.G.S. loc. 11861, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118301.
6. Brachial mold, from U.S.G.S. loc. 11859, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118300.

8, 9. Spirifer cf. S. gregori Weller 79
Pedicle valve showing muscle field, from U.S.G.S. loc. 12707, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118299. 8, exterior showing cast of muscle field; 9, interior, same specimen, magnification: x 2.

Note: All figures are 1.35 larger than shown on plate.

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PLATE 16

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s. 1-3. ? Imbrexia forbesi (Norwood and Pratten) Nalivkin . . . 86
Brachial, pedicle and posterior views of same specimen from U.S.G.S. loc. 12793, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118303.

s. 4, 5, 9. Brachythyris aff. B. chouteauensis Weller 87
4, 5. Pedicle valve, pedicle and lateral views, from U.S.N.M. loc. 3242, Kayak formation, Kayanut Valley, Alaska. U.S.N.M. 118279.
9. Partial pedicle valve, from U.S.N.M. loc. 3232, Kayak formation, Itkillik Valley, Alaska. U.S.N.M. 118280.

s. 6-8. Spirifer cf. S. osagensis Swallow 82
6. Brachial exterior, partially reconstructed, from U.S.N.M. loc. 3095, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118288.
7, 8. Pedicle valve, lateral and pedicle views, partially reconstructed, from U.S.N.M. loc. 3246, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118287.

. 10. Spirifer platynotus Weller 83
Pedicle exterior, partially reconstructed, from U.S.N.M. loc. 3242, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118292.

. 11. Spirifer missouriensis Swallow 81
Pedicle exterior, partially reconstructed, from U.S.N.M. loc. 3137, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118286.

. 12. Ptylopora aff. P. acuta (Ulrich) 50
Reverse of zoecium from U.S.N.M. loc. 3095, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118289.

. 13. Terynifer cf. T. cooperensis (Swallow) Dutro 88
Pedicle exterior from U.S.G.S. loc. 12709, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118290. Magnification: x 2.

. 14. Spirifer striatiformis Meek 85
Pedicle exterior, partially reconstructed, from U.S.N.M. loc. 3137, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118291.

. 15. Lepidocidaris squamosa (Meek and Worthen) 50
Disarticulated interambulacral plates from U.S.N.M. loc. 3242, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118278. Magnification: x 2.

Note: All figures are 1.35 times larger than on original plate

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PLATE 17

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s. 1-5. Amboccelia parva Weller 89
1. Brachial view, characteristic specimen from U.S.G.S. loc. 12796, Utukok formation, lower Nimiuktuk Valley, Alaska. U.S.N.M. 118332. Magnification: x 3.
2, 3, 5. Pedicle, posterior, and lateral views of same specimen. X 3.
4. Posterior view, same specimen. X 1.

s. 6-10. Cleiothyredina glenparkensis Weller 93
6. Brachial view, characteristic specimen from U.S.N.M. loc. 3237, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118333. Magnification: x 2.
7, 8, 10. Pedicle, posterior, and lateral views of same specimen. x 2.
9. Posterior view of same specimen. X 1.

s. 11-15. Paraphorhynchus smithi Dutro, n. sp. 76
11. Brachial view, holotype from U.S.G.S. loc. 12701, central Noatak Valley, Alaska. U.S.N.M. 118331. Magnification: x 3.
12, 14, 15. Anterior, pedicle, and lateral views of holotype. x 3.
13. Anterior view of holotype. x 1.

. 16. Composita humilis var. A 95
Pedicle view of characteristic specimen from U.S.G.S. loc. 12793, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118335. Magnification: x 2.

s. 17-20. Composita humilis Girty 94
17. Brachial view, characteristic specimen from U.S.G.S. loc. 11867, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118334. Magnification: x 2.
18-20. Pedicle, posterior, and lateral views of same specimen. x 2.

Note: All figures are 1.35 larger than shown on plate.

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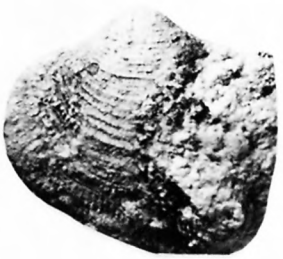

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PLATE 18

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g. 1. Edmondia burlingtonensis White and Whitfield 96
Cast of external mold from U.S.G.S. loc. 12793, Utukok formation, upper Itkillik Valley, Alaska. U.S.N.M. 118336.

g. 2. Conocardium sp. 97
Partial left valve from U.S.N.M. loc. 3237, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118337. Magnification: x 2.

g. 3. Naticopsis sp. 97
Side view of specimen from U.S.G.S. loc. 12709, Utukok formation, Nimiuktuk Valley, Alaska. U.S.N.M. 118338.

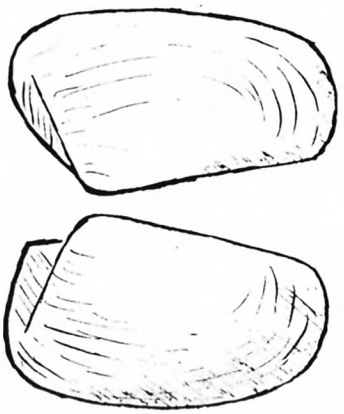
gs. 4, 6. Moorecceras ? sp. 100
Specimens from U.S.G.S. loc. 11862, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118343.

g. 5. Straparolus blairi Miller 98
Apical view and partial vertical section of specimen from U.S.G.S. loc. 11861, Utukok formation, upper Utukok Valley, Alaska. U.S.N.M. 118339.

g. 7. Phillipsia sp. 100
Partial cranidium of specimen from U.S.N.M. loc. 3139, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118344. Magnification: x 2.

g. 8. Platyceras nasutum Miller 99
Side and apical views of specimen from U.S.N.M. loc. 3095, Kayak formation, Kanayut Valley, Alaska. U.S.N.M. 118341. Magnification: x 2.

Note: All figures are 1.35 times larger than on original plate



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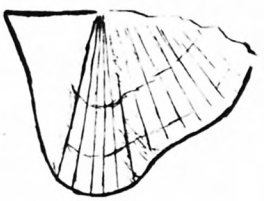

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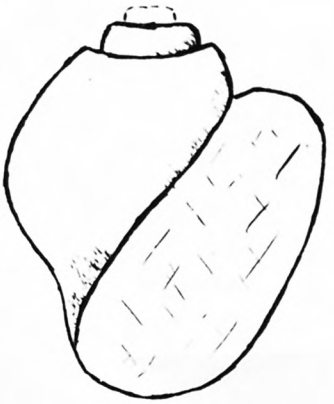

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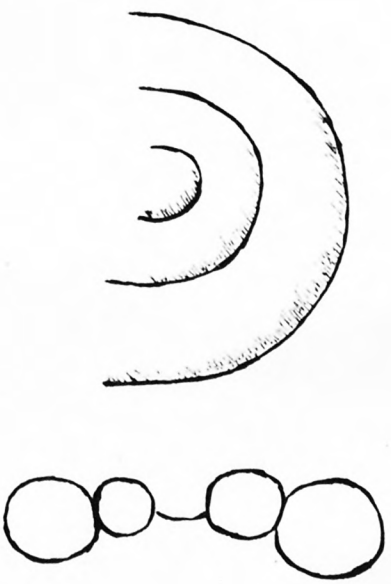

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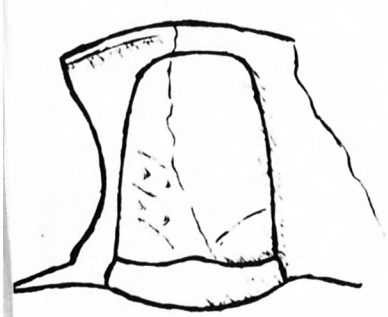

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